Poster: How Do Modelers Read UML Diagrams? Preliminary Results from an Eye-Tracking Study

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ABSTRACT

Background: Conceptual diagrams are widely used. Previous research suggested layout quality, diagram size, and expertise level are relevant impact factors on understanding, while diagram type is not. Surprisingly little is known about how diagrams are read.
Objective: Eventually, we want to understand the cognitive processes of diagram and model understanding. In this paper, we study the behavior of modelers while reading UML diagrams in terms of reading strategies and how they affect diagram understanding.
Method: We conduct an eye tracking study with 28 participants, reusing diagrams and items from previous experiments. We record several objective and subjective performance indicators as well as eye movement and pupil dilation.
Results: We discover behavioral regularities and aggregate them into reading strategies which vary with expertise level and diagram type, but not with layout quality.
Conclusions: Modelers exhibit specific strategies of diagram understanding. Experts employ different strategies than novices, which explains performance differences irrespective of layout quality.

ACM Reference format:
Harald Störrle, Nick Baltsen, Henrik Christoffersen, and Anja M. Maier. 2018. Poster: How Do Modelers Read UML Diagrams? Preliminary Results from an Eye-Tracking Study. In *Proceedings of 40th International Conference on Software Engineering Companion, Gothenburg,Sweden, May 27-June 3, 2018 (ICSE '18 Companion),* 2 pages.
https://doi.org/10.1145/3183440.3195025

1 MOTIVATION

Visual modeling notations like ER-Diagrams, StateCharts, or EPCs are widely used in the IT industry. In the context of software development, the UML is the most prominent one [8]. It is often taken for granted that visual languages are superior to textual languages for tasks that benefit from the natural perceptual and cognitive capacity of humans to process visual stimuli effectively [9]. Clearly, the UML is a case in point, in fact, this is a major reason for many people to use UML in the first place [1; 8].

So, we assume that the quality of UML diagram layout is a significant factor for the understanding UML diagrams—but many studies failed to provide conclusive evidence. For instance, Eichelberger and Schmid conclude that they "*could not identify [...] a significant impact [of diagram quality].*" (cf. [3, p. 1696]). More recent work, however, has provided substantial evidence to this effect [4–6], so that now we seek to understand the behavior leading to the observed effects. Therefore, we study modelers reading UML diagrams. Our first research question is whether we can establish the existence of stable behavior patterns:

RQ 1: Are there any observable regularities in modeler behavior when reading diagrams at all?

Based on introspection, we are fairly certain the answer is positive. Still we must provide sufficient evidence before we can ask:

RQ 2: Which (if any) reading strategies can be identified, across subjects, diagram types, sizes, and qualities?

After all, there could be just a single reading strategy for all modelers and all diagrams. Likewise, there could be many different strategies for various cases, or a small number somehow varying with expertise level, diagram type, or other factors. Assuming the later, we expect them to differ regarding effectiveness, i. e., some will work better than others under certain conditions. Knowing these factors could provide practical guidance for *reading* and *creating* diagrams in cognitively effective ways, and even inform the development of layout algorithms. Note, that we restrict ourselves to *diagram* understanding, leaving the more complex question of *model* understanding for future research.

We used eye tracking as a widely accepted research method to study cognitive processes. We have reused the stimuli developed for our previous studies [4; 5; 7] to align the findings of the current study with earlier results. While our previous studies aimed at proving that layout quality and diagram size actually do impact diagram understanding, the present study investigates how this effect comes about. For this new set of questions, eye tracking is a more suitable research methodology.

ICSE '18 Companion, May 27-June 3, 2018, Gothenburg,Sweden

ACM ISBN 978-1-4503-5663-3/18/05.
https://doi.org/10.1145/3183440.3195025

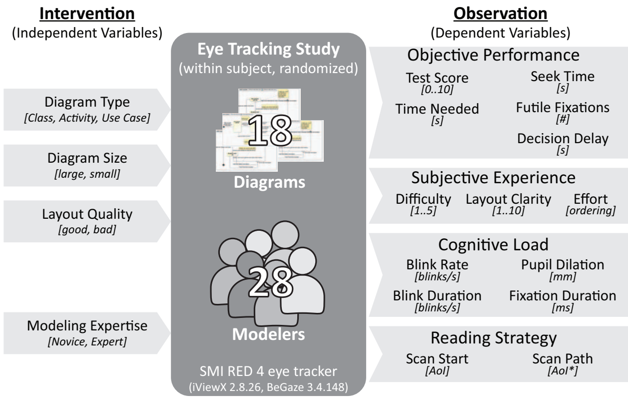

Figure 1: The experimental setup and study design. The values given in angle brackets represent the factor levels, i.e., treatments, or units of measurement. AoI stands for Area of Interest, AoI* means sequences of AoIs.

2 METHODS AND MATERIALS

We developed a study design for eye tracking informed by [2], and ran a pilot study to validate the design. The study design is summarized in Fig. 1. We used the same within-subject design from earlier studies [4] to align our results with previous findings. We also used the same diagrams, selecting a subset to give a good coverage of diagram type and size. The questions per diagram remained unchanged as compared to previous studies. The experiment was run in a vacant single-person office. Participants were briefed on the experiment and its purpose, received written instructions, gave their informed consent, and did the experiment.

3 OBSERVATIONS

Previous empirical work on diagram understanding [10] suggests that reading behavior is characterized by the start and the trajectory of the exploration. Therefore, we observed three groups of phenomena: (1) cognitive load of different elements and flaws in diagram layouts, (2) the starting point of exploratory behavior during diagram reading, and (3) the eye movement trajectory as such.

To analyze the cognitive load levels of diagram elements, we manually analyzed the heat maps and observed elevated fixation times for ordinary model elements, line crossings, and line bends as compared to background and diagram frames. It appears that ordinary diagram elements and layout flaws give rise to similar amounts of cognitive load.

To analyze the start of the exploration paths, we recorded in which quadrant participants started their exploration. Overall, participants tend to start in the top left corner, regardless of diagram type and layout quality, possibly a consequence of the usual reading direction of written text. For activity and class diagrams with poor layout, no recurring pattern for the exploration start could be identified. Likewise, no exploration start patterns were found for use case diagrams regardless of layout quality. Interestingly, no difference was observed between expertise levels.

To analyze the trajectory of exploration paths, we manually classified the scan path recordings and into three distinct patterns of eye movements:

- Diagram Flow: mostly along diagram edges,
- Text Flow: reading direction from top left to bottom right,
- Random Walk: no recognizable order.

Overall, experts have a distinctive profile of applying reading strategies: mostly Diagram Flow, sometimes Random Walk for class diagrams, and sometimes Text Flow for use case diagrams. In contrast, novices have a much less differentiated behavior. They apply the random walk much more frequently, and for bad layouts, this is actually their preferred strategy for any diagram type. Both novices and experts exhibit similar behaviors on class diagrams with good layout, which might result from a more similar level of expertise for this diagram type.

4 CONCLUSIONS

In previous work, we have established that layout quality does impact the understanding of UML diagrams [4]. We have demonstrated that this applies irrespective of diagram type, but dependent on modeler expertise [5], and that diagram size has a major influence [6]. In the present article, we aspire to shed light on how these effects come about. To this end, we conducted an eye tracking study with 28 participants. In it, we have investigated diagram understanding behavior in terms of eye movements, pupil dilation, blink rate, blink duration, and time spent searching for/remaining on a given area of interest on a diagram. The findings of our current study can be used to derive practical guidance for reading and creating diagrams, [7]. Such recommendations can easily be implemented in both industrial and educational settings.

REFERENCES

[1] Sebastian Baltes and Stephan Diehl. Sketches and Diagrams in Practice. In *Proc. 22nd ACM SIGSOFT Intl. Symp. Foundations of Software Engineering (FSE)*, pages 530–541. ACM, 2014.

[2] A. Bojko. *Eye Tracking – The User Experience: A Practical Guide to Research.* Rosenfeld Media, 2013.

[3] H. Eichelberger and K. Schmid. Guidelines on the aesthetic quality of UML class diagrams. *Information and Software Technology*, 51(12):1686–1698, 2009.

[4] Harald Störrle. On the Impact of Layout Quality to Unterstanding UML Diagrams. In *Proc. IEEE Symp. Visual Lang. and Human-Centric Computing (VL/HCC)*, pages 135–142. IEEE CS, 2011.

[5] Harald Störrle. On the Impact of Layout Quality to Unterstanding UML Diagrams: Diagram Type and Expertise. In Gennaro Costagliola and others, editors, *Proc. IEEE Symp. Visual Languages and Human-Centric Computing (VL/HCC)*, pages 195–202. IEEE CS, 2012.

[6] Harald Störrle. On the Impact of Layout Quality to Understanding UML Diagrams: Size Matters. In Jürgen Dingel and others, editors, *Proc. 17th Intl. Conf. Model Driven Eng. Lang. and Syst. (MoDELS)*, number 8767 in LNCS, pages 518–534. Springer, 2014.

[7] Harald Störrle. Diagram Size vs. Layout Flaws: Understanding Quality Factors of UML Diagrams. In M. Genero, A. Jedlitschka, and M. Jørgensen, editors, *Proc. 10th Intl. Conf. Empir. Softw. Eng. and Measurement (ESEM).* ACM, 2016.

[8] Harald Störrle. How are Conceptual Models used in Industrial Software Development? A Descriptive Survey. In Emilia Mendes, Kai Petersen, and Steve Counsell, editors, *Proc. 21st Intl. Conf. on Evaluation and Assessment in Software Engineering (EASE).* ACM, 2017.

[9] Iris Vessey. Cognitive Fit: A Theory-Based Analysis of the Graphs Versus Tables Literature. *Decision Sciences*, 22(2):219–240, 1991.

[10] S. Yusuf, H. Kagdi, and J. Maletic. Assessing the Comprehension of UML Class Diagrams via Eye Tracking. In *15th IEEE Intl. Conf. Program Comprehension*, pages 113–122. IEEE CS, 2007.