Cognitive Efficient Modelling Using Tablets

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Abstract: Recently, conceptual modellers have to choose between modeling tools running on tablets or in a common PC environment. This choice has some implications on how cognitive efficient the modeling process is. While using touch input (given on a tablet) eyes and hand are directly coordinated, which supports human gaze behaviour. On the contrary, modelling with a mouse (given in a common PC environment) does not allow direct eye-hand coordination and therefore needs additional effort to coordinate eye and hand. This effect is investigated within a two-group laboratory experiment using BPMN as a modeling language and thus assesses if modeling on tablet is cognitive efficient. Furthermore, we derive assumptions how improve cognitive efficiency of modeling tools.

1 Introduction

Interacting with an application by directly touching its graphical elements seems more natural than working with a mouse or another pointing device [For07]. This argument is valid also for conceptual modeling, which is why some modeling tools have been developed for tablet-use, recently (e.g. Cubetto BPMN and Mobile Process Designer). But why should modeling on tablets be more natural? And what does naturalness mean?

Several experiments have shown that conceptual modeling can be supported by adjusting the process of modeling [AST96] as well as the modeling grammar [Par02] in such a way that fits human cognition [LS87]. Depending on what has been adjusted to human cognition, the modeling process results more efficient or understanding of the resulting model can be improved. In these cases naturalness has been achieved by distinguishing between entities and properties [Web96], by adjusting the problem representation to the task [AST96] or by allowing conceptual and perceptual integration of different conceptual models [Moo03].
Stark and Esswein have conducted a review of experiments within Conceptual Modeling that base on Cognition. They could neither identify a study that has focused on input devices in particular nor did we find any study with a focus on how a modeling tool can be adjusted to fit human cognition in general [SE12].

Yet, within the field of Human Computer Interaction (HCI) advantages and disadvantages of different input possibilites, such as mouse-input for PC-use or touch-input for tablet-use, have been discussed and investigated. Tablets are easy to use, do not require any additional workspace and do not have moving parts. But they lack precision [BS78], [Pic86]. It is difficult to implement precise selection mechanisms as the finger as input medium is usually larger than the area which needs to be selected [HA11]. On the contrary, the mouse is the standard input medium and tool designers can suppose that conceptual modellers are familiar with it. Nevertheless, using a mouse requires an extensive eye-hand coordination [GA88], since hand-positioning cannot be supported by the modellers gaze [CMM04], [Des98].

Prior research of HCI has tested efficiency and effectiveness of touch and mouse input. AHLSTRÖM ET AL., KARAT ET AL. and MEYER ET AL. have investigated errors generated by performing pointing tasks [AL87], [KMA86] and drawing tasks [MCN94]. Yet, these investigations were performed over 20 years ago, which is why their findings may not represent results obtained with current hardware [HA11]. Two experiments were conducted recently. FORLINES ET AL. have investigated touch and mouse input for pointing and dragging tasks using one and two hands. They used a horizontal 107 cm diagonal MERL DiamondTouch touch sensitive table displaying 1024x768 pixels with each pixel approximately 1.2mm square. For one-hand input tasks touch and mouse input showed similar performance. More specifically, touch input was slightly but not significantly outperforming mouse input. For two-hand tasks using touch input significantly outperformed using mouse input [For07]. HOOTEN AND ADAMS investigated mouse and touch input for drawing tasks. They used a DELL XT2 tablet laptop that allowed touch-based interaction and found out that for drawing tasks touch-based interaction is significantly faster than mouse-based interaction [HA11]. Both experiments cannot simply be projected to conceptual modeling on tablets for two reasons: First, there is a difference in hardware requirements. Conceptual modeling tools for tablets have so far been developed for ipad use, which is currently sold with a size of 24,6 cm (width) and 9.7 inch displaying 2.048x1.536 pixels (1024x768 ipad1). Thus, the size of the display is significantly smaller than in [For07] and slightly smaller than in [HA11]. Furthermore the pixel-size on ipads is significantly different from that used in [For07]. Second, so far conceptual modeling on ipad requires only pointing and dragging tasks but no drawing task. Elements can be selected by pointing on the screen. Dragging is used to relate different elements to each other. Consequently, results of [HA11], who investigated drawing tasks, cannot be applied for modeling on tablets, so far.

This study aims on empirically investigating if touch-input for modeling is “more natural” than mouse-input. We claim that a direct eye-hand coordination (given with touch-input) is more cognitive efficient than an indirect eye-hand coordination (given with mouse-input). We describe a laboratory experiment, which evaluates the effect of eye-hand coordination for conceptual modeling. This research contributes to research and practice. For practice, we identify the effect touch- and mouse-input has on the modeling process and thus, give developers of conceptual modeling tools an idea of how to make their tool cognitive efficient for the input variable. Furthermore, we derive propositions how to develop cognitive efficient modeling tools.

For research we integrate our results within the framework of rules for conceptual modeling from cognition [SE12] that summarizes independent and dependent variables from empirical investigations within conceptual modeling that base on cognition. Furthermore, the authors have discussed future research possibilities to test cognitive efficiency of the grammar, use of grammar, user and task characteristics as well as medium of content delivery. We add future research possibilities for the modeling tool. The paper is structured as follows: In section 2 we describe prior research of eye-hand coordination. In section 3 the method is described. Results are presented in section 4 and discussed in section 5. The paper concludes with a summary in section 6.

2 Theoretical Background and Hypotheses

Conceptual modeling using touch-input differs from modeling using mouse-input in eye-hand coordination. In this section these differences are discussed and hypotheses are presented.

2.1 Eye-Hand Coordination

When pointing to a single target, people direct their gaze to the target while they initiate their hand movement. They maintain their gaze on the target until the hand arrives [GA88], [Des98]. This behaviour improves reach accuracy [BJF09]. Looking at the target allows an effective use of visual feedback of the hand position while guiding the hand to the target [Lan99], [Pai96]. This gaze behaviour normally happens when performing simple tasks such as pointing tasks [NB00], drawing tasks [RS03] as well as more complicated tasks such as manipulating tasks [Joh01].

If the pointer directed by the mouse arrives the target instead of the hand, eye and hand are still coordinated. Efferent and afferent signals related to gaze position can be used to guide the hand when the hand is not visible [PDG03]. This happens if the pointer of the mouse moves towards or away from the target. In this situation an indirect eye-hand coordination occurs.

Conceptual modeling using paper requires drawing tasks, which are supported by direct eye-hand coordination. However, modeling on paper reveals some important disadvantages as the result cannot easily be shared and worked on within physically separated groups [Her07]. Furthermore creating versions and variants of the model requires reconstructing the model on a new paper.

Using modeling tools bridges these gaps and allows to save, to change and to share the results. On traditional modeling tools the input of model elements and labels requires the use of a mouse while the output is usually displayed on a screen. Creating a conceptual model using a mouse usually requires both pointing and dragging tasks. [MSB91] have shown that dragging is a variation of pointing. While performing pointing tasks a typical gaze behaviour is focusing the target until the hand arrives [LBS09]. Since a cursor, directed by a mouse instead of the hand, arrives the target, additional effort is required to coordinate eye and hand. In addition, the movement amplitude of the mouse and the precision of the hand movement required influence the effort required for eye-hand coordination [SJ05].

Traditional modeling tools usually offer a wide range of functionalities such as configuration management, application of reference models or creation of modeling languages. Yet, these tools are generally not applicable for modeling on spot. This is where tablet-use is advantageous.

Only recently tablets have been discussed for conceptual modeling. Especially mobile process modeling might be relevant for use cases such as modeling procedure models in health care (model-based clinical treatment processes) or for the adaptation of process models in logistical processes. However, there are only a few tools for modeling on tablets: Some process modeling tools for the iPad (e.g. Cubetto BPMN and Mobile Process Designer) and some tools for modeling with UML (e.g. astah* UML Pad). In addition, there are a few web based modeling tools that can be used conveniently on tablets (e.g. Signavio). The most evident advantage of using tablets for conceptual modeling is that the input is also the output device, which is why there is a direct eye-hand coordination as well as a direct relationship between the modeller's input and the output on the tablet [GA88]. Creating a model on a tablet normally requires pointing and dragging tasks that belong to those tasks that benefit from a direct eye-hand coordination. Eye-hand coordination of modeling on paper, with traditional modeling tools or on tablets is summarized in Fig. 1.

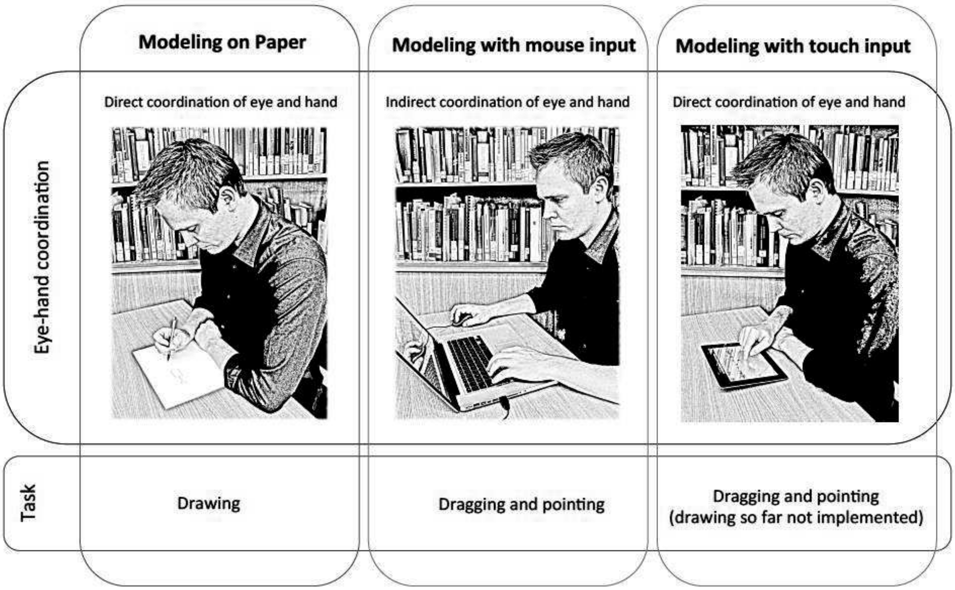

Figure 1: Eye-Hand Coordination for Modeling on paper, with a mouse or touch input

2.2 Hypotheses

As modeling on paper became uncommon with the advances of information technology and its subsequent development of modeling tools we have focused on modeling using tablets (touch-input) and PC (mouse-input). We argue that direct eye-hand coordination is cognitive efficient and thus, leads to a higher modeling efficiency.

We have operationalized this hypothesis in a two-group laboratory experiment, one group working on a tablet and one group working with a PC. As a measurement for modeling efficiency we use the time required to complete the task. We argue that:

H1: (time) *The tablet-group will need less time to complete the modeling task than the PC-group.*

Performance-based measurements, such as required time to complete the model generally provide more convincing evidence than perception-based measurements, such as perceived Ease of Use [Moo03]. Yet, for decisions to use a tablet-application or a traditional modeling tool it is more important how efficient the modeller thinks the tool is. According to the work of MOODY we include three perception-based measurements: Perceived Ease of Use, Perceived Usefulness, Intention to Use. The method evaluation model is presented in Fig. 2.

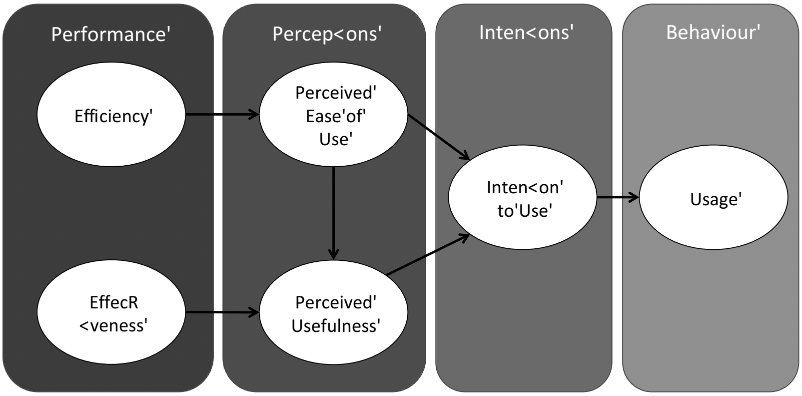

Figure 2: Method Evaluation Model [Moo03]

Based on the Method Evaluation Model we argue:

H2: (Perceived Ease of Use) *The tablet-group will believe to a higher degree that conceptual modeling would be free of effort than the PC-group.*

H3: (Perceived Usefulness) *The tablet-group will believe to a higher degree that using the modeling software will be effective to achieve their objectives than the PC-group.*

H4: (Intention to Use) *The tablet-group will intend to a higher degree to use the modeling software than the PC-group.*

3 Research Methodology

We have investigated the above-presented hypotheses in a two-treatment group laboratory experiment including pre- and post-test. The experimental design is shown in Fig. 3.

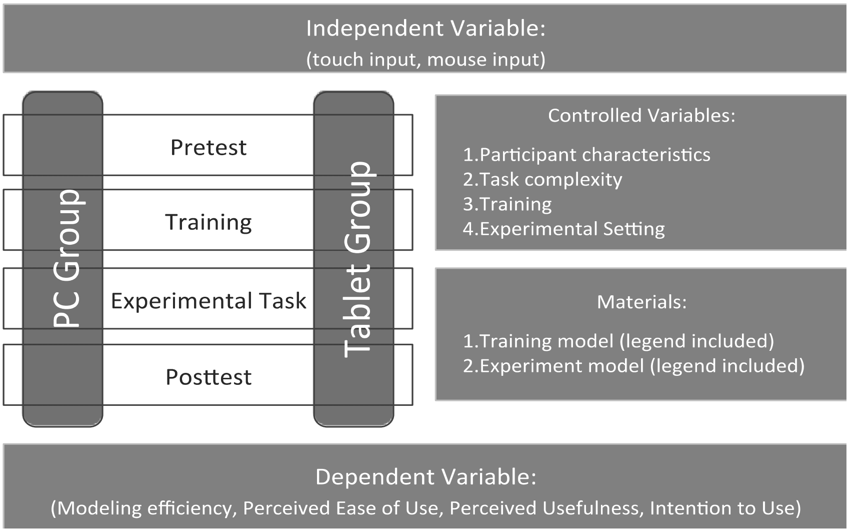

Figure 3: Experimental Design of the study

3.1 Task Setting

We have operationalized modeling efficiency by measuring the time it requires participants to rebuild a conceptual model on a tablet (Treatment Group 1) or on PC (Treatment Group 2). On tablet, participants worked with the ipad application Cubetto BPMN [Grei10]. We have selected the Business Process Modeling Notation (BPMN) as modeling language for the reason that we tried to reduce affecting variables such as different layout and different handling of the program. This is why we have selected a program available on tablet and on PC that requires the same handling. We only found Cubetto BMPN on tablet and a simulator program of Cubetto BPMN on PC. These two programs only differ in their input-mediums (mouse and keyboard on PC and touchscreen on tablet). Furthermore, we have reduced keyboard-use to a minimum, which is why labels of elements only consisted of a few letters. The experiment model is shown in Fig. 4. We expected that participants did not have any previous knowledge in modeling with BPMN. To enable them using the modeling environment on tablet or on PC each experimental group was given a 45 minutes training session. Part of the session was explaining the modeling environment and together rebuilding a model that contains all modeling elements that they needed to complete the experimental task. The training model is presented in Fig. 4, too.

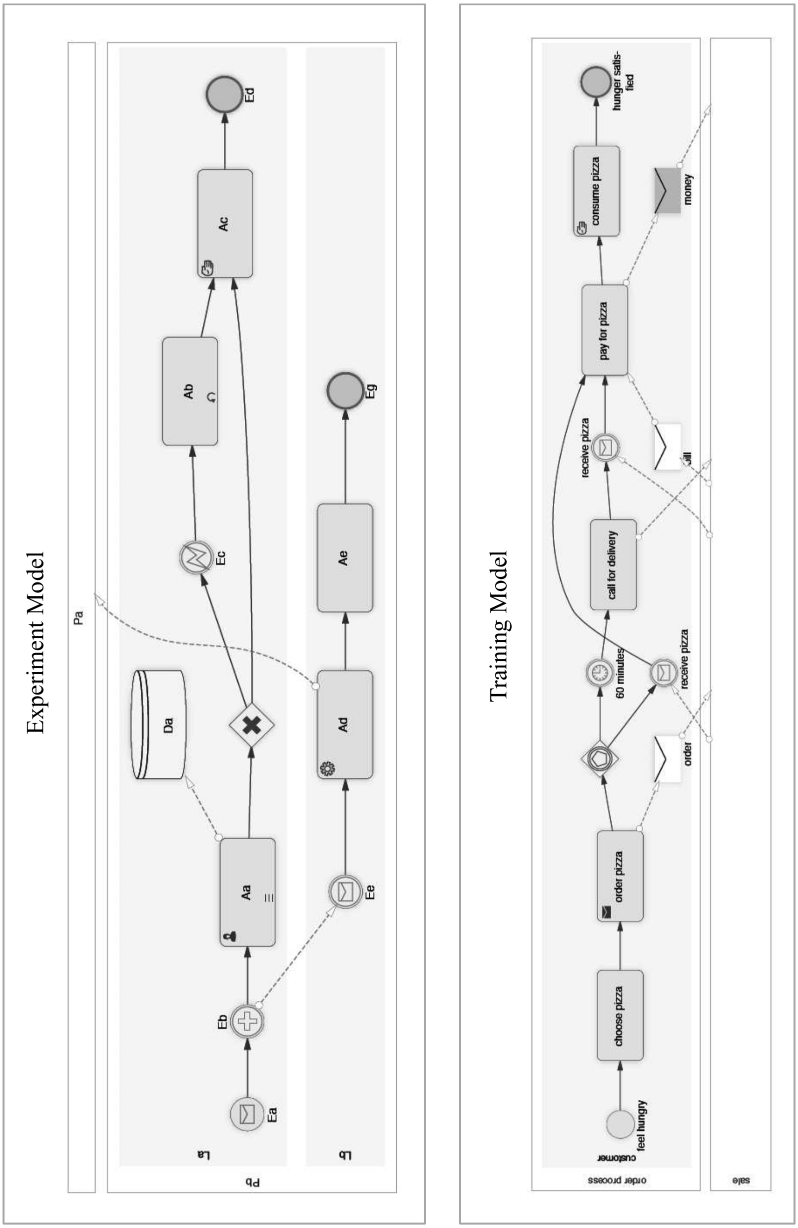

Figure 4: Experiment and Training model for PC- and tablet-group

After concluding the experimental task, students were given a post-test consisting of 13 questions for operationalizing Perceived Ease of Use, Perceived Usefulness and Intention to Use as well as to control possible affective variables such as if a participant felt to be set in a very stressful situation. For the post-test a 0-7 scale was used developed by [MB91].

3.2 Participants

We invited 40 business and information systems students participating in a General Qualification Course for undergraduate Students to take part in the experiment. The students were randomly assigned to the tablet-group (treatment group 1) and to the PC-group (treatment group 2). We used a pre-test to assure that none of the students had previous knowledge using BPMN or had previously used the modeling tool. Students could reduce their expenditure of work by taking part in the experiment. Apart from three all students decided to take part in the experiment.

3.3 Pilot Study

We had conducted a pilot study with undergraduate students not taking part in the General Qualification Course. This study helped to eliminate ambiguity in pre- and post-test questions as well as finding a number of constructs for training and experimental model that students would not be overburdened and thus, would be set in a stressful experimental atmosphere.

4 Results

4.1 Performance-based Measurements: Modeling Efficiency (Time)

PC- as well as tablet users have exactly rebuilt the paper model on tablet or on PC and did not leave out constructs or choose to take another design within the time taken. The mean time required to rebuild the model is 7 minutes and 21 seconds for the tablet-group seconds 8 minutes and 32 seconds for the PC-group. The times for modeling on tablets and on PC do not follow a normal distribution (Shapiro-Wilk-Test, $\alpha<0.02$). Since the times for both groups show a similar distribution (Kolmogorow-Smirnow-Test, $\alpha<0.02$) we decided to apply a Mann-Whitney U test to assess if the means differ significantly. Table 1 shows the means, standard deviation and significance for both groups.

Table 1: Times for tablet- and PC-group

Treatment Group:	Mean (μ) in mm:ss	STDEV (δ) in mm:ss	Significance
Tablet Group	07:21	01:39	0,02
PC Group	08:32	01:48	

A significant difference between the tablet- and the PC-group was found for $\alpha<0.02$ which is why we can assume that for $\alpha<0.02$ the means differs significantly. Thus, H1 is strongly confirmed.

4.2 Perception-based Measurements

For Perception-based measurements we have used the Shapiro-Wilk-Test to show that for every measurement (Perceived Ease of Use, Perceived Usefulness and Intention to Use; both groups) data collected does not follow a normal distribution ($\alpha<0.02$), which is why we could neither use an analysis of variance nor a t-test. Since data is equally distributed (according to a Kolmogorow-Smirnow-Test) we could apply the Mann-Whitney U Test. Results of the tests are presented below in Table 2.

Table 2: Perception-based measurements for tablet- and PC-group

Dependent Variable	Treatment Group:	Mean (μ) (0-7 scale)	STDEV (δ) (0-7 scale)	Significance
Perceived Ease of Use	Tablet Group	6,35	0,76	-
	PC Group	5,95	1,89	
Perceived Usefulness	Tablet Group	6	0,74	-
	PC Group	5,85	1,06	
Intention to Use	Tablet Group	5,95	0,91	-
	PC Group	5,55	1,43	

According to Table 2 the means of Perceived Ease of Use, Perceived Usefulness and Intention to Use of the tablet-Group outperform slightly those of the PC-group. Yet, we could not identify a significant difference between those two groups ($\alpha<0.02$). Hence, H2, H3 and H4 are not supported.

5 Discussion and Future Research

5.1 Discission of the Results

Out of four hypotheses one was supported while the others lack any support. The mean time required to complete the modeling task was found to be significantly shorter for the tablet-group than for the PC-group, which is why we can assume that with a direct eye-hand coordination modeling efficiency can be enhanced. Thus, a direct eye-hand coordination is cognitive efficient for conceptual modeling.

For perception-based measurements the tablet-Group also slightly outperforms the PC-Group but we could not find any significant difference between the two groups. We might explain the loss of significance with the rating behaviour of the participants. On a 0-7 point scale the means range between 5,55 and 6,35. These means show that the students have ranked Perceived Ease of Use, Perceived Usefulness and Intention to Use for both tablet and PC relatively high, which is why discrimination for the two groups was hardly possible. A further reason might be that students mainly work with the mouse as input medium and hence, are more used to it. This behaviour might effect that they do not feel more comfortable using touch input while completing the modeling task.

5.2 Strength and Limitations of the Study

To secure internal validity the variables such as participants' characteristics, tool characteristics, experimental setting, task complexity and training have been controlled (see Table 3). We could not control the input medium for text. The PC-group could use an external keyboard while the tablet-group had to use an integrated keyboard on the tablet, which is smaller than the PC-keyboard. To reduce the effect of this variable we have only used very short names for the elements.

The type of participants we have chosen influences external Validity. As many other laboratory experiments in the field of conceptual modeling we have asked students to participate. Their knowledge of conceptual modeling is relatively low in contrast to that of practitioners. However, the task was designed to test modeling efficiency of rebuilding a model that participants are given on paper. Provided with a training how to use the modeling tool, students should not be disadvantaged while performing this task.

Table 3: Controlled Variables

Variable	Control mechanisms
Participants' characteristic	Participants stem from the same course. Students only took part in the experiment if they had any tablet experience.
Tool	We have used the same tool running on tablet and on PC. The

characteristics	only difference is the input-medium.
Experimental setting	We have run several experimental sessions, as we did not have enough tablets. In each session we have integrated participants of both experimental groups. That way conditions for tablet-group-members and PC-group-members were similar.
Task complexity	Since the modeling tools were identical on tablet and on PC apart from the input medium, we could use the same task for both experimental groups.
Training	Since participants did not have any previous knowledge in conceptual modeling, members of both groups have been trained before. The training for both groups was the same.

5.3 Future Research

STARK & ESSWEIN have reviewed independent and dependent variables for conceptual modeling based on cognition and integrated these variables into a framework. They have found independent variables that concern Medium of content delivery (e.g. narrated instead of written explanation [Gem04]), User characteristics (e.g. modeling language experience [RD07]), Task characteristics (e.g. task matches languages [AST96]), Grammar's constructs (e.g. distinction between entities and properties [Web96]) and Use of Grammar (e.g. classification rules [PW08]). They did not find any variable concerning the modeling tool. With this study we extend the framework for the modeling tool (see Fig. 5). We have investigated the effect of eye-hand coordination (given with the touch input) on the dependent variables Modeling Efficiency, Perceived Ease of Use, Perceived Usefulness and Intention and have found a significant influence of eye-hand coordination on modeling efficiency.

Based on the experiment we have received comments from participants. Some students found the layout algorithm we used to distribute model elements on the screen as helpful. Others perceived the same algorithm as disruptive. Based on these comments we asked a few students to complete the same experimental task for a traditional modeling tool not offering a layout algorithm. We found significant differences for the mean times. Using a layout algorithm for conceptual modeling might influence model understanding. On the one hand elements are equally distributed among the screen. That way the model is balanced. On the other hand the modeler might not be able to fit modeling elements that belong together into the same part of the screen. This influence of using a layout algorithm on modeling efficiency and model understanding still needs to be investigated.

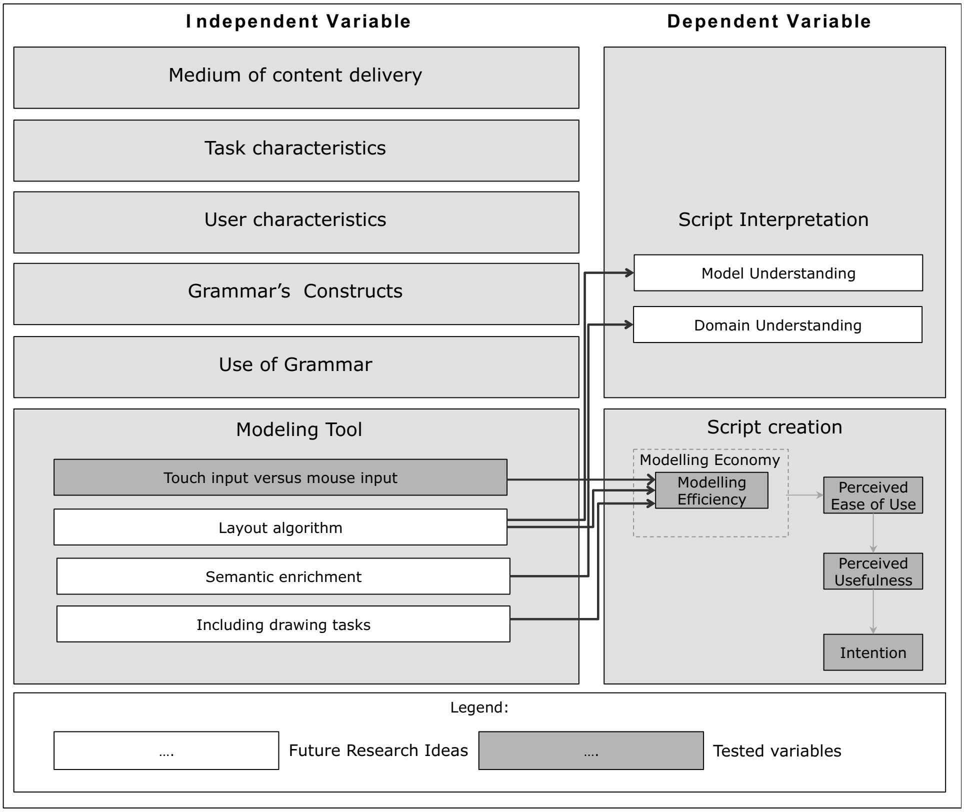

Figure 5: Variables tested and future research ideas

So far conceptual modeling tools require pointing and dragging tasks. [For07] have found significant advantages for modeling efficiency and effectiveness for drawing tasks using touch input. Besides drawing tasks might offer new possibilities for modeling language development as concrete syntax might be developed more easily.

A further starting point to make modeling tools cognitive efficient is integrating speech to obtain semantically enriched modeling elements. GEMINO has investigated the effect of narrated explanation of a model for domain understanding. Integrating speech within the modeling tool make explanations available for the model user without having to use annotations.

6 Summary

In this study we have investigated the effect of eye-hand coordination (given on a tablet) on modeling efficiency as well as on perception-based measurements. We found that modeling on a tablet has a significant effect on modeling efficiency and a slight but not significant effect on Perceived Ease of Use, Perceived Usefulness and Intention to Use.

For practitioners this might be a starting point to use the advantages a modeling tool for tablets offers not only for modeling efficiency but also for using the tool whenever it is needed.

For researchers we have started to investigate features of a cognitive efficient modeling tool and have furthermore derived future research ideas such as investigating the effect of a layout algorithm of modeling efficiency and model understanding.

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