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How do Experts Adapt their Explanations to a Layperson's Knowledge in Asynchronous Communication? An Experimental Study

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Abstract. Despite a plethora of recommendations for personalization techniques, such approaches often lack empirical justification and their benefits to users remain obscure. The study described in this paper takes a step towards filling this gap by introducing an evidence-based approach for deriving adaptive interaction techniques. In a dialogue experiment with 36 dyads of computer experts and laypersons, we observed how experts tailored their written explanations to laypersons' communicational needs. To support adaptation, the experts in the experimental condition were provided with information about the layperson's knowledge level. In the control condition, the experts had no available information. During the composition of their answers, the experts in both conditions articulated their planning activities. Compared with the control condition, the experts in the experimental condition made a greater attempt to form a mental model about the layperson's knowledge. As a result, they varied the type and proportion of the information they provided depending on the layperson's individual knowledge level. Accordingly, such adaptive explanations helped laypersons reduce comprehension breakdowns and acquire new knowledge. These results provide evidence for theoretical assumptions regarding cognitive processes in text production and conversation. They empirically ground and advance techniques for adaptation of content in adaptive hypermedia systems. They are suggestive of ways in which explanations in recommender and decision support systems could be effectively adapted to the user's knowledge background and goals.

Key words. adaptive instructional explanations, advice-giving and recommender systems, audience design, cognitive processes in writing and written communication, computer-mediated communication, human experts' adaptation strategies, human tutoring, natural language generation, personalization techniques, user-adapted communication

1. Introduction

To communicate effectively with laypersons, experts should have a reasonably accurate idea of what a layperson does and does not know about the topic of the communication (Nickerson, 1999). However, their very expertise may make it difficult for experts to anticipate the limited domain knowledge of a layperson. This phenomenon has tellingly been coined as an "expert blind spot" (Nathan and Koedinger, 2000) or the "curse of expertise" (Hinds, 1999). Nathan and Koedinger found that high-school teachers with advanced mathematics education overestimated the accessibility of symbol-based representations for students who were learning introductory algebra. Hinds had experts predict the time needed by novices to perform an unfamiliar complex task. In her study, experts systematically underestimated novices' performance and difficulties with the task. Hinds concluded that the ready availability (Tversky and Kahneman, 1974) and interconnectedness of the experts' knowledge (Chi et al., 1988) may interfere with the task of taking into account the limited knowledge of a layperson.

In as much as experts' estimates of another person's knowledge are likely to be biased towards their own knowledge, it could be useful to provide them with information about the layperson's knowledge background. Such information could help the experts develop a more accurate mental model about their recipient's knowledge and thereby improve their communication with the layperson. Nückles et al. (2005) tested this hypothesis using an asynchronous computer helpdesk scenario. In their experimental study, computer experts answered queries of laypersons via an asynchronous communication interface. In preparing their explanations, the experts were either presented with valid information about the layperson's computer knowledge, no information, or distorted information. Nückles et al. found that the laypersons learned the most (increased *communicative effectiveness*) and asked the fewest questions (increased *communicative efficiency*), when the computer expert was presented with valid data about the layperson's knowledge level. When the information about the layperson was distorted, the laypersons learned the least and asked the most questions. Nückles et al. concluded that the individuating information about the layperson facilitated the task of building an accurate mental model about the layperson's knowledge (Nickerson, 1999) and thereby supported adaptation to the layperson's communicational needs. With their study, Nückles et al. successfully replicated and extended the results of a previous experiment (Nückles and Stürz, 2006).

In the following, we use the term "layperson" to refer to people with varying levels of knowledge in the computer and Internet domain clearly below the expert level. In our context, laypersons seek advice from a computer expert in order to comprehend a concrete computer problem and to extend their knowledge. However, in doing so, laypersons usually do not intend to become computer experts, although their aim is to better understand the computer or to use it more effectively (cf. Patel et al., 1999). The term "computer expert" is used to refer to someone who has sufficient expertise in the computer and Internet domain to give advice to other people. Often, computer experts have no formal training in advisory skills although giving advice to laypersons may be a part of their job.

The studies of Nückles et al. (2005) and Nückles and Stürz (2006) suggest that presenting information about a layperson's knowledge level supported the experts in adapting their explanations to the layperson's communicational needs. Nevertheless, they cannot exactly explain how the experts used this information to produce adaptive explanations. How did the information about the layperson's knowledge influence the experts' planning and translating into written explanations (Hayes and Flower, 1980; Hayes and Nash, 1996)? How did they tailor their explanations to the individual knowledge prerequisites and informational needs of their lay audience (Clark and Murphy, 1982; Nückles and Bromme, 2002)? The current study was dedicated to provide answers to these questions. Its aims were twofold: first, experts' planning processes during the composition of instructional explanations for laypersons were analyzed using thinking-aloud protocols (Ericsson and Simon, 1993; Janssen et al., 1996). Second, a content analysis of the experts' written explanations was conducted to identify adaptive linguistic and semantic features of the experts' explanations.

Results of these analyses can be interesting both for research on expertise in cognitive psychology and research on user modeling in computer science. From a cognitive psychology perspective they are interesting because communication between experts and laypersons has become an almost ubiquitous phenomenon but comparatively little is known about the cognitive processes of experts when communicating specialist knowledge to laypersons (Bromme et al., 2001; Nückles and Bromme, 2002). This is surprising given the huge body of scientific knowledge that research on expertise has accumulated on the cognitive structure of expert knowledge and experts' skills in problem solving (e.g., Chi et al., 1988; Ericsson and Smith, 1991; Hoffmann, 1992; Rikers et al., 2002). In this research tradition, high-performance experts are typically compared with novices and intermediates while the knowledge base and skills under study are confined to the problem domain, that is, a certain field of expertise. Hence, the knowledge and cognitive processes required for communication and cooperation are not investigated; instead, the expert is construed as a "lonely" problem-solver (Bromme et al., 1999).

From a computer science perspective, the results of this study could be of interest for the design of adaptive hypermedia systems that use personalization techniques to improve the quality of web-based information services. Such systems include adaptive online-information systems (e.g., online-help systems and electronic encyclopaedias, Milosavljevic and Oberlander, 1998), educational hypermedia (e.g., web-based intelligent tutoring systems, Weber and Specht, 1997), and information retrieval systems (for an overview of adaptive hypermedia, see Brusilovsky, 2001). Normally, these systems acquire data about a specific user (e.g., knowledge, interests, preferences) in order to tailor the content and presentation of information to a user's particular needs (e.g., additional explanations for very inexpert users; Boyle and Encarnacion, 1994; Kobsa et al., 1994). However, although such adaptation strategies are frequently employed in adaptive hypermedia (see Kobsa et al., 2001, for a comprehensive overview of adaptation techniques), they are usually not derived from naturalistic observations of human interactions between experts and laypersons, and therefore lack, at least to some extent, empirical justification (cf. Alpert et al., 2003, du Boulay and Luckin, 2001).

Thus, the results of the present study could contribute towards empirically grounding and justifying the automated personalization techniques used in these systems.

In addition to adaptive hypermedia, the present study could be further utilized in cased-based reasoning approaches to product recommendation and decision support. Recommender systems typically support a user in selecting a product from a huge range of possible items that best satisfies the user's preferences (e.g., McSherry, 2003, 2004, 2005). Decision support systems assist users in making decisions regarding critical target cases, for example, whether a patient with diabetes is suitable for participation in an e-clinic or needs closer medical monitoring (Doyle et al., 2004). Recent work in recommender systems has started to give considerable attention to the issue of explanation, for example, how a recommender system can attempt to explain its suggestions to a user in such a way as to convince the user that the recommendation meets their needs, or that the system's proposed decision regarding a query case is appropriate (Cunningham et al., 2003; McSherry, 2005). However, while there is increasing awareness of the need to make the recommendation process transparent to users through explanation, it is less clear what makes a good explanation or justification of a given recommendation (Sørmo and Cassens, 2004). In particular, most approaches implicitly assume that the explanation offered by the system is comprehensible for all users, regardless of his or her particular level of expertise and personal frame of reference. Accordingly, current case-based reasoning approaches to product recommendation and decision support typically lack a methodology that would allow the computer system to better tailor its explanations to the user's individual needs (cf. Sørmo and Cassens). Thus, the present study could help identify techniques to effectively adapt explanations in recommender and decision support systems according to the user's knowledge background and goals.

For our study of experts' cognitive processes and message design, we used the same asynchronous computer helpdesk scenario that had previously been employed by Nückles et al. (2005). Again, the scenario required computer experts to compose instructional explanations of diverse computer and Internet issues in response to queries asked by a layperson. In the experimental condition, the experts were provided with a so-called assessment tool to facilitate the construction of a mental model of the layperson's knowledge (cf. Figure 1). The assessment tool displayed the layperson's prior knowledge level in the computer and Internet domain. In the control condition, the experts had no available information about the layperson. Our approach of providing concrete information about a layperson's knowledge level was based on the assumption that the displayed information (see Figure 1) would help the experts to recollect concrete experiences with laypersons from long-term memory. This activated long-term knowledge of specific others (e.g., complete beginners, advanced lay users, etc.) should make it easier for the experts to calibrate their mental model of the layperson's knowledge (Nickerson, 1999) and to adapt their explanations to the layperson's individual knowledge (see Nückles et al., 2005, for a comprehensive discussion of different methods to support experts' perspective taking in relation to laypersons).

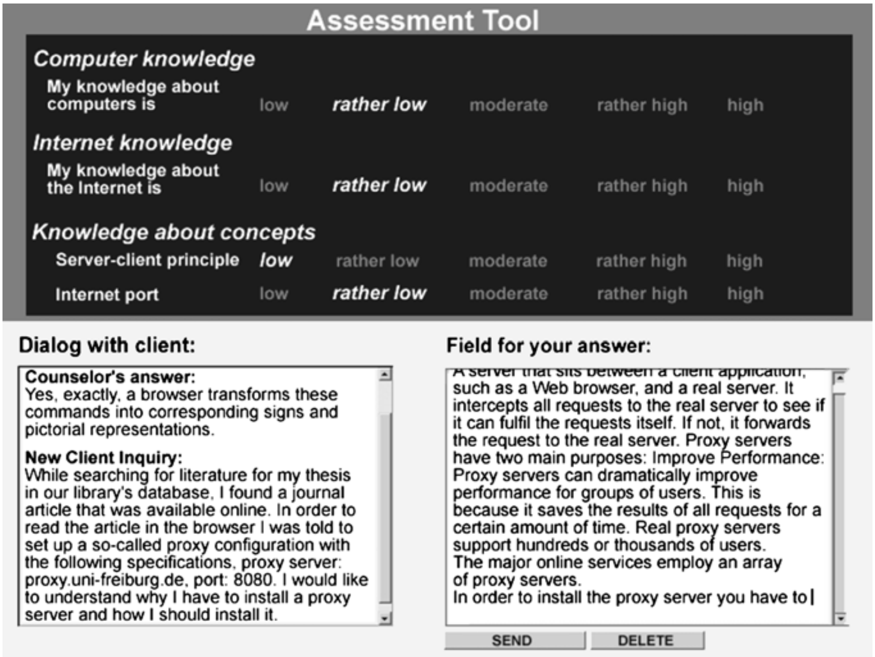

Figure 1. Screenshot of the assessment tool as it was available to the computer expert in the experimental condition with the assessment tool.

In contrast to our previous experiments, we asked the experts in the present study to verbalize their thoughts during the composition of their explanations. Following Hayes and Nash (1996) and Janssen et al. (1996), concurrent think-aloud protocols is the method with the most overall usefulness for the study of planning processes in writing. Nevertheless, several researchers have objected that thinking aloud may also be reactive to some degree. That is, the additional demand of verbalizing one's thoughts may influence the writing process (cf. Janssen et al., 1996; Levy et al., 1996). In the present study, for example, it cannot be ruled out that thinking aloud might cause the experts to attend more carefully to the design of their responses than they would without this additional demand (cf. Levy et al., 1996). However, such a raised awareness of one's writing activities would affect the experts in both experimental conditions equally. Therefore, it cannot undermine the validity of our research design because all hypotheses tested in the present experiment (see Section 4) predicted differences *between* the experimental conditions.

2. Experts' Planning and Translating of Answers to Laypersons' Queries

Due to its rather informal character and the possibility to provide and receive feedback, asynchronous written communication resembles verbal communication to some degree. Nevertheless, it is primarily a written act. The costs of message production are higher than in verbal communication because every message has to be typed on a keyboard (Clark and Brennan, 1991). On the other hand, the delay costs are lower compared with verbal communication because there is less social pressure to respond instantly to an interlocutor's message (Clark and Brennan). Thus, asynchronous communication allows for the careful planning of a message before it is sent. There is time to reflect upon a communication partner's background knowledge and communicational needs.

In as much as asynchronous communication is a writing activity, the taxonomy of planning types proposed by Hayes and Nash (1996) can be applied to conceptualize the cognitive processes involved in experts' composition of explanations in asynchronous advisory dialogue. First of all, Hayes and Nash distinguish between process planning and text planning. Process planning describes how the writer intends to carry out the writing task ("First, I'll read the layperson's query, then I will think about the answer"). Text planning is focused on what is being written, and what the planned text will be like. Within text planning, Hayes and Nash further distinguish between abstract (i.e., conceptual) planning and language planning. In conceptual planning, writers propose ideas for the text without specifying the particular language to be used. The writers produce an abstract and simplified version of what they intend to convey. In doing so, writers typically represent the potential topics as brief names (like the "nodes" in a concept map, cf. Jonassen et al., 1993) that capture the most important feature of the topic. The names of the topics may be thought of as "pointers" to packages of information in the author's memory (Hayes and Nash). Language planning, in contrast, refers to the planning of concrete clauses and sentences in thought or in speech before writing them down. The abstract representation of the intended text is expanded and translated into grammatical text. Accordingly, Hayes and Nash conceive of language planning as a part of the translation process, that is, the translation of the conceptual representation into a finished text.

Chin (2000) has constructed a natural language advisory system that illustrates how Hayes' and Nash's theory of text planning (1996) can be applied to the composition of answers to computer users' queries in text-based advisory dialogue. In Chin's *UNIX Consultant,* the conceptual planner generates a network of concepts and relations that embodies the conceptual model of an answer. This conceptual model of the answer is supplemented by a model of the user's knowledge (i.e., the user model). During the conceptual planning of an answer, the user model is used to determine, which concepts and relations are likely to be known or not known by the user, and which are candidates for being mentioned in the final answer (so-called "pruning", cf. Chin). The conceptual network of the answer is adjusted to make the answer as informative as possible for the layperson. On the basis of this pruning and selection process, the adjusted conceptual model is translated into written text. In a language planning process, called "answer expression", appropriate expository formats are selected, such as example, definition or simile, to format the conceptual information to be communicated for clarity and intelligibility. The user model constrains this selection of appropriate expository formats and determines the degree of elaboration by which a specific expository format eventually becomes instantiated.

The value of Chin's advice giving model (2000) is that it allows for precise predictions of how information about a layperson's prior knowledge could constrain computer experts' efforts to adapt their answers to the layperson's communicational needs. Following Chin, the information provided by the assessment tool should influence both the conceptual planning and the translation (i.e., language planning) during the production of an answer. If the displayed information supported the experts' conceptual planning, one would expect that they would use this information to decide, which concepts and relations are known or not known by the layperson, and which of them they wish to include in their explanation. Consider an expert's answer model that is represented by a conceptual network comprising of 10 specialist concepts. If the layperson has a high prior knowledge level, he or she may roughly know the meaning of about seven of these concepts. Hence, the expert could use these concepts in constructing their answer without causing serious comprehension problems for the layperson. As for the three concepts which are unknown to the layperson, the expert would have to decide whether to omit them or to introduce them explicitly. Now consider a layperson with a low prior knowledge level. From the ratings displayed by the assessment tool, the computer expert might infer that the layperson would probably know only three out of 10 concepts. In this case, the expert would have to decide whether to include any of the seven remaining concepts in the answer and how to introduce them if so. Consequently, more pruning decisions would be required if the layperson had a lower prior knowledge level than if they had a higher knowledge level. Hence, we predicted a negative relation between the layperson's knowledge level as indicated in the assessment tool and the number of pruning decisions as identified in the experts' think-aloud protocols. This negative relation, however, should only occur in the experimental condition with the assessment tool, because it was only in this condition that the experts had available information about the layperson. Therefore, the extent to which a negative correlation between the number of pruning statements and the layperson's knowledge level would be detectable should depend on the experimental condition (i.e., communication with versus without the assessment tool). In other words, the experimental condition should moderate (cf. Baron and Kenny, 1986) the relationship between the number of pruning statements and the layperson's knowledge level.

Following Chin (2000), the model of the user's knowledge should not only constrain the conceptual planning but also the language planning of an answer (i.e., the translation process, cf. Hayes and Nash, 1996). Given that a layperson with a low knowledge level will probably not know most of the concepts that are semantically relevant to the answer, the computer expert cannot simply use these concepts without giving further explanations. In this case, however, selecting and generating appropriate expository formats for the communication of these concepts becomes more demanding. In order to be intelligible, the expert will have to find appropriate paraphrases and similes, and to provide characterizing and contextual information that enables the layperson to relate the new information to their prior knowledge and personal experience. In contrast, given a layperson with a high level of computer knowledge, the expert could use most of the relevant specialist concepts with only a few modifications. The expert would have to invest less effort in finding appropriate expository formats and contexts for translating the answer. On the basis of these considerations, we predicted a negative relation between the layperson's knowledge level as indicated in the assessment tool and the number of statements indicating translation processes in the experts' think-aloud protocols. Again, we expected this negative relation only to hold for the communication condition with the assessment tool, because only in this condition were the experts presented with information about the layperson's knowledge level. Thus, the extent to which a negative correlation between the number of translation statements and the layperson's knowledge level would be observable should also depend on the experimental condition, that is, whether or not the experts had the assessment tool available.

3. Adaptive Features of Experts' Answers to Laypersons' Queries

Provided that information about a layperson's knowledge constrains both the conceptual planning and language planning of experts (Hayes and Nash, 1996), their written answers to laypersons' queries should vary in accordance with the layperson's knowledge level. The previous discussion suggests that the lower a layperson's level of knowledge, the more the experts might be tempted to exclude unknown or difficult concepts and to include only those technical concepts considered indispensable in constructing the answer. Hence, the lower a layperson's knowledge level, the more experts might focus on a few relevant concepts in their explanations to make sure that they can provide enough context to guarantee the layperson's comprehension. In doing so, the experts would follow the *principle of optimal design* (Clark et al., 1983), which states that communicators seek to provide sufficient context to facilitate a recipient's comprehension in order to design messages that are optimal for each recipient (Horton and Gerrig, 2002). However, such an adaptation strategy would not only be in accordance with Clark's conversation principle (1996), at the same time it would also reflect a kind of *cognitive economy*. From the above-mentioned hypothesis concerning the relation between translation statements and the layperson's knowledge level follows that the generation of appropriate expository formats (e.g., appropriate paraphrases and similes) for the expression of technical concepts should be more demanding for the expert, the less prior knowledge the layperson possesses. Hence, concentrating on the translation of fewer technical concepts would help to keep the experts' language planning costs manageable, that is, the cognitive effort required to translate technical concepts into explanations that are intelligible to a layperson.

In contrast, the higher a layperson's knowledge level, the more experts can use technical concepts in their answer without having to give particular attention to the paraphrasing and characterizing of these concepts in order to make them intelligible to the layperson. Based on these considerations, we predicted a positive relation between the layperson's level of knowledge as indicated in the assessment tool and the proportion of statements about processes and events related to technical concepts in the computer experts' answers. At the same time, we predicted a negative relation between the layperson's level of knowledge and the proportion of statements intended to characterize and contextualize the meaning of technical concepts, for example, by use of analogies or illustration of the practical relevance of concepts. This interaction, however, should only be observed in the communication condition with the assessment tool because only in this condition were the experts presented with explicit information about the layperson's knowledge level.

Nückles (2001) as well as Bromme et al. (2005) report empirical evidence that experts varied the type of information in their explanations depending on the recipient's knowledge level. In the study by Nückles, computer experts indicated how extensively they intended to explain several specialist concepts to a beginner and an advanced computer user. He found an interaction between the topical relevance of the concepts to be communicated (basic vs. advanced concepts) and the recipient's knowledge level: basic concepts that were central to a topic would be explained more extensively to a beginner than to an advanced computer user. Advanced concepts that elaborated on specific technical details would be explained more extensively to an advanced user than to a beginner. Bromme et al. (2005) had medical experts produce explanations for a fictitious layperson and for a fictitious colleague (i.e., a general practitioner). A content analysis of the explanations showed that the explanations for the expert colleague contained more advanced themes that focused, for example, on the function of medical substances in the human body, whereas the explanations for the laypersons contained more behavioral tips mostly concerning the application of drugs. These results support the claim that experts vary the type of information communicated depending on their assumptions about the recipient's level of knowledge. However, in the study of Nückles, only the planning of explanations was investigated rather than the explanations themselves. Bromme et al. (2005) analyzed written explanations of medical experts, but the recipients of the explanations were fictitious like in the study of Nückles. Thus, it remains unclear whether the results of these studies can be generalized to communication settings with real recipients who can provide feedback. For example, Schober (1993) found that communicators showed less audience design (Clark and Murphy, 1982) and produced more egocentric messages when the recipient was real rather than imaginary. Schober speculated that speakers might relax their laborious audience design when the recipients can give them feedback if they do not understand something. Against this background, the current study may help to shed light on experts' audience design, that is, their effort to adapt their explanations to the recipient's knowledge, in more naturalistic communication settings such as asynchronous advisory dialogue.

4. Research Questions and Hypotheses: Overview

4.1. DOES THE ASSESSMENT TOOL INCREASE THE EFFECTIVENESS AND EFFICIENCY OF THE COMMUNICATION?

The principal goal of the present study was to highlight the cognitive planning processes and linguistic means by which experts adapted their explanations to a layperson's knowledge level. However, before asking how the experts used the information displayed in the assessment tool, it makes sense to establish whether the information about the layperson helped the experts to improve their communication. Therefore, we initially investigated whether the results of the Nückles et al. study (2005) could be replicated by the current experiment. On the basis of our previous results, we expected that the laypersons would acquire more knowledge (*communicative effectiveness hypothesis*) and return less comprehension questions in response to the experts' explanations (*communicative efficiency hypothesis*) when the experts had available information about the layperson's knowledge (i.e., communication with the assessment tool) than if they had no available information (i.e., communication without the assessment tool).

4.2. DOES THE ASSESSMENT TOOL INCREASE THE EXPERTS' AWARENESS OF THE LAYPERSON'S KNOWLEDGE BACKGROUND?

Compared with face-to-face communication, there is less information available in asynchronous communication that an expert could use to develop a mental model about a recipient's knowledge. For example, nonverbal feedback is virtually impossible because the interlocutors cannot see nor hear one another (Clark and Brennan, 1991). Thus, providing computer experts with information about a layperson's knowledge should increase their awareness of the layperson. This should intensify their effort to take the layperson's perspective in order to get an idea of their knowledge background and situation. Hence, we expected that the experts in the experimental condition with the assessment tool would articulate more statements in the think-aloud protocols expressing their effort to construct a model of their recipient's knowledge compared to the experts in the condition without the assessment tool (*recipient model hypothesis*).

4.3. DOES THE INFORMATION ABOUT THE LAYPERSON'S KNOWLEDGE LEVEL INFLUENCE THE EXPERTS' CONCEPTUAL PLANNING AND LANGUAGE PLANNING OF THEIR ANSWERS?

From the discussion of Chin's advice giving model (2000), we derived predictions regarding the influence of the layperson's knowledge level on the frequency of pruning decisions and on the frequency of translation statements in the experts' think-aloud protocols. Following the *pruning hypothesis*, the lower the layperson's knowledge level displayed by the assessment tool, the more pruning decisions should be observed during the conceptual planning of an answer. Following the *translation hypothesis*, the lower the layperson's level of knowledge, the more translation statements should be articulated during the language planning of an answer. At the same time, the extent to which these negative correlations would be detectable should depend on the experimental condition. Accordingly, we expected the experimental condition (i.e., with vs. without the assessment tool) to be a moderator (cf. Baron and Kenny, 1986) of the relationship between the layperson's knowledge level and the frequency of pruning statements as well as the frequency of translation statements.

4.4. DOES THE INFORMATION ABOUT THE LAYPERSON'S KNOWLEDGE LEVEL INFLUENCE THE WAY THE EXPERTS DESIGNED THEIR ANSWERS TO THE LAYPERSON'S QUERIES?

From the previous discussion about adaptive features of the experts' answers, we concluded that their answers should differ specifically in relation to the layperson's level of knowledge (specific adaptation effect, cf. Nückles et al., 2005). However, we did not expect any differences between the experimental conditions independent of the layperson's knowledge level. Such differences in the experts' answers would indicate a nonspecific sensitizing effect of the assessment tool, instead of a specific adaptation to the layperson's knowledge. A nonspecific sensitizing effect might imply, for example, that the mere presence of the assessment tool would stimulate the experts to produce explanations that were generally (i.e., independent of the layperson's knowledge level) more clear and intelligible than the explanations of experts who had no assessment tool. The *adaptive features hypothesis*, in contrast, postulates that the layperson's knowledge level influences the linguistic and semantic properties of the experts' answers differently and in specific ways. In particular, we predicted that the lower the layperson's level of knowledge was, the less the experts should express statements about processes and events related to technical concepts and, at the same time, the more they should provide contextual and illustrative information of the concepts. As before (see Section 4.3), we expected experimental condition (i.e., with vs. without the assessment tool) to be a moderator, that is, the hypothesized interaction between the type of explanatory statements and the layperson's knowledge level should only occur in the communication condition with the assessment tool.

5. Methods

5.1. THE ASSESSMENT TOOL

The assessment tool provided the computer experts both with ratings of the layperson's general computer knowledge and their Internet knowledge (see Figure 1). Apart from these global evaluations, it was also displayed to what extent the layperson already knew the meaning of two specialist concepts semantically relevant to the understanding of the problem addressed by a query. Thus, the experts had the possibility to adapt their explanations both to the layperson's general knowledge background and, on a more concrete level, to their prior knowledge regarding a specific query. A short description was available that assisted the expert in interpreting the 5-point rating scales. For example, if the assessment tool displayed a layperson's computer knowledge to be *low*, this would indicate a layperson's status as a beginner. A *high* knowledge level, in contrast, would indicate that the layperson's knowledge level would be – compared with the typical layperson – definitely above average. The displayed values in the assessment tool were determined through an objective and standardized assessment procedure. To this end, an updated and shortened version of the computer and Internet knowledge test developed by Richter et al. (2000) was constructed and pre-tested on 40 Humanities students. The test consisted of 20 multiple choice items, with 10 items representing the computer knowledge scale and 10 items representing the Internet knowledge scale (see Appendix A for sample items). The test was specifically constructed to differentiate among people who are laypersons in the computer domain. Thus, even someone with high scores on this knowledge test would still have substantially less knowledge than a computer expert. In the experiment, the number of items that the laypersons had solved correctly was translated into values on the corresponding 5-point scales in the assessment tool. This was done by dividing the raw score a layperson achieved in the test by 2. For example, if a layperson solved only one or two items on the Internet knowledge subtest, this was indicated in the assessment tool as a *low* Internet knowledge level. In contrast, if a layperson solved 9 or 10 items on the subtest, this would be represented as a *high*-knowledge level (cf. Figure 1). The layperson's knowledge regarding the meaning of the specialist terms relevant to the queries was assessed by a concept description procedure. The laypersons were asked to describe the meaning of each of the concepts. The written descriptions were scored for correctness and the resulting scores were displayed in the assessment tool.

5.2. SAMPLE, DESIGN AND MATERIALS

5.2.1. *Participants*

Thirty-six computer experts and 36 laypersons participated in the experiment. Computer experts were recruited among advanced students of Computer Science. They were paid 12 EURO for their participation. Their average age was 24.11 years ($SD = 3.55$). As the computer experts' task in the present experiment would be to advise laypersons on several Internet topics, the students of computer science were asked to indicate their experience in using the Internet based on several criteria. Regarding the question of how long they had been working with the Internet, the students of computer science responded with a mean of 6.22 years ($SD = 1.93$).

They reported that on average, they would spend 24 hours per week working on the Internet ($SD = 18.73$), which is a large amount of time. When asked to rate their computer and Internet skills on a 5-point rating scale ranging from 1 (= *very inexperienced*) to 5 (= *very experienced*), a mean of 4.01 ($SD = 0.80$) resulted. All in all, these values pointed out sufficiently high computer and Internet expertise with regard to the purpose of the present experiment. In regards to the question as to how often they usually advise computer and Internet users (1 = *very rarely*, 5 = *very often*), the experts' mean response was 3.81 ($SD = 1.19$). Hence, the computer experts in this experiment apparently counseled other computer users rather frequently.

The 36 participants serving as laypersons were recruited among students of Psychology and of the Humanities. They received 15 EURO as compensation for their participation. The increase in financial compensation was justified by the extended knowledge tests laypersons had to complete in addition to the communication phase of the experiment. The laypersons' mean age was 25.94 years ($SD = 3.29$). On average, they reported that they had been using the Internet for 3.79 years ($SD = 1.54$), and they would spend about 3.29 hours per week working on the Internet ($SD = 2.74$). In rating computer and Internet skills, a mean of 2.39 resulted ($SD = 0.78$). A MANOVA with years of Internet usage, hours of Internet usage per week and self-rated computer and Internet skills as dependent measures, and participants (expert vs. layperson) as the independent factor showed that the laypersons' expertise was clearly lower than the expertise reported by the experts, $F(3, 68) = 41.07$, $p < 0.001$, $\eta^2 = 0.64$ (strong effect).

Because the present study tested hypotheses concerning correlations with the laypersons' knowledge level, the prior knowledge levels of students serving as laypersons should be quite varied to allow for such correlations. The results of the general computer knowledge test as well as of the Internet knowledge test (see Section 4.1) showed that this constraint was met. In the general computer knowledge test, the average number of solved multiple-choice items was 5.47, with a standard deviation of 2.58 and a range of nine items. For the Internet knowledge test, a mean of 5.14 solved items resulted, with a standard deviation of 2.32 and a range of eight items. Hence, the present sample of laypersons evidently displayed sufficient variability of prior knowledge levels.

5.2.2. *Design*

Computer experts and laypersons were combined into dyads that were randomly assigned to the experimental conditions. The experimental design was one-factorial with "assessment tool" as the independent variable, that is, communication with or without the assessment tool. There were three classes of dependent variables: first, measures of communicative effectiveness and communicative efficiency were obtained to check whether the communication with the assessment tool improved the layperson's acquisition of knowledge (enhanced communicative effectiveness) and reduced the number of questions asked by the layperson in response to an expert's explanation (enhanced communicative efficiency). Second, from the experts' think-aloud protocols recorded during the composition of answers to the layperson's queries, measures of the experts' planning processes were obtained (e.g., the frequency of pruning statements and translating statements; cf. coding of the think-aloud protocols). Third, the analysis of the experts' explanations yielded several measures regarding the type of statements used for constructing an answer (e.g., statements about processes and events related to technical concepts, statements containing contextual information about technical concepts, cf. coding of the experts' explanations).

5.2.3. *Materials*

A pool of 20 queries was constructed that demanded explanations of relevant computer topics and problems. Twenty computer experts rated how familiar they were with each of the queries and whether they thought they would be able to explain them to a layperson. These computer experts were part of the same population (i.e., advanced students of computer science) from which the expert participants serving as advisors in the experiment were recruited. Based on the familiarity and explainability ratings, three queries were selected for the experiment. This procedure guaranteed that in the communication phase of the experiment, the computer experts would encounter queries for which they would be able to give appropriate answers. The queries required the computer expert to explain a technical concept or to provide an explanation of why a particular technical problem occurred in order to help the layperson understand the nature of the problem (cf. Table I).

5.3. PROCEDURE

The dyads of experts and laypersons participated in individual sessions in the experiment. An experimental session including the pre-test phase, communication phase, and post-test phase lasted about two and a half hours.

Table I. Queries used in the experiment.

Recently I visited a website that told me to wait while 'Flash is loading'. Could you please tell me exactly what the difference between HTML and Flash is?
In the context of data security, I repeatedly read the abbreviation 'SSH'. Could you please explain the meaning of 'SSH' to me in more detail?
While searching for literature for my thesis in our library's database, I found a journal article that was available online. In order to read the article in the browser I was told to set up a so-called proxy configuration with the following specifications, proxy server: proxy.uni-freiburg.de, port: 8080. I would like to understand why I have to install a proxy server and how I should install it

5.3.1. *Pre-Test Phase*

At the beginning of the pre-test phase, the students serving as laypersons were administered a paper and pencil questionnaire that consisted of several subtests: the general computer knowledge test, the Internet knowledge test, and the concept description task to assess the layperson's knowledge about specialist concepts relevant to the problems addressed by the queries. Additionally, we asked the laypersons to try to answer each of the queries. This latter task provided us with a baseline which we needed for the computation of a layperson's individual increase in knowledge after the advisory dialog with the expert. The laypersons were informed that they were participating in a study on students' knowledge about computers and the Internet.

First, the laypersons answered the multiple choice items on the general computer knowledge subtest and the Internet knowledge subtest. Second, the laypersons completed a concept description task. Two raters independently scored the written descriptions for correctness by using the 5-point rating scale displayed in the assessment tool (cf. Figure 1). The reliability for the mean of the two raters, as determined by the intra-class coefficient was 0.92, which indicates excellent inter-rater agreement. Third, we encouraged the laypersons to answer each of the queries if possible. As before, the answers were scored for correctness by two independent raters. Both raters were blind to the experimental conditions. For each answer, up to three points could be assigned (0 = *no or wrong answer*, 1 = *partly correct answer*, 2 = *roughly correct answer*, 3 = *completely correct answer*). Inter-rater agreement as determined by the intra-class coefficient was very good ($r = 0.90$).

5.3.2. *Communication Phase*

In the communication phase, the expert and layperson sat in different rooms and communicated through a text-based interface. The layperson's task was to sequentially direct each of the prepared queries verbatim to the expert by typing the prepared wording of the query into the text form of the interface. The experts were asked to answer each query as well as possible. Following the guidelines of Ericsson and Simon (1993), they were instructed to spell out everything that came to mind during the composition of their answers. When an expert stopped talking for more than 15 seconds, the experimenter said: "Please keep talking". In order to have the expert participants get accustomed to thinking aloud, they were asked to verbalize their thoughts while figuring out the correct sequence of pictures in a picture story. The experts' verbalizations were digitally recorded on a notebook equipped with audio software. The laypersons were encouraged to write back and ask as many questions as needed. In the experimental conditions with the assessment tool, the completed form was visible to the expert during the entire course of the exchange.

5.3.3. *Post-Test Phase*

After the communication phase, the laypersons were again asked to write down their knowledge about each of the three queries. In this way, it was possible to calculate the individual increase in knowledge for each layperson. After completion of the post-test, the layperson and the expert were debriefed and compensated for their participation.

5.4. CODING OF THE EXPERTS' THINK-ALOUD PROTOCOLS AND THE EXPERTS' ANSWERS TO THE LAYPERSONS' QUERIES

To assess the experts' planning processes and the linguistic features of their explanations, we focused in our analysis on their initial answers to the laypersons' queries. Nückles and Stürz (2006) showed that asking additional questions in response to an expert's answer usually did not contribute to enhancing the layperson's comprehension because they often asked questions that referred to details in the expert's explanations that were rather irrelevant or even detrimental to the layperson's comprehension. These results underscore that in asynchronous advisory communication, the expert's initial answer to a layperson's query is crucial with regard to communicative effectiveness and efficiency. Thus, it is appropriate to concentrate on the initial answers for the investigation into experts' planning processes and adaptation strategies.

5.4.1. *Coding of the Experts' Think-Aloud Protocols*

For the analysis of the experts' planning processes during the composition of their answers, the protocol statements were coded into five distinct categories. The categories were derived from the taxonomy of planning types suggested by Hayes and Nash (1996) and from Chin's expert advisory model (2000):

(1) *Process planning*. In this category, statements were coded that expressed how the expert intended to carry out the writing task ("First, I'll read the layperson's query, then I will think about the answer.").
(2) *Construction of an answer model*. This category referred to statements that expressed the experts' attempts to retrieve relevant knowledge from long-term memory in order to construct a mental representation of the answer through self-explaining ("Okay, with regard to the message 'Flash is loading' something comes to my mind... this is simply because Flash is a plug-in, which then is executed by the browser...").
(3) *Construction of a recipient model*. This category was used to characterize statements that expressed the experts' effort to take the layperson's perspective in order to get an idea of the layperson's knowledge background and situation ("Okay, apparently this is really a beginner with few skills."; "I guess he probably uses Windows at home.").

(4) *Pruning*. In this category, statements were coded which revealed experts' reflections on whether they thought a particular concept of the answer model was known or unknown to the layperson, in order to decide whether they intended to include this concept in their answer ("He will probably not know what is meant by plug-in. I think it would be helpful for the layperson if I explained this concept.").

(5) *Translation*. This category referred to statements that indicated how the experts intended to express concepts and relations ("Hmm, how could I describe this more clearly…"; "What could I say instead of 'cache'?").

A preliminary inspection of the protocols showed that the frequently employed method of first segmenting and then coding the protocols did not make sense. This was due to the fact that the size of the units varied strongly across categories so that no reasonable common grain-size of segmentation could be found. Thus, the protocols were segmented with the coding categories in mind (cf. Renkl, 1997). However, the coding categories were distinct and there were no inclusions of segments. The protocols were segmented and coded by a trained research assistant. Ten percent of the segments were coded by another trained rater who was blind to the codings of the research assistant. The inter-rater agreement with respect to assigning the protocol segments to the coding categories was very good (Cohen's $\kappa = 0.91$).

5.4.2. *Coding of the Experts' Answers to the Laypersons' Queries*

For the analysis of the experts' adaptation strategies, another coding scheme was developed that aims to identify the linguistic and semantic features of the experts' answers. The coding scheme consists of two levels of judgment. The first level assigns one of 14 inductively determined categories that allow for an exhaustive classification of each statement in the experts' answers. The coding scheme specifies for each statement the linguistic features used in order to describe or explain the separate aspects of a technical concept. Statements at this level are assigned to categories such as instantiation, part-whole relationship, simile, difference, or categorization. At an abstract level, these 14 categories fit into four further abstract classes that are organized around the technical concepts described in the statements of the experts' explanations:

(1) *Processes and events related to technical concepts*. In this category, statements were coded that explained technical concepts in relation to the technical processes and events that are accomplished by these concepts. Accordingly, statements that, for example, describe the concrete technical functionality of a concept ("The proxy server acts as an intermediary between a Web client and a Web server.") are categorized on this dimension.

(2) *Definitions of technical concepts*. On this dimension, the denotative meaning of a concept is explained, for example, by providing instantiations of this concept ("Rudimentary text formatting commands are, e.g., paragraph setting commands and font size."), or by relating the concept to a super ordinate concept ("HTML is a text formatting language.").

(3) *Characteristics of technical concepts*. On this dimension, attributes that specifically characterize a concept are mentioned or explained. In order to make the proprietary attributes of a concept more clear, these statements make use, for example, of similes ("Flash has similarities with short films."), and differences ("Plug-ins perform the functions that Internet Explorer is not capable of performing.").

(4) *Contextual information about technical concepts*. In this category, statements are coded that provide information that helps the layperson understand the broader practical meaning of a concept. To this purpose, the concept is embedded in a specific context that illustrates, for example, the personal relevance of the concept to the layperson ("SSH is important when you are doing Internet banking.").

As a preparation for the coding, the experts' written answers were first segmented into statements as the coding unit. To this end, we used a procedure originally suggested by Erkens et al. (2003) for the segmentation of argumentative text. A trained research assistant split the sentences of each expert answer into smaller units on the basis of grammatical and organizational markers such as *and*, *or*, *because*, *for example*, *such as*, and *that is*. Then she assigned the resulting statements to one of the 14 first-level categories. A second trained rater who was blind to the codings of the research assistant coded 10% of the statements. Inter-rater agreement as determined by Cohen's Kappa was very good ($\kappa = 0.82$). For the purposes of the data analysis, the first-level codings were aggregated into the four categories described above.

6. Results

6.1. DID THE ASSESSMENT TOOL INCREASE THE EFFECTIVENESS AND EFFICIENCY OF THE COMMUNICATION?

In our first analysis, we checked whether the information displayed by the assessment tool improved the communication between experts and laypersons. More specifically, we tested whether the laypersons acquired more knowledge (communicative effectiveness hypothesis) and returned fewer comprehension questions in response to the experts' explanations (communicative efficiency hypothesis) when the experts had available information about the layperson (communication with the assessment tool) than if they had no information (communication without the assessment tool).

Before the laypersons' individual increase in knowledge was computed, the laypersons' prior knowledge about the queries used in the experiment was checked. An increase in knowledge could only be observed if the laypersons did not have enough prior knowledge to answer the queries themselves. An inspection of the mean scores of the laypersons' answers collected before the communication phase showed that this precondition was fulfilled. The mean scores of the laypersons' answers showed values close to zero (on a 4-point rating scale, see Section 5.3.1.) indicating that, on average, they did not know the correct answer to the queries prior to the exchange with the computer expert (cf. Table II). A t-test for independent samples performed on the pre-test scores further revealed that there were no significant differences between the experimental conditions, $t(34) = 0.64$, *ns*.

The laypersons' individual knowledge gain was computed by subtracting the mean scores of the their own answers to the queries before the communication phase from the corresponding mean scores collected after the communication phase (cf. Table II). To analyze the impact of the assessment tool on the effectiveness and efficiency of the communication, a multivariate analysis of variance (MANOVA) was computed with the layperson's knowledge gain and the number of comprehension questions asked by the laypersons as dependent variables. "Experimental condition" (i.e., communication with vs. without the

Table II. Laypersons' knowledge about the queries before and after the communication phase, their knowledge gain and number of follow-up questions.

	Means and standard deviations (in parentheses) listed separately for experimental conditions	
Dependent variable	With the assessment tool $n = 18$	Without the assessment tool $n = 18$
Mean scores of the laypersons' answers to the queries before the communication phase*	0.15 (0.24)	0.22 (0.43)
Mean scores of the laypersons' answers to the queries after the communication phase*	1.82 (0.54)	1.42 (0.42)
Mean difference of the laypersons' increase in knowledge	1.67 (0.50)	1.20 (0.51)
Number of comprehension questions asked by the layperson in response to the experts answers	2.00 (1.78)	4.50 (3.31)

Note. *For each answer up to three points could be assigned (0 = *no or wrong answer*, 1 = *partly correct answer*, 2 = *roughly correct answer*, 3 = *completely correct answer*).

assessment tool) was the independent measure. This MANOVA was highly significant, $F(2, 33) = 12.03$, $p < 0.001$, $\eta^2 = 0.42$ (large effect). Separate ANOVAs showed that the laypersons achieved a significantly larger knowledge gain, $F(1, 34) = 8.25$, $p < 0.01$, $\eta^2 = 0.20$ (large effect), and posted significantly fewer comprehension questions, $F(1, 34) = 7.95$, $p < 0.01$, $\eta^2 = 0.19$ (large effect), in the condition with the assessment tool compared with the condition where the experts answered the laypersons' queries without the assessment tool. Thus, our hypotheses regarding communicative effectiveness and efficiency were confirmed. At the same time, the results of the Nückles et al. study (2005) were replicated successfully. Having established that the assessment tool improved the communication, we can now turn to the analysis of the question how the information about the layperson's knowledge supported the computer experts in producing more effective and efficient answers to the laypersons' queries.

6.2. DID THE ASSESSMENT TOOL INCREASE THE EXPERTS' AWARENESS OF THE LAYPERSON'S KNOWLEDGE BACKGROUND?

Table III (second and third columns) shows the mean frequencies and standard deviations of the different types of planning statements. A MANOVA was conducted with the types of planning processes (process planning, construction of an answer model, construction of a recipient model, pruning, and translation) as the dependent variables and "experimental condition" (i.e., with vs. without the assessment tool) as the independent variable. The MANOVA revealed a highly significant effect of experimental condition, $F(5, 30) = 6.06$, $p = 0.001$, $\eta^2 = 0.50$ (large effect).

Table III. Frequencies of types of planning statements and correlations with the layperson's knowledge level.

	Mean number of planning statements (standard deviations in parentheses)		Correlation with the layperson's knowledge level	
Types of planning processes	With the assessment tool $n = 18$	Without the assessment tool $n = 18$	With the assessment tool $n = 18$	Without the assessment tool $n = 18$
Process planning	1.65 (0.99)	1.76 (0.99)	−0.63**	0.12
Construction of an answer model	6.50 (3.85)	6.28 (0.48)	−0.22	0.22
Construction of a recipient model	4.06 (2.05)	1.50 (0.85)	0.27	0.22
Pruning	3.07 (2.69)	2.54 (1.49)	−0.49*	−0.09
Translation	3.56 (1.83)	2.74 (1.54)	−0.71**	0.28

Note. $^{**}p < 0.01$, $^{*}p < 0.05$.

Separate ANOVAs showed that this effect was specifically due to the differences in the frequency of planning statements regarding the construction of a recipient model, $F(1, 34) = 23.89$, $p < 0.001$, $\eta^2 = 0.41$ (large effect). Hence, the recipient model hypothesis was confirmed: the computer experts who received information about the layperson's knowledge made a better attempt to formulate an idea of the layperson's knowledge background compared with the experts who had no available information. This result shows that the experts actively processed the information displayed by the assessment tool and attempted to use this information for the construction of a mental model of the layperson's knowledge. None of the other ANOVAs approached statistical significance (process planning: $F(1, 34) = 0.11$, *ns*; construction of an answer model: $F(1, 34) = 0.03$, *ns*; pruning: $F(1, 34) = 0.55$, *ns*; translation: $F(1, 34) = 2.09$, *ns*.

6.3. DID THE INFORMATION ABOUT THE LAYPERSON'S KNOWLEDGE LEVEL INFLUENCE THE EXPERTS' CONCEPTUAL PLANNING AND LANGUAGE PLANNING OF THEIR ANSWERS?

For the tests of the pruning hypothesis and the translation hypothesis, the frequencies of the different types of planning statements were correlated with the layperson's level of knowledge separately for the experimental conditions. To avoid the computation of multiple correlations – given the relatively small sample size in the experimental conditions – and to obtain a singular measure of a layperson's knowledge level, the individual values displayed about a layperson in the assessment tool (cf. Figure 1) were averaged for each participant. This was appropriate because the different values of a layperson's knowledge (i.e., general computer knowledge, Internet knowledge, knowledge about concepts) were moderately to highly inter-correlated (correlations ranging from $r = 0.55$, $p < 0.001$, to $r = 0.77$, $p < 0.001$). Although no information was displayed in the condition without the assessment tool, it was nevertheless possible to compute a measure of the layperson's knowledge level, because the laypersons in this condition had also completed the computer and Internet knowledge test and the concept description task in the pre-test phase of the experiment (see Section 5.3). A t-test for independent samples showed that the laypersons had a similar average knowledge level in both experimental conditions, $t(34) = 0.80$, $p = 0.430$ (with the assessment tool: $M = 2.33$, $SD = 0.88$; without the assessment tool: $M = 2.09$, $SD = 0.93$). The Levene test for equality of variances revealed no significant differences between the experimental conditions, $F(1, 34) = 0.04$, $p = 0.952$. Thus, the statistical chances to detect correlations with the layperson's knowledge level were comparable between the experimental conditions.

Table III (fourth and fifth columns) provides a summary of the correlations. Evidently, both the pruning hypothesis and the translation hypothesis were confirmed by the data: as predicted by the pruning hypothesis, there was a significant negative correlation between the number of pruning decisions and the laypersons' knowledge level in the condition with the assessment tool. As predicted by the translation hypothesis, the number of translation statements correlated negatively with the layperson's knowledge level in the condition with the assessment tool. At the same time, no significant correlations were observed in the condition without the assessment tool. To test the hypothesis that "experimental condition" (i.e., with vs. without the assessment tool) moderated the influence of the layperson's knowledge level on the frequency of pruning statements and on the frequency of translation statements, we conducted the following moderator analysis (cf. Baron and Kenny, 1986; Cohen and Cohen, 1983): we computed a MANOVA with "experimental condition" and the "layperson's knowledge level" as the independent variables. The frequency of pruning statements and the frequency of translation statements were treated as the dependent variables. If "experimental condition" moderated the influence of the layperson's knowledge level on the frequency of pruning statements and translation statements, the interaction between "experimental condition" and "knowledge level" should be significant. This was indeed the case as the multivariate test of the interaction between "experimental condition" and "knowledge level" was highly significant, $F(2, 31) = 6.17$, $p < 0.01$, $\eta^2 = 0.29$ (large effect). Subsequent univariate tests showed that this interaction effect was somewhat less pronounced for the number of pruning statements, $F(2, 32) = 3.13$, $p < 0.09$, $\eta^2 = 0.09$ (medium effect) as compared with the number of translation statements, $F(2, 32) = 12.74$, $p < 0.01$, $\eta^2 = 0.29$ (large effect).

In summary, the analyses of the experts' planning processes provide support for both the pruning hypothesis and the translation hypothesis. The layperson's knowledge level clearly influenced both the experts' conceptual planning and their language planning (i.e., the translation) during the production of an answer. The moderator analysis further suggests that this influence of the knowledge level was mainly restricted to the experimental condition with the assessment tool. Only in this condition were the computer experts able to consider the layperson's prior knowledge for the conceptual planning and the translation of their answer model into written text.

6.3.1. *Influence of the Layperson's Knowledge Level on the Experts' Process Planning*

Apart from these theoretically expected relationships, there also was a substantial negative correlation between the layperson's knowledge level and the statements indicating process planning. Again, this correlation only occurred in the condition with the assessment tool. Accordingly, when we tested whether "experimental condition" moderated the influence of the layperson's knowledge level on the frequency of process planning statements (cf. Cohen and Cohen, 1983), we obtained a significant result, $F(1, 32) = 6.58$, $p < 0.05$, $\eta^2 = 0.17$ (large effect). The negative sign of the correlation coefficient in Table III means that the experts engaged in more process planning, that is, they reflected more intensively how to proceed in writing the answer (e.g., "Uh, I will have to re-read the query before I can proceed with the answer."), the lower the displayed knowledge level of the layperson was. This negative relation suggests that the planning of explanations was indeed more demanding for the experts, the less knowledge they expected their recipient to possess; evidently, the experts did not only invest more effort into the pruning and translation of the conceptual model of their answer but, on a more general, that is, noncontent level, they intensified the regulation of their writing processes.

6.4. DID THE INFORMATION ABOUT THE LAYPERSON'S KNOWLEDGE LEVEL INFLUENCE THE WAY THE EXPERTS DESIGNED THEIR ANSWERS TO THE LAYPERSON'S QUERIES?

According to the adaptive features hypothesis, the experts' answers should differ in relation to the individual layperson's level of knowledge. However, we did not expect any systematic differences between the experimental conditions. Such differences regarding linguistic and semantic features of the experts' answers would indicate a nonspecific sensitizing effect of the assessment tool rather than a specific adaptation to the layperson's knowledge. To check for such a nonspecific sensitizing effect first, we conducted a MANOVA with the four types of explanatory statements as the dependent variables (processes and events, definitions, characteristics, contextual information) and "experimental condition" as the independent variable.

Table IV shows the mean proportions and standard deviations of the four types of statements. As expected, there were no significant differences between the experimental conditions. The mean values and standard deviations of the different types of statements were virtually identical. Accordingly, both the multivariate test, $F(3, 32) = 0.39$, $p = 0.549$, and also the separate ANOVAs for each type of statement clearly failed to reach statistical significance, all $Fs < 1$. Note that the multivariate test still remains nonsignificant, even if the alpha level is raised to 30% in order to avoid inflation of type two errors.

Table IV. Average proportion of types of explanatory statements of an expert's answers.

Types of explanatory statements	Means and standard deviations (in parentheses) listed separately for experimental conditions	
	With the assessment tool $n = 18$	Without the assessment tool $n = 18$
Processes and events related to technical concepts	0.25 (0.08)	0.25 (0.10)
Definitions of technical concepts	0.32 (0.07)	0.33 (0.09)
Characteristics of technical concepts	0.34 (0.07)	0.34 (0.07)
Contextual information about technical concepts	0.09 (0.06)	0.08 (0.04)

For the test of the adaptive features hypothesis, the proportions of the different types of explanatory statements were correlated with the layperson's level of knowledge separately for both experimental conditions. Because statements expressing contextual information were relatively infrequent compared with the other types of statements (cf. Table IV), we decided to combine them with statements specifying characteristics of technical concepts into one category, in the following called "characterizing and contextual information". The correlation coefficients are separately displayed for the experimental conditions in Table V. As predicted by the adaptive features hypothesis, there was a significant positive correlation between the layperson's knowledge level and the proportion of statements specifying technical processes and events.

On the other hand, the correlation of knowledge level with the proportion of statements expressing characterizing and contextual information was significantly negative (cf. Table V). Hence, the less knowledge the experts assumed their recipient to possess, the less they focused in their answers on explaining technical processes and functions, and the more they attempted to provide context information and to characterize the meaning of concepts, for example, through similes and analogies. The interaction of the type of explanatory statements with the layperson's knowledge level is shown by the left graph in Figure 2.

To test whether this interaction was statistically reliable, we conducted – separately for each experimental condition – an ANOVA with "type of explanatory statements" (i.e., "processes and events" vs. "characterizing and contextual information") as a repeated measures factor. The layperson's knowledge level represented a continuous independent variable (cf. Baron and Kenny, 1986; Cohen and Cohen, 1983). The results show that the interaction between "type of explanatory statements" and "knowledge level" was significant in the condition with the assessment tool where the experts had information about the layperson's knowledge level available, $F(1, 16) = 9.71$, $p < 0.01$, $\eta^2 = 0.38$ (large effect). In the condition without the assessment tool (see right graph, Figure 2), there was

Table V. Correlation of the layperson's knowledge level with the different types of explanatory statements.

Types of explanatory statements	Correlations with the layperson's knowledge level	
	With the assessment tool $n = 18$	Without the assessment tool $n = 18$
Processes and events related to technical concepts	0.60**	−0.30
Definitions of technical concepts	−0.18	0.20
Characterizing and contextual information	−0.49*	0.13

Note. $^{**}p < 0.01$, $^{*}p < 0.05$.

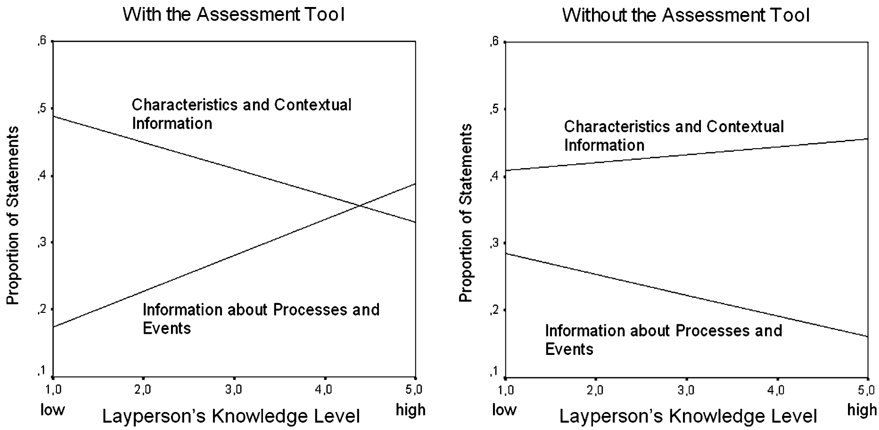

Figure 2. Interaction between type of explanatory statements and the layperson's knowledge level plotted separately for the experimental conditions.

no significant interaction, $F(1, 16) = 1.13$, $p = 0.303$. The test of the second order interaction term (type of explanatory statements*knowledge level*experimental condition) further confirms that "experimental condition" indeed moderated the interaction of "type of explanatory statements" with the layperson's knowledge level, $F(1, 32) = 7.23$, $p < 0.05$, $\eta^2 = 0.18$ (large effect). Evidently, depending on the layperson's level of knowledge, the experts shifted the focus of their answers by adjusting the relative proportion of process-related statements and contextual statements in their answers. However, this "interaction heuristic" was restricted to the condition with the assessment tool because only in this condition were the experts provided with information about the layperson's level of knowledge.

Table VI provides a summary of the main results obtained in the present experiment.

7. Discussion

The present study showed that providing computer experts with information about a layperson's knowledge background made their advisory dialog with the layperson more effective and efficient. When the experts had information about the layperson's knowledge available, the laypersons were able to acquire significantly more knowledge from the experts' explanations and they formulated fewer comprehension questions as compared with laypersons who received explanations from experts who had no available information about the layperson. Evidently, despite their rich and highly integrated specialist knowledge (Chi et al., 1988), the computer experts in the current study were not inevitably caught by the "curse of expertise" (Hinds, 1999; Nathan and Koedinger, 2000). Presenting the experts with information about the layperson's knowledge helped them to successfully adjust their answers to the layperson's communicational needs and to optimize their

Table VI. Summary of the results obtained in the experiment.

Research question	Results
Did the assessment tool increase the effectiveness and efficiency of the communication? (Section 4.1)	Both the *communicative effectiveness hypothesis* and the *communicative efficiency hypothesis* were confirmed: the laypersons acquired significantly more knowledge and returned less comprehension questions when the experts had available information about the layperson's knowledge (i.e., communication with the assessment tool) than if they had no available information
Did the assessment tool increase the experts' awareness of the layperson's knowledge background? (Section 4.2)	The *recipient model hypothesis* was confirmed: the experts in the condition with the assessment tool articulated significantly more statements in the think-aloud protocols expressing their effort to construct a model of their recipient's knowledge compared with the experts in the condition without the assessment tool
Did the information about the layperson's knowledge level influence the experts' conceptual planning and language planning of their answers? (Section 4.3)	Both the *pruning hypothesis* and the *translation hypothesis* were confirmed: the lower the layperson's knowledge level was, the more pruning decisions were observed during the conceptual planning of an answer and the more translation statements were articulated during the language planning of an answer. Both relationships were restricted to the experimental condition with the assessment tool. There also was a significant negative correlation between the layperson's knowledge level and statements indicating process planning
Did the information about the layperson's knowledge level influence the way the experts designed their answers to the layperson's queries? (Section 4.4)	The *adaptive features hypothesis* was confirmed: the lower the layperson's level of knowledge was, the less the experts expressed statements about processes and events related to technical concepts and the more they provided contextual information and characteristics of concepts in their answers. As predicted, this interaction was restricted to the condition with the assessment tool

learning. The present results replicate and confirm the findings of Nückles et al. (2005) as well as of Nückles and Stürz (2006) although we did not use think-aloud protocols in those studies. Thus, the close similarity of the present results with those obtained in our previous studies refutes the potential caveat (cf. Levy et al., 1996) that the demand of thinking aloud may have caused the experts to attend more carefully to the design of their explanations and thereby jeopardized communicational success. Ruling out this methodological caveat underscores the validity of our results which offer valuable insights into experts' cognitive processes and the linguistic means they employ to tailor their answers to the layperson.

7.1. HOW DID THE INFORMATION ABOUT THE LAYPERSON'S KNOWLEDGE INFLUENCE THE EXPERTS' PLANNING OF EXPLANATIONS?

First of all, the analysis of the think-aloud protocols showed that the computer experts who received information about the layperson's knowledge sought to formulate a better understanding of the layperson's knowledge background compared with the experts who had no available information. Thus, the experts actively processed the information displayed by the assessment tool and attempted to use this information for the construction of a mental model of the layperson's knowledge. Accordingly, the information about the layperson's knowledge level influenced both the conceptual planning and the language planning of the experts' answers (Hayes and Nash, 1996). As predicted by the pruning hypothesis, during the conceptual planning of an answer, the experts articulated more pruning statements when the layperson had a low knowledge level than when they had a high knowledge level. Hence, the experts used the information about the layperson's knowledge to decide whether a particular concept of their answer model was likely to be known or unknown to the layperson, and whether they intended to include this concept in their answer. However, consistent with Chin's advisory model (2000), the initial construction of the answer was largely unaffected by the layperson's knowledge level. This is reflected in the nonsignificant correlation of the layperson's knowledge level with the experts' statements indicating the construction of an answer model, that is, retrieval of relevant knowledge from memory and self-explaining (cf. Table III).

As predicted by the translation hypothesis, the experts articulated more translation activities, that is, they invested more effort in finding appropriate expository formats and contexts for translating their answer the lower the layperson's level of knowledge was. At the same time, both predicted relationships – the relation of knowledge level with the frequency of pruning statements and with the frequency of translation statements – were restricted to the experimental condition where the experts had the assessment tool available. In the condition without the assessment tool, no significant relationship between the layperson's knowledge level and the planning statements could be observed. This shows that the expert's orientation towards the recipient clearly depended on the availability of explicit information about the layperson's knowledge.

Apart from the predicted influence of the layperson's knowledge level on the experts' pruning decisions and translation processes, the layperson's knowledge further affected the experts' process planning. The negative sign of the relationship between the knowledge level and the frequency of translation statements suggests that the translation of technical concepts and relations into appropriate linguistic formats, such as similes or analogies from everyday life, were apparently cognitively more demanding for the experts, the less prior knowledge their recipient possessed. In these cases, the experts intensified their efforts to bridge the gap between their own specialist knowledge and the less sophisticated knowledge of the layperson, and these increased cognitive demands not only manifested themselves in the raised frequency of pruning and translation activities but also on a noncontent level, that is, the level of process planning by which the experts regulated their writing processes (Hayes and Nash, 1996). Together, these results provide evidence for the different planning processes (i.e., process planning, conceptual planning, and language planning) as they were hypothesized by Hayes and Nash and implemented in the advice giving model of Chin (2000). They substantiate the model's cognitive adequacy and show how information about a recipient's knowledge constrains computer experts' efforts to adapt their answers to the layperson's communicational needs.

A remarkable feature of Chin's model (2000) is that the experts' initial conceptual planning of an answer is not affected by assumptions about the layperson's knowledge. The system first produces a conceptual model of a possible answer to the layperson's query, which is subsequently pruned and adjusted to fit with the layperson's knowledge prerequisites. A similar theory has been proposed by Horton and Keysar (1996) and Keysar (1998) to describe the cognitive processes underlying the production of verbal utterances. Following Horton's and Keysar's monitoring and adjustment model, speakers initially plan their messages egocentrically using the knowledge that is cognitively available to them without taking into account the knowledge of the recipient. The monitoring and adjustment model, then, assumes that speakers take into account their recipient's perspective as part of a monitoring process in order to adjust their initial utterance plans to fit them with the recipient's informational needs. The empirical basis which Horton and Keysar report in favor of their theory has been seriously questioned (Polichak and Gerrig, 1998). The similarities between the monitoring and adjustment model and Chin's advisory model nonetheless are striking, irrespective of the differences between the media of communication (verbal vs. asynchronous written communication). On the whole, the think-aloud data of the present study support the common underlying assumption of both models: the experts initially produced a conceptual representation of the answer on the basis of the expert knowledge available to them, which they subsequently adjusted and translated into written explanations on the basis of their representation of the layperson's knowledge.

7.2. HOW DID THE EXPERTS TAILOR THEIR EXPLANATIONS TO THE INDIVIDUAL KNOWLEDGE PREREQUISITES AND INFORMATIONAL NEEDS OF THEIR LAY AUDIENCE?

The content analysis of the experts' answers to the laypersons' queries showed no significant differences between the experimental conditions (cf. Table IV). Hence, the raised communicative effectiveness and efficiency of the experts' answers in the condition with the assessment tool cannot simply be attributed to a nonspecific sensitizing effect of the assessment tool (cf. Nückles et al., 2005). That is, there was no indication that the experts who were provided with the assessment tool produced explanations that were generally more intelligible – irrespective of the laypersons' individual level of knowledge – for example, because they contained more contextual information or more similes and analogies than the explanations of experts who had no assessment tool.

Instead, the reported moderator analysis showed a substantial interaction between the layperson's level of knowledge and the types of explanatory statements used for the construction of the answers: as predicated by the adaptive features hypothesis, the experts clearly limited the proportion of statements about technical concepts and technical functions, the lower the layperson's knowledge level was, while, at the same time, they raised the proportion of statements expressing contextual information and characteristics of concepts. As expected, this interaction was restricted to the condition where the experts had the information about the layperson's knowledge level available. In applying this "interaction heuristic", the experts followed the principle of optimal design (Clark et al., 1983) in order to design messages that were optimal for each recipient (Horton and Gerrig, 2002). According to this logic, "optimal" answers for laypersons with a low level of knowledge would concentrate on a few technical concepts which are thoroughly characterized through similes, analogies and additional context information that illustrates, for example, the personal relevance of a concept to the layperson, or practical consequences that the layperson can directly experience. On the other hand, "optimal" answers for laypersons with a higher level of prior knowledge would be explanations that contain a substantially higher proportion of technical information (i.e., information about technical processes and events) in combination with a comparatively lower proportion of contextual and characterizing information – in order to make the answer as informative for the layperson as possible (see Table VII for examples of experts' answers for laypersons with a low or a high knowledge level).

From the perspective of pragmatics, in applying this adaptation strategy, the experts complied with a certain pragmatic principle that proved to be beneficial to the layperson's comprehension and learning. From a cognitive point of view, one can assume that their adaptation strategy was cognitively parsimonious: in as much as the experts had to invest more effort in finding appropriate expository formats for translating their answer the lower the layperson's level of knowledge was, concentrating on the translation of fewer technical concepts allowed them to keep their language planning costs manageable. Thus, the way the experts in the present

Table VII. Examples of computer experts' answers to one of the laypersons' queries (cf. Table I) produced in the condition with the assessment tool.

Layperson's query: "In the context of data security, I repeatedly read the abbreviation 'SSH'. Could you please explain to me in more detail the meaning of 'SSH'?"

Sample answers for	
Low-knowledge level	High-knowledge level
SSH means Secure Shell, which is basically a secure user interface. One can work with SSH, as though he or she were sitting in front of the computer with which one has established an SSH connection. The SSH is a network protocol, with which one can access a computer through the Internet. A network refers to the connection of one or more computers, which are able to communicate with each other due to this shared connection. A protocol is like a language that enables computers in a network to communicate with each other. Since the data sent through SSH is encrypted, the transfer of this data between the two computers is more secure. The same principle is employed in online banking, from logging in to making a transfer	SSH gives a computer access over the Internet to a shell. The principle task of the shell is to execute commands and handle the corresponding in- and output. To achieve proper data transmission, it is important that the computers work with the same protocols. These protocols assist in specifying the format, structure, and proper sequencing of the data to be transferred. Cryptography is particularly used in the transmission of data containing important information and passwords. Accordingly, this encryption follows the Public-Key Principle, which states that only the recipient possesses the ability to decode the encrypted information. The SSH marks an improvement, since other protocols transmit unencrypted data

study adapted their explanations to the layperson's communicational needs was not only adequate with regard to the compliance with pragmatic principles, such as the principle of optimal design (Clark et al., 1983), but also with regard to the cognitive demands on the experts' audience design.

Our results showing that the type of the communicated information interacted with the layperson's knowledge are consistent with the findings of Nückles (2001) and Bromme et al. (2005). In Nückles' study, computer experts intended to explain basic concepts more extensively to a beginner than to an advanced computer user, while advanced concepts would be explained more extensively to an advanced user than to a beginner. In the study by Bromme et al., medical experts mentioned advanced topics more often when they expected to write a message to a medical colleague, whereas their explanations contained more practical tips when their expected recipient was a layperson. Hence, the studies by Nückles as well as by Bromme et al. also showed an interaction between the recipient's knowledge level and the type of information communicated by experts. Together with the current study, these results provide evidence that experts are able to take into account a recipient's knowledge in a complex and sophisticated manner. Nevertheless, the current study considerably extends the findings by Nückles and Bromme et al. because, in contrast to their studies, the present results on computer experts' adaptation strategies were obtained in a naturalistic communication setting with real recipients who were free to provide feedback. Due to this setting, it was possible to demonstrate that the adaptation strategy applied by the computer experts was indeed successful: when the experts had information about the layperson's knowledge available, their answers proved to be more effective and efficient than the answers of experts who had no information about the layperson.

7.3. IMPLICATIONS FOR THE DESIGN OF PERSONALIZED ONLINE INFORMATION SERVICES AND PERSONALIZED RECOMMENDER SYSTEMS

7.3.1. *Supporting Adaptation of Human Online Advisors*

Our experimental study showed that the assessment tool proved to be an appropriate means to support computer experts in providing adaptive advice to laypersons. Laypersons were more able to process, within the frame of their personal understanding, the experts' explanations that were produced with the assessment tool as was indicated by their higher learning gains and their reduced need for asking follow-up questions. In this vein, the assessment tool helped to improve laypersons' experience of receiving advice that was better tailored to their individual needs (Kobsa et al., 2001). Providing effective and personalized advice has been shown to be of particular importance in the anonymous World Wide Web where competitors are just a mouse-click away (e.g., Dilts and Lyth, 2000). Hence, an assessment tool could be fruitfully employed in online computer support services in order to improve, via personalization of the advice provided, customer satisfaction and retention (Mohr and Bitner, 1991; Rust and Lemon, 2001). However, the idea of the assessment tool is not necessarily confined to the computer field but could also be applied to other domains such as medicine and health care. Email consultation requests to doctors' offices are rapidly growing (e.g., Maulden, 2003). At the same time, there is empirical evidence that physicians often have difficulties adapting their explanations to the informational needs of their patients (e.g., Bromme et al., 2005; Chapman et al., 2003; Hack et al., 1994). Hence, supporting physicians in giving more effective medical explanations by means of an assessment tool that provides information about a patient's communicational needs could have similarly beneficial outcomes.

7.3.2. *Empirically Grounding Adaptation of Content in Personalized Hypermedia Systems*

Moreover, the present findings of how experts adopted different types of explanatory statements for tailoring their explanations to a layperson's knowledge could be also interesting for the design of automated personalization techniques used by adaptive hypermedia systems, such as online-information systems and educational hypermedia (cf. Brusilovsky, 2001). There is a huge body of research dedicated to the question of how information can be optimally adapted to the user's individual needs, for example, in order to improve information retrieval or learning (e.g., Brusilovsky, 2001; Dillon and Gabbard, 1998; Graesser et al., 2001; Kobsa et al., 2001). It is notable, however, that research on user modeling for human-computer dialog is seldom guided by naturalistic observations of human interactions (Carroll and McKendree, 1987; du Boulay and Luckin, 2001) and rarely involves empirical testing of the effectiveness of implemented personalization techniques (Alpert et al., 2003). In this respect, the results of the present study could be especially useful to empirically ground techniques for adaptation of content in hypermedia systems (see Kobsa et al., 2001, p. 135). As Kobsa et al. show in their comprehensive review of adaptation techniques, many approaches to adapt the content of hypermedia applications to the prior knowledge of the user have been suggested. For example, *optional explanations* are geared towards users who lack the necessary background knowledge in order to facilitate comprehension of certain items in a hypermedia page (Boyle and Encarancion, 1994; Kobsa et al., 1994). Conversely, *optional detailed information* is provided specifically to those users who are likely to already be familiar with the basic contents of a hypermedia page in order to keep the page interesting and challenging for them (Boyle and Encarancion, 1994; Kobsa et al., 1994). However, while these adaptation strategies appear intuitively plausible, the underlying didactic principles from which they are derived usually remain implicit. The present study now provides an evidence-based didactic rationale for these strategies and advances them further in two ways: first, with regard to the *semantic type of information* provided to users with different levels of prior knowledge, and second, with regard to the *quantitative proportion* by which different types of information are presented *within* a particular content unit (e.g., a web-page) depending on the user's knowledge. With regard to the semantic type of provided information, the present study showed that it was effective to distinguish between three main types: *information about processes and events* (i.e., information about the causal and functional relations between concepts, cf. Keil and Wilson, 2000; Sørmo and Cassens, 2004), *definitions* conveying denotative meanings of concepts, as well as *characterizing and contextual information* facilitating integration of new concepts into a user's prior knowledge (cf. Kobsa et al., 2001; Milosavljevic and Oberlander, 1998). With regard to the quantitative proportion by which these information types should be presented, the results of the present study suggest an inversely proportional relationship between the amount of presented information about processes and events on the one hand, and characterizing and contextual information on the other hand: for users with a low level of prior knowledge the proportion of information about processes and events needs to be low while the proportion of characterizing and contextual information should be high. Conversely, for users with a high level of prior knowledge, the proportion of processes and events needs be high while the proportion of characterizing and contextual information could be rather low.

7.3.3. *Adapting Explanations in Recommender and Decision Support Systems*

Finally, the results of the present study could be relevant to the design of recommender and decision support systems. There is an increasing awareness in this field of research of the need to make the recommendation process more transparent to users, for example, to offer the user a justification of why or in what respect a system's recommendation meets the user's preferences (Cunningham et al., 2003; McSherry, 2005). In this way, an attempt to increase the effectiveness and acceptability of such systems is made. Current approaches to product recommendation and decision support mostly use a case-based reasoning methodology because of – amongst other things – the ease with which the recommendation process can be explained and the system's recommendations justified (McSherry, 2005; Sørmo and Cassens, 2004). The basic principle of these approaches is to search for cases that are similar to the user's query case in order to provide a basis for current decision-making. Accordingly, a simple rationale of explanation in decision support systems is to present the proposed decision for a particular query case together with a retrieved similar case in order to convince the user of the correctness of the decision (Sørmo and Cassens). For example, in the domain of blood alcohol testing (cf. Doyle et al., 2004), the proposed decision "blood alcohol is over the limit" for the query case "male, weight = 65 kg, 12 units of alcohol consumed" could be justified by presenting a similar case such as "male, weight = 70 kg, 11 units of alcohol consumed, over the limit". In product recommender systems (e.g., ShowMe; cf. McSherry, 2003), recommendations of products (e.g., personal computers) are likewise made on the basis of the similarity between the features specified in the user's query and the instances stored in the case library. In the absence of a product that exactly matches the user's preferences (e.g., laptop computer with 17 in. screen), the most similar cases are shown to the user, and the system additionally offers an explanation why the system failed to produce a perfect match (e.g., "Sorry, there is no match for the following combination of features in your query: type = laptop, screen size = 17", cf. McSherry, 2003). The aim of this explanation is to support the user in making an informed choice, that is, either to accept the system's recommendation, or to revise the query on the grounds put forward in the explanation (cf. McSherry, 2003).

The strength of these case-based reasoning approaches is the ease and intuitive plausibility by which explanations or justifications for the system's recommendations can be generated. Nevertheless, presenting a similar case as explanation or telling the user that a certain combination of features is not possible, presupposes that the user already possesses the relevant domain knowledge to understand the case or to know the meaning of the features, which would allow her/him to modify the query in accord with the her/his preferences (e.g., "If there is no laptop with 17 in. screen, I would also accept a somewhat smaller screen"). However, as users' domain knowledge is typically quite heterogeneous (cf. Bromme et al., 2001), it is impossible to assume every user will be able to understand the presented case or to modify the query based on the system's explanatory feedback. Hence, cased-based reasoning approaches to decision-making support and product recommendation could benefit considerably from methods that would allow for adapting the explanation offered by the system to the user's individual level of knowledge (cf. Sørmo and Cassens, 2004). For example, depending on the user's level of knowledge, the system might offer additional characterizing and contextual information regarding the meaning of certain features in the presented case or in the system's corrective feedback to an incomplete or inconclusive user query. In this respect, the present study may help identify ways in which explanations in recommender and decision support systems could be effectively adapted to the user's knowledge background and goals. For example, an assessment tool similar to the one presented in the current study, could be used to collect self-assessments of the user's level of domain knowledge in order to adjust the explanatory feedback provided by the system to the individual user's needs. The current study showed that offering additional characterizing and contextual information improved the comprehension especially of users with a low level of domain expertise whereas more advanced information about causal relations and technical principles was particularly effective to enrich the understanding of users with a higher knowledge level. In line with Sørmo and Cassens, we believe that such adaptation of content (cf. Kobsa et al., 2001) could substantially contribute to improving the intelligibility and persuasive power of the explanatory feedback provided by recommender and decision support systems and thereby enhance the acceptability of these systems.

In summary, the present experimental study offered insights into the cognitive processes and the linguistic means by which experts adjusted technical explanations to a layperson's knowledge level. From a psychological perspective, one can conclude that our results underscore the cognitive adequacy of important theoretical assumptions in current theories of text production (Hayes and Nash, 1996; Keysar, 1998) and conversation (Clark, 1996; Horton and Gerrig, 2002). From a computer science perspective, our results may serve in particular as an evidence-based didactic rationale for the design of personalization techniques. More generally, the present study has shown that the observation of human experts' adaptation strategies and the experimental testing of their effects on the user's side is a fruitful methodology for deriving effective personalization techniques both for adaptive hypermedia and cased-based recommender systems.

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Appendix A

Sample multiple-choice items used in the computer and internet knowledge test.

Items 1–4 assess computer knowledge, items 5–8 assess Internet knowledge. Note that for each item only one response is the correct or best answer (indicated by a cross).

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1. Partition

[ ] Special area for saving data files in an operating system
[X] Area on the hard drive that is treated as a separate drive and can have its own operating system
[ ] Defines a storage area on a hard drive
[ ] Area of working memory that the graphics card accesses
[ ] Do not know

2. RAM

[X] Computer's working memory consisting of chips
[ ] Part of a computer's processor that determines its speed
[ ] Name of so-called Radiation-Attenuated-Monitors with a low level of radiation emissions
[ ] Fixed storage space for files such as Word documents
[ ] Do not know

3. You have bought a new more capable monitor. Now there are very large program symbols on your screen. How can you make them smaller?

[ ] I choose a higher screen frequency in the menu 'Monitor Characteristics'
[X] I choose a higher pixel resolution in the menu 'Monitor Characteristics'
[ ] I choose a lower screen frequency in the menu 'Monitor Characteristics'
[ ] I choose a lower pixel resolution in the menu 'Monitor Characteristics'
[ ] Do not know

4. Your mouse is not working and you would like to close the program that you have opened. What do you do?

[ ] I end the program by pressing the key combination 'Ctrl'+ 'Enter'. Pressing 'Alt'+ 'F3'is another way to end the program
[ ] I end the program by holding down the key 'Ctrl' while pressing the key combination 'End'+ 'Enter'. Pressing the keys 'Alt'+ 'F6'is another way to end the program

[ ] I end the program by simultaneously pressing 'Shift' and 'End'. Pressing 'Alt'+ 'F5'is another way to end the program
[X] I end the program by holding down the 'Alt' key and then pressing the keys 'F' and 'X'. Pressing the keys 'Alt'+ 'F4'is another way to end the program
[ ] Do not know

5. Hypertext
[ ] Text that contains many hypermedia elements
[X] Text from which one can jump to related documents, sections of text or other information
[ ] Data bank system for large libraries
[ ] Marked passage in a computer-based document that calls up another document when activated
[ ] Do not know

6. Link
[ ] Connection between files that are on multiple computers connected to the Internet
[ ] Connection between two or more computers with Internet access
[X] Marked passage in a computer-based document that calls up another document when activated
[ ] Reference to very important information in an Internet document
[ ] Do not know

7. You would like search for a specific word on a very large webpage. How do you proceed?
[ ] I copy the webpage and paste it into Word. I then look for the word using the 'Search' function
[ ] I type in the word after the Internet address. The correct position is then automatically shown
[X] I navigate the browser menu bar to 'Edit' and 'Find'
[ ] I click on the Start symbol from Windows and go from there to 'Find'
[ ] Do not know

8. You are visiting a certain website and would like to save it on your browser. What do you do?
[ ] I type the Internet address under the menu item 'Links' on my browser
[X] I save the website under the menu item 'Favorites' or 'Bookmarks' on my browser
[ ] I save the website on the browser under the menu item 'Links'

[ ] I save the website on the browser under the menu item ‘Links’
[ ] I choose the menu item ‘Internet Options’ on my browser and type in the address
[ ] Do not know

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