Case processing in supporting the development of expertise in pharmacy
- what can eye movements reveal?

Abstract
The purpose of this study is to utilize process-level analyses to investigate pharmacy students’ reasoning during solving a written case task that handled acute patient counseling situation in the pharmacy. Participants’ \( N = 34 \) problem-solving processes were investigated using the eye-tracking method together with written tasks and 2\(^{nd}\) \( n = 16 \) and 3\(^{rd}\) \( n = 18 \) –year students’ processes were compared. The text included semantically different level sentences: task-relevant sentences including essential information for the solution and task-redundant sentences that contained irrelevant or misleading information. The results showed that students differed in their performance and only four 2\(^{nd}\) year students solved the case correctly, whereas almost all of the graduating students were successful. Further, most of those students, who ended up with a correct solution had presented a correct working hypothesis already after reading the first text page. Generally, the average total reading times did not differ between the comparison groups. However, better-succeeding students read significantly longer the very first task-relevant sentences of the case task indicating that they were able to focus on relevant information and discard the task-redundant text parts. Based on the results, pedagogical suggestions for advancing higher education are discussed.

Introduction
In recent decades, several studies have aimed to understand how university students acquire a high level of competence on their way to achieving expertise (Boshuizen & Schmidt, 2018; Schmidt & Rikers, 2007). Most part of the research related to cognitive adaptations during expertise development has been conducted in medical domains (see e.g. Boshuizen & Schmidt, 1992; de Bruin, Schmidt & Rikers, 2005; Feltovich & Barrows, 1984; Schmidt & Rikers, 2007). However, based on the recent extensive review related to the theory of knowledge restructuring through case processing, similar cognitive processes and transitions on a way towards expertise seem to be relevant also across domains (Boshuizen et al., 2020).

Pharmacists involved in patient-centred duties in pharmacies typically act as critical mediators between the pharmaceutical industry and customers, who may have adopted false or oversimplified information related to drugs and their appropriate use. This is of particular concern when it comes to common medication, such as antibiotics. For example, resistance to antibiotics is a globally growing problem that presents real threats to public health and costs due to failure in the treatment and prevention of infectious diseases (WHO, 2015). Thus, the quality of pharmacy experts’ work drastically contributes to the well-being of human society in
numerous levels and hence, fostering the development of expertise is a goal of utmost importance in pharmacy education institutions.

According to current understanding, expertise is, to a large extent, domain-specific, meaning that experts in a specific domain do not develop problem-solving skills that could be effectively applied across domains. Instead, knowledge and the associated skills to use the knowledge develop simultaneously and interdependently (Boshuizen & Schmidt, 2018). This poses an instructional challenge and the use of authentic, discipline-specific case tasks are assumed to have potential to effectively support learning especially in the early stages of education, when learners have to do abundantly reasoning related to conceptual knowledge and when real hands-on problems can still be overwhelming (see e.g. Boshuizen & Schmidt, 2018; Boshuizen, Gruber, & Strasser, 2020). However, students typically struggle when applying basic knowledge in practical problem-solving situations, such as in case tasks (e.g. Boshuizen, Gruber, & Strasser, 2020; Persky & Murphy, 2019).

Case tasks can be defined as descriptions of specific events or problems that are drawn from the real world of professional practice (Ramaekers, van Keulen, Kremer, Pilot & van Beukelen, 2011). Thus, case tasks activate meaningful linking of learners’ prior knowledge so that new knowledge can be effectively connected to existing knowledge structures (Boshuizen & Schmidt, 1992). Solving of them should require the similar mental activities and processes that are faced later in real work life (Brown, Collins & Duguid, 1989). In real life situations, for example, not all required information is typically available in the beginning of the problem-solving situation, but becomes available step by step requiring evaluation of information during the action. This process relates to a script-verification process in which the expert attempts to determine whether the activated script or any of the activated scripts adequately fits the findings until all available information is received (see e.g. Charlin, Boshuizen, Custers & Feltovich, 2007). Even more importantly, in real settings, experts must address complex and multifaceted cases and therefore they should include contingencies, complexities, and dilemmas requiring differentiating of relevant substance and aspects from not-so-relevant, competing noise. Effective case processing and knowledge restructuring are considered to be the key concepts of expertise development (see Boshuizen et al., 2020), and thus, learners’ knowledge structures need to become organized in a way that enables effective processing of information.

Previous studies have provided interesting insights into reasoning of cases (see e.g. Boshuizen, van de Wiel, & Schmidt, 2012), but research focusing on the processes by which participants use the case description text while coming to a solution, is scarce. Eye tracking offers a suitable method for investigating that since there is a close connection between the direction of human gaze and the focus of attention (regarding the widely-accepted eye–mind hypothesis, see Just & Carpenter, 1980). Despite large number of studies concerning expertise in comprehension of visualizations, eye-tracking studies using domain-specific, relevant texts as stimuli seem to be scarce. However, processing various kinds of texts, such as journal articles, records,
prescriptions, and product descriptions, is an essential part of life science experts’ tasks, which encouraged us to focus on written cases in our studies.

Thus, based on these premises, the research questions and hypotheses of the study were as follows:

1. How successful pharmacy 2nd and 3rd-year students are in solving a problem-solving case task? We hypothesize that 3rd-year students would succeed better because of their higher level of expertise.

2. Do the processing times for a case text differ between participants who give a correct versus an incorrect diagnosis or between participants with different level of expertise? Following previous eye-tracking studies, it is expected that more experienced actors and those who diagnose the case correctly will process the case more quickly (e.g. Charlin et al., 2007; Mann, Williams, Ward & Janelle, 2007; Schmidt & Rikers, 2007).

3. What kind of differences exist between the participants with different level of expertise and a correct versus an incorrect final solution in focusing on the task-relevant and task-redundant parts of the case text? Based on previous research, it is hypothesised that those who solve the case correctly will be more effective in directing their attention to the task-relevant areas of the text. Further, it is assumed that for those, who activate all possible scripts in the beginning of the reasoning process, will be more successful in solving the case (Södervik, Vilppu, Mikkilä-Erdmann & Österholm, 2017).

Methods

Participants and design

The participants (N = 38) were native (language removed)-speaking pharmacy students from the University of (removed), who participated in the single-case study phase, which was conducted in spring 2020. The eye-tracking data were poor for four students; hence, a total of 16 second-year students and 18 third-year students were included in the study.

The study phase was administered in the eye-tracking laboratory, and it consisted of an orientation and a trial phase. The purpose of the orientation was to familiarise the participants with the test situation. Eye movements were recorded during the reading utilizing with Tobii ProSpectrum (Tobii Technology, Inc., Falls Church, VA). The session lasted approximately one hour.

At the beginning of data collection, the eye tracker was adjusted accordingly and calibrated, and instructions regarding the orientation and trial phases were given. The participants were told that they would be shown a short text concerning a customer counselling in pharmacy, and after each factual slide, an interspersed slide would ask them to answer questions without the help of text. After the questions had been answered, participants were instructed to continue reading by pressing an arrow key on the keyboard. Participants were
informed that they should read the text carefully, as it would not be possible to move back to the previous slide. There were no time limits, and the participants could move on at their own pace.

After the trial, a stimulated recall interview was conducted, in which the eye-tracking data were reviewed with the participants and questions were posed about parts of the text where issues of interest, such as longer fixations or rereading, emerged in the eye movement data.

**Measures**

The written case task was presented in three PowerPoint pages and the idea of the case text was to simulate the phases of a customer counselling situation in a pharmacy. The case was designed based on the idea that certain working hypotheses i.e. scripts would have been activated and tested during reading. When more information is provided, certain hypotheses become excluded and finally, there will be solely one verified script that would be the correct solution (in that case, it was about adverse effect caused by an antibiotic). The topic of the case was chosen based on the fact that it is relatively common, familiar for students and severe requiring acute action from the pharmacist.

The text sentences were semantically categorised into different levels, as follows: task-relevant sentences including essential information for the solution and task-redundant sentences that contained irrelevant or misleading information. Supplementary sentences (which included neutral information) were excluded from the analyses. The questions asked after each page were as follows: 1. Which aspects you considered relevant on the page that you just read? 2. What is the case about in your opinion?

**Data analysis**

First, the written answers that were given after each text page were scored based on the flow chart model (Figure 1). Students’ scores related to the most important findings and working hypotheses were calculated after each slide. The final solutions made by the participants for the patient case were categorised as either correct or incorrect. Participants’ reading processes were analysed using TobiiProLab. The analysis of eye-tracking data began with defining the areas of interest (AOIs), the regions in the stimulus from which the authors were interested in gathering data. Metric of total visit duration was chosen and it indicates the duration of all visits within an active AOI. Each slide and sentence constituted an AOI. IBM SPSS Statistics 25 was used for further analyses.
Figure 1. The analysis tool following the structure of the case task. The flow chart illustrates the script activation/verification from the beginning to the solution.

**Results**

A total of 20 (59 %) out of 34 of the students gave a correct answer after reading the case. The 2nd and 3rd-year students differed in terms of their success and solely four (25 %) of the second-year students gave a correct answer, whereas almost all (n = 16; 89 %) of the 3rd-year students succeeded well. The scores for the written answers did not differ between the groups after reading the first text page. However, those students who solved the case correctly, received indicatively higher scores after the second text page, (t(32) = 1,990, p = .055) and significantly higher scores after reading the whole case text (t(32) = 4,891, p < .000). Furthermore, most of the students (n =14/20, 70 %) that solved the case correctly had mentioned the correct working hypothesis (among other possible hypotheses) already after reading the first slide.

The total average reading times did not differ between the 2nd and 3rd-year students or between the students giving a correct versus an incorrect solution. Page-level comparisons revealed significant differences regarding processing times of the first slide. The 3rd-year students and students, who gave a correct final answer, read the first page significantly longer compared to younger or weaker succeeding students (t (21,808) = -2.48, p = .021; t(25,478) = 2,211, p = .036). A more detailed, sentence-level analysis, revealed that 3rd-year students and students with a correct final solution read the task-relevant sentences of the first slide significantly longer compared to 2nd year or weaker succeeding students (t(22,708) = 2,187, p =.039). There were no differences
in reading times related to task redundant sentences. Neither were there differences in reading times of different level sentences in following pages of the case text.

Discussion

The purpose of this study was to establish how the second- and third-year pharmacy students solve and process a case task and how the processing times of a text differed between the participants who gave a correct versus an incorrect final solution. We also investigated how the participant groups differed in making use of task-relevant and task-redundant aspects of the case text.

The study shows that there are differences among pharmacy students in their reasoning skills. Graduating students were more successful in the task and almost all of them ended up with a correct final solution, whereas solely a couple of novices solved the case correctly. Against to our hypothesis, general average total reading times did not differ between the groups. Additionally, the groups did not differ in terms of their written answers after reading the first text page meaning that all students succeeded equally well in naming the most central information from the first page and making the working hypotheses. However, longer processing time of task-relevant sentences in the first text page was related to better success the case task. Furthermore, most of the students that solved the case correctly had mentioned the correct working hypothesis already after reading the first text page. The result indicates that early activation of the correct script is essential in the reasoning process. This result is in line with earlier studies, in which the experienced and better-succeeding actors spent relatively longer time with the early relevant information (see Södervik et al., 2017).

All in all, this study is one of the first to investigate the reading of texts at the processing level via eye movements among actors at different levels of expertise. Eye-tracking methodology appears to have a great deal of potential in evaluating performance and growing of professional expertise in processing texts in higher education. This study focussed on pharmacy expertise, but it also has implications for many other domains. On a more general level, this study contributes, for example, to the discussion among learning researchers related to the interaction of theory and practice in the development of professional expertise (e.g. Tynjälä & Gijbels, 2012).

References


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