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ABSTRACT

The effects of experience with a series of similar cases on the knowledge restructuring and learning from text were studied in a longitudinal design. Two groups of fourth-year medical students were confronted with a series of cases, part of them having the same underlying disease. The cases were interspersed with fillers, and each set of cases had one filler from the other set. Students were asked to diagnose the cases and to try to learn as much as possible, and they were asked to learn as much as possible from a text. Case processing time showed that students who had worked in a series of similar cases needed less time for the same case than students who did not have that experience. Results show that one series of cases, those dealing with polycystic ovaries syndrome, was more intensively processed than the other series, and that those students showed more traces of knowledge construction, although it was not clear why. Prior processing of a series of cases led to better text recall of the part of the text that concerned these specific diseases, but did not affect reading time. Results do suggest that students learned case content from processing multiple cases, and that they integrated it into their prior knowledge. It is hypothesized that the theory on construction and integration of W. Kintsch explains these outcomes. (Contains 1 table, 4 figures, and 10 references.) (SLD)

Learning from Multiple Cases: A New Paradigm for Investigating the Effects of Clinical Experience on Knowledge Restructuring and Knowledge Acquisition

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April 1998

Learning from multiple cases; a new paradigm for investigating the effects of clinical experience on knowledge restructuring and knowledge acquisition[1]

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Abstract

Aim of the present project was to investigate the effects of experience with a series of similar cases on knowledge restructuring and learning from text by means of a longitudinal design.

Method: two groups of 4th-year medical students were confronted with a series of cases, part of them having the same underlying disease. One group worked on a series of PolyCystic Ovaries Syndrome (PCO) cases, the other group worked on a series of HyperprolactAemia (HPA) cases. The cases were interspersed with fillers. One filler in the PCO group was the final HPA case of the other group and vv. Afterward they read a text describing both disease processes. The order of the text parts was varied. Students were instructed to diagnose the cases and to try to learn as much as possible from it. The text was introduced by saying that they had worked on a series of menstrual problem cases, and that the text addressed that problem as well. Again the instruction was to learn. Case processing time and text-part reading time were recorded. Furthermore the reports on what the participants had learned from the cases and the text recall were analysed.

Results: Case processing time showed that students who had worked on a series of similar cases needed less time for the same case than students who did not have that experience. The reports suggest that the PCO series were more intensively processed than the HPA series; they showed more traces of knowledge construction. Prior processing of a series of cases led to a better text recall of the part that concerned these specific disease, but did not affect text reading time.

Discussion: Interpretation of the results was complicated because it could not de decided why the PCO students seemed to put more effort into case processing. This could be due to group differences or differences in case difficulty. Results on case processing time suggest a structural change or at least a change in accessibility of the associated knowledge. Furthermore, it can be concluded that students learned case content from processing multiple cases and that they integrated it in their prior knowledge. Differences in text recall were not due to metacognitive effects on resource (reading time) allocation. Instead it was hypothesized that Kintsch's theory on construction and integration provides a better explanation for these outcomes.

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Introduction

Cases play an important role in many professional education programmes. Accountancy, Business Administration, Medicine, Pharmacy and Psychology are examples. Students who for the first time in their lives see such a specific case are supposed to learn several things from it. In the first place, there is the case itself that is always different from what students have learnt from the textbooks. These individual cases are stored in memory as a first illustration of theoretical knowledge. They can also be stored in conjunction with the solution of the case, depending on how much energy the student has spent on solving the case. In this way the case helps to build the connection between theoretical knowledge and the conditions for application. These cases can be retrieved later, when a new, similar one is encountered. The same applies to the second, third, fourth case (Kolodner & Kolodner, 1987). After having seen several of them, a student will have acquired experiential knowledge. The generalities and specifics of these cases will be remembered in a more general format. In the domain of medicine this more general format is called 'illness scripts' (Boshuizen & Schmidt, 1995; Schmidt, Norman, & Boshuizen, 1990) . Illness scripts contain generalized information about the conditions in a patient (e.g., age, gender and psychomedical history) that have directly or indirectly led to the disease at hand (the Enabling Conditions). Illness scripts also contain information about the Fault (the specific disorder that is presently manifesting itself), and about the Consequences of the Fault: the complaint, signs and symptoms of the patient. Research in the domain of accountancy suggests that expert accountants have developed similar structures (Vaatstra, 1996).

Another, also very important effect is a 'by-product' of the diagnostic reasoning process. When someone sees his/her first patient with a specific disease, the reasoning process will be characterized by active search in the knowledge base and by explicit reasoning. This active search will lead to permanent restructuring of the knowledge base. New links that are constructed in this reasoning process will remain, and connections that are activated become stronger. Hence on a following occasion, search times will be reduced and the application of detailed biomedical knowledge will be replaced by higher order (often clinical) concepts (encapsulations) (Schmidt et al., 1990; Van de Wiel, 1997)).

This reasoning process also has a more temporary, metacognitive 'by-product'. Students whose knowledge seamlessly fits the cases presented will experience a feeling of mastery, while those who have to do a great deal of reasoning based on biomedical knowledge will assess their knowledge base as deficient in this respect. It is assumed that such metacognitive assessments play an important role in ensuing, self-directed learning (De Grave, 1998).

Empirical evidence for illness script formation and knowledge encapsulation has been provided by studies using a cross sectional design. Problem with this design is that differences found can never be traced back to specific experiences with specific cases. Yet the theory assumes that these experiences trigger the encapsulation and illness script formation processes. The metacognitive effect in self-directed learning has never been investigated in this paradigm, but it has been in problem-based learning studies (De Grave, 1998). In the present experiment we have tried to investigate these processes using a new paradigm. Medical students were presented with a series of clinical cases, followed by a learning task. Working on multiple cases should lead to knowledge building and knowledge restructuring; the latter should lead to a decrease in the time needed to solve such cases. Ensuing self-directed learning should lead to different learning results on experience relevant and experience irrelevant text parts.

Method

Subjects

Subjects were 31 4th-year medical students. The experiment was done during the second semester. The students can be expected to have all relevant theoretical knowledge concerning the two medical conditions and the necessary underlying biomedical knowledge. They received a compensation of Dfl 15.-- per hour participation.

Procedure

One group of students (N=14) were presented with five cases with the same underlying disorder (polycystic ovaries, PCO) plus three 'fillers'. The other group (N=17) worked on five cases of another disorder (hyperprolactinaemia, HPA) plus the fillers inserted at the same places in the case sequence. Fillers 2 and 3 were the same for each group; filler 1 was identical to the target case of the other group, i.e., the last PCO or HPA case. Table 1 represents the presentation order of the different cases. Both disorders lead to menstrual problems and eventually to infertility. The filler cases concerned menstrual problems as well. The students were told that they would be presented with a series of cases and that their task was to diagnose these cases *and* learn as much as they could from all these cases. After having given their diagnosis, the subjects were told the official diagnose of the case. Cases were presented on a computer screen. To improve readability, each case was split up into coherent parts of about four lines. Processing times were recorded.

Table 1. Presentation order and content of the cases for the two groups

case #	content, PCO group	content, HPA group
8	PCO 5 (own target)*	HPA 5 (own target)*
7	filler 3*	filler 3*
6	PCO 4	HPA 4
5	filler 2*	filler 2*
4	PCO 3	HPA 3
3	filler 1: HPA 5 (other target)*	filler 1: PCO 5 (other target)*
2	PCO 2	HPA 2
1	PCO 1	HPA 1
(0)	(introduction plus test case)	(introduction plus test case)

* Cases that were included in the analyses.

After having studied the cases, students were asked to report what they had learned from the cases. These reports were recorded on audiotape and transcribed later.

Finally the students studied a text in which both disorders, HPA and PCO, were described and explained. The text was structured according to the categories definition (3 propositions), epidemiology (2 propositions), pathophysiology (21 propositions), symptoms (8 propositions), physical examination (6 propositions), further examination (5 or 6 propositions), differential diagnosis (3 propositions), and therapy (8 or 7 propositions). Both parts had equal length (total and per category[2]) and structure; the order of the two parts was systematically varied. Text reading time was recorded. After having read the text, students were asked to tell what they could remember.
Subjects were run individually. The experiment took about four to five hours per person.

Analysis

Knowledge restructuring was measured in two ways:
a) By means of two target cases: 1) The 'own' target case was the last case with the same disorder (PCO or HPA) of a series of five; 2) the 'other' target case was target case of the other group, but new for this group of subjects. Case processing time was measured and should be shorter for the 'own' case. No differences would be expected on the filler cases. The fillers and target cases that were included in the analysis are indicated by '*' in Table 1.
b) After the students had completed their series of cases, they were asked to describe what they had learned about PCO or HPA. These descriptions were compared with a model description of that condition and classified into categories: definition, epidemiology, pathophysiology, symptoms, physical examination, further examination, differential diagnosis, therapy, normal physiology, inferences and elaborations. Utterances were classified as inferences when they could be described as conclusions within the relevant knowledge domain; they were classified as elaborations when they were additions based on other (related) knowledge fields. Furthermore, the number of metacognitive statements (e.g., 'I don't know if ..') were counted. Inferences, elaborations and reasoning based on normal physiology were taken as indicators for active knowledge (re)construction (Boshuizen, 1994); scores in the pathophysiology category represent the use of knowledge referring to the Fault. Epidemiology, symptoms, physical and additional examination represent the other illness script categories.
Self-directed learning was investigated by means of the text in which the two disorders were described and explained. If metacognitive effects of case processing guide the way the student studies the text, then more time should be spent on the 'own' text part. Furthermore, students should also remember more of their 'own' text part. Due to errors in the instruction of some students, only twelve text recall protocols in each group could be used.

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[2] With two very slight exceptions: The text on further examination in the PCO part was one item longer than in the HPA part, the opposite was the case with therapy.

Results

Case processing time No general differences in case processing time were expected between the two groups. Students who had worked on the PCO were supposed to spend as much time on the cases as those who had worked on the HPA cases ($F(1,81) = 1.517$; $p = .2287$). We did, however, expect an interaction between the kind of cases students had worked on and the time taken to process their 'own' target and the target of the other group. As Figure 1 shows, students processed their 'own' target case faster than the 'other' target ($F(3,81) = 3.152$; $p = .0293$). Finally, the results show that the different cases were not processed equally fast ($F(3,81) = 34.509$; $p = .0001$). However, this outcome has no theoretical relevance.

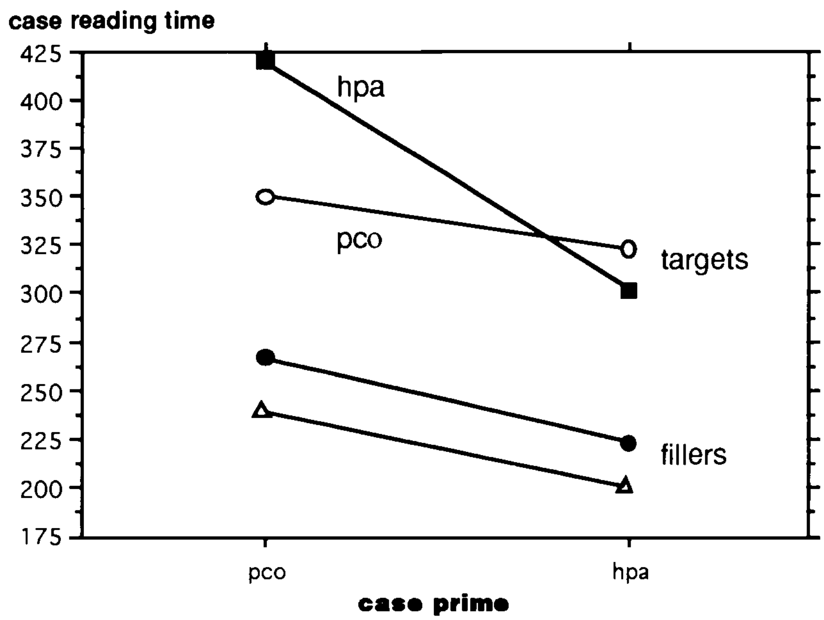

Figure 1 Case processing times of two target and two filler cases of students who had either worked on the PCO series (case prime PCO) or on the HPA cases (case prime HPA).

Learner report Results on the learner reports show that the students who had worked on the PCO series were more extensive in their reports (M=13.211) than the students who had worked on the HPA cases (M=6.424) ($F(1,29) = 14.737$; $p = .0006$). Furthermore, the different response categories were represented differently in the students' reports ($F(10, 290) = 10.10.702$; $p = .0001$). Most frequently reported were issues concerning pathophysiology, inferences, normal physiology, symptoms, and therapy (see Figure 2). The significant interaction effect ($F(10, 290) = 4.519$; $p = .0001$) was especially due to the following categories (see Figure 2): normal physiology, inferences and elaborations where the PCO group scored substantially higher than the HPA group. On the other hand, the HPA group outperformed the PCO group regarding pathophysiology.

Remarkably several of the most prominent categories in these learner reports had not been elements of the cases studied, i.e., pathophysiology, inferences, normal physiology and therapy. When we confine the analyses of the learner reports to those categories that were present in the cases (epidemiology, symptoms, physical examination, further information and differential diagnosis), the following results emerge: Again the students who had studied the PCO cases reported more (M=.653)

than those who had studied the HPA cases (M=.257); $F(1, 29) = 9.285$; $p = .0049$). Again the categories were represented differently in the reports ($F(4,116 = 12.934$; $p = .0001$). Symptoms were the most prominent elements. In this analysis the interaction effect disappeared.
The students in the PCO group tended to generate more metacognitive utterances, but this difference was not significant.

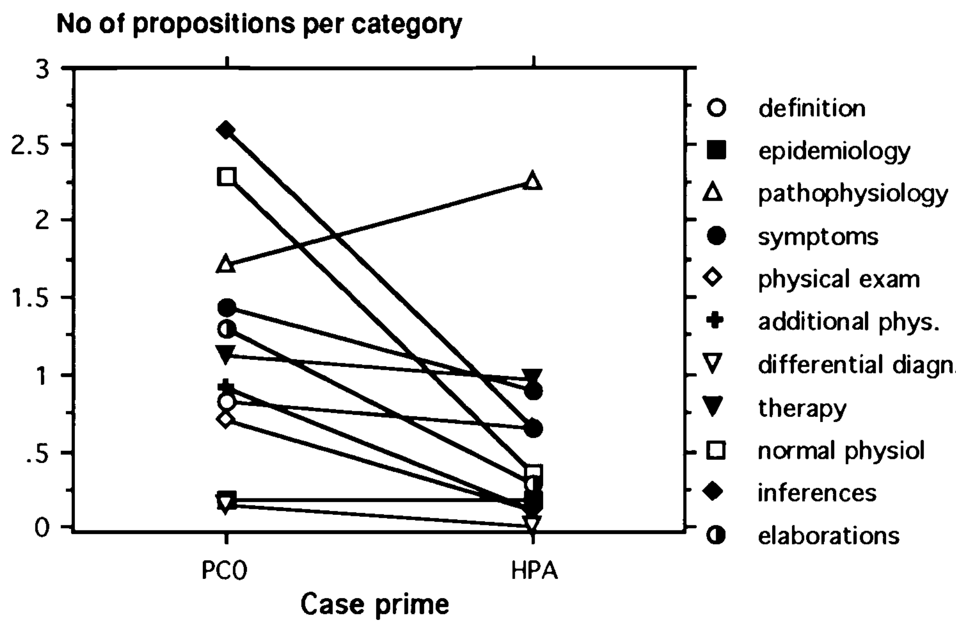

Figure 2. Learner report of students who had either worked on the PCO series (Case prime PCO) or on the HPA series (Case prime HPA)

Text reading times The two groups did not differ in text reading time ($F(1,27= 1.130$; $p = .2972$), nor did we find the expected interaction effect ($F(1,27 = .252$; $p = .6198$). That is, students did not spend more time on their 'own' text part. Instead, both groups spent more time on the HPA part of the text (M= 9.697 min.) than on the PCO part (8.487 min) ($F(1,27) = 15.340$, $p = .0006$).

Text recall The two text parts were remembered equally well ($F(1,22) = .870$; $p = .3611$). The HPA group tended to recall less (M= 15.191) than the PCO group (M=20.185), but this difference failed to reach the required level of significance ($F(1,22) = 3.839$; $p = .0629$). Furthermore we found an interaction between text part (HPA-PCO) and case prime, the kind of cases studied before, ($F(1,22) = 6.780$; $p = .0162$) suggesting that the two groups remembered most of the text-part that regarded their 'own' series of cases (see Figure 3).

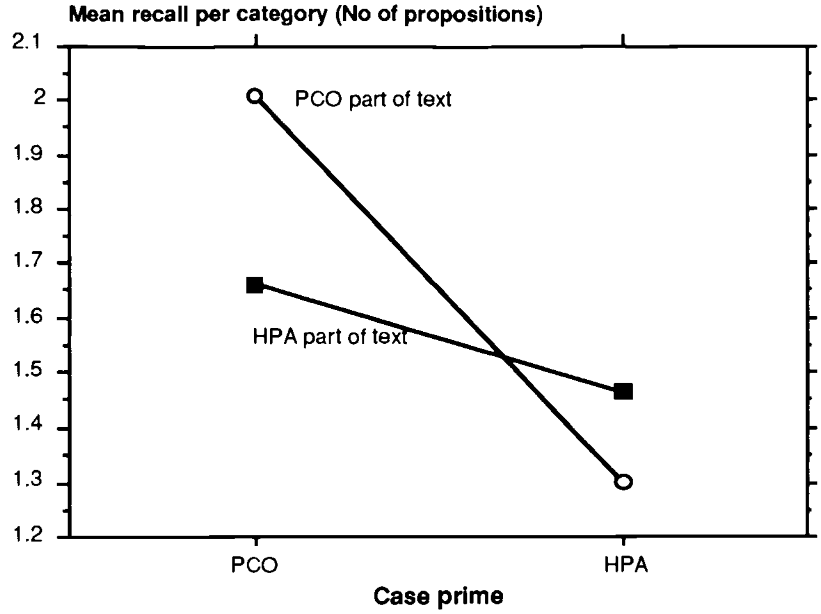

Figure 3. Text-parts recall by students who had either worked on the PCO (case prime is PCO) or the HPA series (case prime is HPA).

Further analysis of the kinds of categories that were remembered best showed a large main effect of categories ($F(10,220) = 48.874$, $p = .0001$). This effect is not very interesting, since recall differences largely reflect the differences in the number of text-items per category. There was maybe one exception. The number of therapy propositions in the text recall part was remarkably high, compared to the number of these items in the text. It reflects the attention given to this topic in the learner reports, where it was high as well. The text categories are completed with normal physiology, elaborations and inferences. An interaction was found between the recall per category and text part ($F(10,220) = 2.438$; $p = .0089$; $.G\text{-}G = .0401$). Figure 4 shows that for the categories definition, epidemiology, symptoms, and additional investigations the recall of the HPA text exceeded the PCO text recall. The opposite was the case for pathophysiology, DD, normal physiology, inferences and elaborations. A three-way interaction effect with case prime was not found.

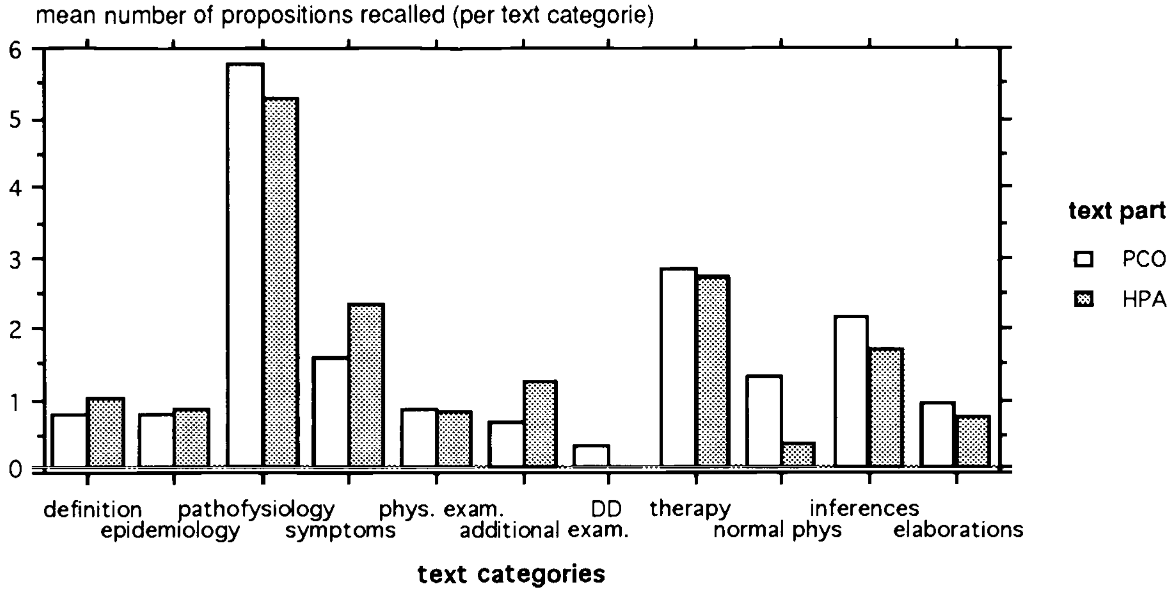

Figure 4. Recall of the different text-categories per text part.

Discussion

The outcomes of the present study face us with some unexpected findings that complicate answering the research questions that were: 1) What do students learn from working on multiple cases and does the knowledge structure change due to that process? and 2) Does working on multiple cases have a metacognitive effect that guides later learning from text? Before we can even try to answer these research questions, a few other, preliminary questions must be posed and solved. The first question is: are our two groups comparable enough to draw conclusions based on the differences we found between them? The other question is: are the two topics, HPA and PCO comparable enough, or is one more difficult than the other? And if our groups and/or topics are different, how does that affect the outcomes?
To start with the groups: The results suggest that the HPA group reported fewer propositions in the learner reports and recalled less from the cases (although the latter finding was only marginally significant, $p = .06$). Group differences in case processing time (see Figure 1) happened to be far from statistical significance. The group that had worked on the PCO cases showed the largest variance in processing time on *all* cases. The same impression arises from the text reading time data. Group differences are far from significant, but again the variance in the PCO group was larger. The overall message of these findings is that at least some students in the PCO group have put more effort into the tasks than students in HPA group.. How about the difficulty of the cases they had to deal with? An answer to that question must be based on the results pattern in the learner report and text reading times. In the learner reports we found a very intriguing phenomenon, i.e. that the interaction effect observed between case prime and the different categories in the report was mainly due to differences in the number of normal physiology, inference and elaboration propositions that were higher in the PCO group, while the HPA group outperformed the PCO group regarding pathophysiology. This indicates that the group who had worked on the PCO series did not have the relevant underlying pathophysiological knowledge that explains the Fault in PCO. Instead they had to construct that explanation, using their

knowledge of the normal physiology. An analysis by Boshuizen and Van de Wiel (in press) corroborates this assumption. In analysing the think aloud protocols of a student who diagnosed two PCO cases, these authors focused the question as to what kind of knowledge was used under what circumstances. They found that this student reverted to her knowledge of the normal physiology when she ran into trouble with her clinical explanation. She used that knowledge to check and strengthen her earlier line of reasoning, scaffolding her reasoning based on clinical knowledge with this normal physiology knowledge. Hence, probably the groups working on the PCO cases experienced more difficulty and put more effort into building the case representations. It is impossible to decide if this difference is due to differences in overall prior knowledge between the two groups or that PCO is generally more difficult for this group of students than HPA. The last suggestion is, however, contradicted by the observed differences in reading times of the text parts, where more time was taken for the HPA part than for the PCO part. For our further analysis we'll assume that the PCO cases were more intensively processed and for the time being leave the question unresolved as to if that is due to group or case difficulty differences.

Our first question was: What do students learn from working on multiple cases and does the knowledge structure change due to that process? The students' reports suggest that they did not only learn case content from their experience with the multiple cases, although some students commented in that vein saying that what struck them most was the variation in symptoms and other findings over the different cases. On the whole the learner reports were not very extensive (a mean number of 13.211 propositions in the PCO group and 6.424 in the HPA group). It is unclear if this might be due to the students' level of involvement in the cases and their own learning process or that they were not challenged enough to report as much as they could. However, the very fact that students reported a substantial amount of normal physiology or pathophysiology knowledge suggests that they did were involved and have integrated the new information with what they already knew.
The analysis of the case processing times suggests that the knowledge base of the students indeed restructured while they were working on the case, or became at least more easily accessible. It is however possible that this restructuring was primarily a temporary effect, due to knowledge priming. It is impossible to decide on that, since the target case was presented at the end of the same session. Hence we can only conclude from the present results that at least the base has been laid for knowledge restructuring.

Despite the fact that they were instructed to learn as much as they could from the cases, students did not seem to learn very much from them. Some students spontaneously reported on that topic. They indicated that they had learned most from the variation in the cases leading to additions to their illness scripts. One student remarked that she did not have the idea that she learned much from the reasoning process itself. If she is right, not much knowledge encapsulation takes place. However, it is doubtful if this process is accessible for introspection.

Our second question was if working on the series of cases had metacognitive effects and guided later selfstudy activities.
It was expected that students would allocate more time to their 'own' part of the text, which was not the case. Both groups spent most time (about one minute more) on the HPA text part. However, both groups learned most about their 'own part': the HPA students learned most from the HyperProlactAemia part in the text while the PCO students learned most from the PolyCystic Ovaries Syndrome text part. What does this tell us about the role of metacognition? The effect of metacognition through resource (time) allocation is not shown in this study. However, the interaction effect that students who had worked on the PCO cases remembered more from that text part, while students who had worked on the HPA cases remembered more of the HPA part proves that working on cases has a positive effect on learning. This finding comes closest to an earlier result found by Machiels-Bongaerts (1993) in one of her experiments. She gave students a text about EU fishing policy and its effect on a small Portuguese village. Half of the students had activated knowledge about EU fishing policy while the other half had activated knowledge on tourism. Study time was fixed; both student groups recalled more about their 'own' topic. The same differences were found when study time was free. Machiels-Bongaerts found, however, that in the latter case students spent more time on their 'own' information. So in the present experiment we found that even in free reading time conditions students can allocate as much study time to 'own' and other information and still remember more of their own part. Older text-processing theories like the cognitive set-point theory, stating that activating prior knowledge affects resource (reading time) allocation, and the selection hypothesis stating that activation of prior knowledge leads to schema-activation, cannot explain this result. The cognitive setpoint theory requires time allocation effects, the selection hypothesis cannot account for the construction effects shown by the number of inferences, elaborations and normal physiology propositions in the text recall. The findings are however in accordance with Kintsch's construction and integration model (Kintsch, 1988), if we assume that working on the cases speeds up the construction phase. Machiels-Bongaerts (1993) has already brought forward this hypothesis.

The paradigm itself appears useful for the investigation of more fine grained and better controlled learning processes based on experiences with multiple cases. More detailed analyses than reported here are possible. The unexpected differences between the two groups are probably due to sampling biases in small samples. These problems can be prevented in several ways: a) Enlarging the sample size which is difficult with this time consuming paradigm; b) Doing the experiments with matched groups of subjects with well known knowledge levels; or c) Introducing a second factor in the experiments: knowledge or expertise level. By doing this the design again gets a cross sectional flavor. However, this can be an advantage when processes in one group can be used to validate the interpretation of processes in other groups.

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