How experts change their (viewing) behavior when modeling a task to a novice

Emhardt, Jarodzka, H., S. N., Kok, E. M., Drumm, C., Brand-Gruwel, S., & van Gog, T. (2019, August*)*.

Abstract

Instructional videos are gaining popularity, for instance on online learning platforms. Indeed, videos that display an expert ('s eye movements) while demonstrating how to perform a complex problem-solving task such as code debugging, has the potential to foster novices' learning. To study the cognitive and perceptual challenges novices usually face during code debugging, our first aim was to investigate how novices' debugging behavior and eye-movement patterns differ from those of experts. Experts showed shorter fixations in the code area, showed fewer transitions between the panels of the programming environement per click on the run button, tested the code less often, and debugged the code more linearly compared to novices. These expertise-related differences in attention allocation and debugging behavior suggest that novices might benefit from attention guidance of experts. However, following authentic expert behavior might be challenging for novices. This is why expert models are typically instructed to behave didactically, yet it is not known how this affects experts' behavior. Thus, the second aim of this study was to explore how experts change their eye-movement patterns and mouse click behavior when explaining their task solution didactically. In comparison to experts' regular debugging behavior, didactically behaving experts showed longer fixation durations, shorter saccade amplitudes, ran the code less often, performed more transitions between code and output when running the code and debugged the code more linearly. Given that experts clearly change their (viewing) behavior in order to didactically guide a learner's attention, an interesting question for future research would be to investigate which expert instruction is most suitable for video-based modeling example for novice students.

Keywords: Experimental study, video analysis, educational technology, instructional design, higher education, computer-assisted learning, programming, eye tracking, expertise

Extended summary

Aims of the present study

Modeling examples provide learners the opportunity to observe a model (e.g., a teacher, expert, peer student, or animated agent) performing a task didactically or naturally (for a general review see Van Gog & Rummel, 2010). Especially video-based modeling examples are increasingly gaining popularity (e.g., on online learning platforms like YouTube or Khan Academy) and have the potential to foster the learning of complex procedural problem-solving tasks, such as programming and code debugging. A recent approach to foster attention guidance of novices in such videos are Eye-Movement Modeling Examples (EMME, Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009) which superimpose a visualization of an expert model's eye movements onto instructional videos (e.g., a screen recording). This kind of attention guidance should be especially helpful in tasks with substantial differences between the model's and novice students' eye-movement patterns. However, most EMME studies do not address expertise differences first (for an exception see Jarodzka, van Gog, Dorr, Scheiter, & Gerjets, 2013). Our first aim was to show why novices might profit from attention guidance of a model by investigating how programming experts and novices differ in their eye movements and mouse clicks during code debugging. Based on existing expertise theories (Gegenfurtner, Lehtinen, & Säljö, 2011) we expected to find shorter average fixation durations, longer saccade amplitudes, less code testing, less transitions between the code and an output area per running the code, a longer time until first testing the output of the code, and a less linear code reading behavior for experts than for novices.

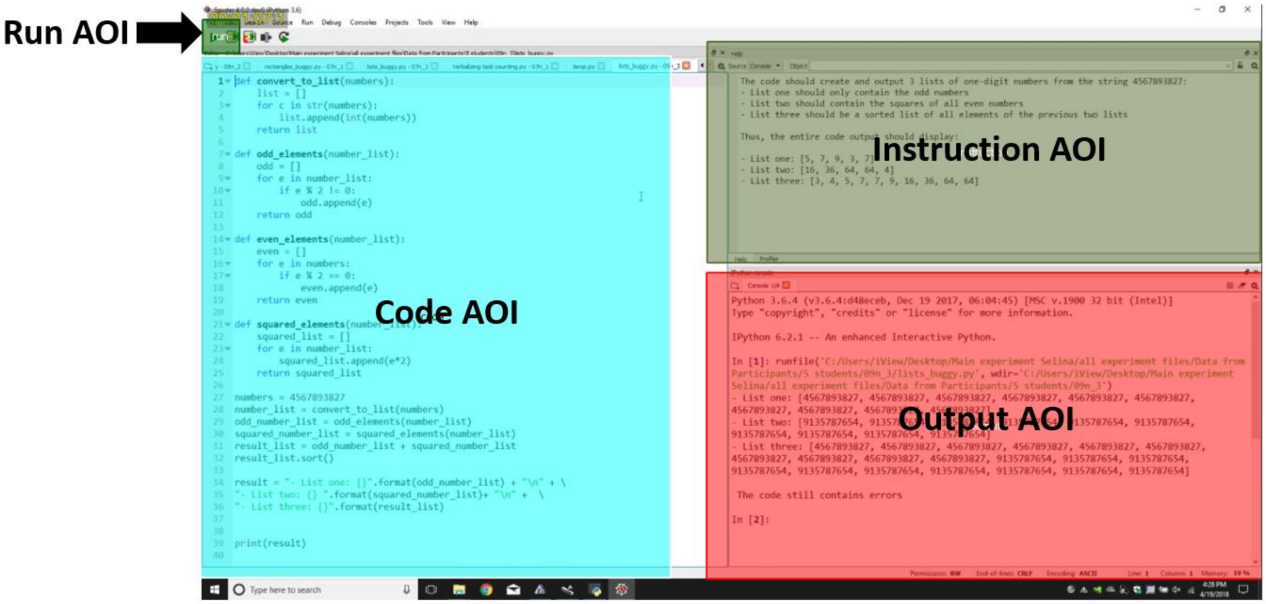
The second aim of this study was to investigate how experts' eye movements and mouse clicks differs when being instructed to behave didactically. When creating EMMEs, experts are in fact often, but not always, asked to behave didactically but until now we do not know how this instruction affects the model's behavior and (and thus the characteristics of the EMME). Clear changes in experts' (viewing) behavior would raise the question what expert-behavior and therefore what expert instruction is most suitable to create effective EMMEs.

Methodology

Eighteen expert (2 females, M_{age} = 29.82 years, SD_{age} = 7.14) and 23 novice (7 females, M_{age} = 23.59 years, SD_{age} = 2.62 years) programmers debugged two Python code snippets while their eye movements and mouse clicks were recorded. The programming environment consisted of a code, an output area, and a task-instruction area, as well as a run button to test the code (Figure 1). The experts first completed each debugging task with the instruction to behave as usual (non-didactically) and subsequently with the instruction to explain the task didactically. The novices only debugged the code once.

Figure 1

Figure 1. Screenshot of the programming environment with superimposed areas of interests (AOIs).



Analysis and findings

Generally, novices debugged the code slower and less accurate (novices: 19.06 (*SD* = 2.50) minutes to fix 1.03 (*SD* = 1.43) bugs; experts: 7.61 (*SD* = 3.92) minutes to fix 3.95 (*SD* = 0.21) bugs). For the main analysis we compared statistical models without and with the factors expertise (experts vs. novices, between-subject analysis) and instruction (non-didactical vs. didactical instruction, within-subject analysis) to see if and in what direction the factor levels significantly influences the outcome variables. Experts performed shorter fixations in the code area ($\chi 2(1) = 37.71$, $p < .001$), performed less transitions between code and output area when clicking on the run button ($\chi 2(1) = 4.35$, $p = .037$), tested the code less often than novices ($\chi^2(1) = 22.69$, $p < .001$), and debugged the code more linearly ($\chi^2(1) = 22.68$, $p < .001$) than novices. No significant difference was found in terms of saccade amplitude ($\chi^2(1) = 2.34$, $p = .126$) and the time until first running the code ($\chi^2(1) = 1.85$, $p = .173$).

When exploring the effect of instruction on experts' eye movement patterns, we found that the experts, when behaving didactically, showed longer fixation durations ($\chi^2(1) = 15.93$, $p < .001$), longer saccade amplitudes ($\chi 2(1) = 8.43$, $p = .004$), ran the code less often ($\chi^2(1) = 17.92$, $p < .001$), performed more transitions between code and output when running the code ($\chi^2(1) = 13.58$, $p < .001$) and debugged the code even more linearly ($\chi^2(1) = 5.64$, $p = .018$) than when behaving non-didactically. No significant differences were found for the measure time until first running the code ($\chi^2(1) = 0.60$, $p = .439$).

Theoretical and educational significance

First, our results revealed that experts and novices differ in their usual behavior during code debugging, which contributes to and extends research about expertise-related problem-solving processes and supports the claim that novices might benefit from attentional guidance of experts in code debugging tasks.

Second, our study is the first to show that eye movements and mouse clicks of experts differ substantially from their usual behavior when they are instructed to behave didactically. So far, EMMEs were often, but not always created with the instruction to behave didactically. Our findings raise awareness that this instruction, however, clearly influences the expert models' (viewing) behavior and with it the characteristics of EMME displays and consequences for the creation of EMMEs should be discussed. An interesting question for future research is instance which expert instruction is most suitable for creating effective video-based modeling examples for novice students.

References

Gegenfurtner, A., Lehtinen, E., & Säljö, R. (2011). Expertise differences in the comprehension of visualizations: A meta-analysis of eye-tracking research in professional domains. *Educational Psychology Review, 23*, 523-552.

Jarodzka, H., van Gog, T., Dorr, M., Scheiter, K., & Gerjets, P. (2013). Learning to see: Guiding students' attention via a model's eye movements fosters learning. *Learning and Instruction*, *25*, 62-70.

Van Gog, T., Jarodzka, H., Scheiter, K., Gerjets, P., & Paas, F. (2009). Attention guidance during example study via the model's eye movements. *Computers in Human Behavior, 25*, 785-791.

Van Gog, T., & Rummel, N. (2010). Example-based learning: Integrating cognitive and social-cognitive research perspectives. *Educational Psychology Review*, *22*(2), 155-174.