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# Can Experts Benefit from Information about a Layperson's Knowledge for Giving Adaptive Explanations?

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## Abstract

E-consulting services such as asynchronous helpdesks for hardware and software are a common and comfortable way to get expert advice. However, the constraints of asynchronous communication and the experts' inclination to forget about the exclusiveness of their specialist knowledge may impair the advisory success. Against this background, an assessment tool has been developed which aids helpdesk experts in evaluating an inquirer's background knowledge. In a previous study, it could be demonstrated that the assessment tool increased the effectiveness and efficiency of asynchronous communication. In order to test the mechanisms that make the assessment tool effective, another dialogue experiment was conducted that varied the validity of the information displayed in the assessment tool. The results showed that the information presented to the experts did not only sensitize them for the inquirers' needs but also allowed for specific adaptation to their individual knowledge state. Hence, the validity of the information provided by the assessment tool is crucial.

## Introduction

Inasmuch as knowledge becomes ever more specialized and complex, individuals often lack the expertise necessary for making a decision or solving a problem on their own (Nückles & Bromme, 2002). Thus, in many situations, laypersons are reliant on expert advice. The proliferation of the Internet offers new possibilities for laypersons to enlist the assistance of experts. Not only can laypersons retrieve expert information publicly available from the World Wide Web but they can also obtain personal advice from experts in a one-to-one fashion. Helpdesks for hardware and software are a prominent example of e-consulting services that enjoy increasing popularity (Moncarz, 2001). Virtually every large computer company and university computer centre offers helpdesk support, often in a text-based, asynchronous way via electronic mail. The aim of computer consulting is to convey knowledge, which enables the inquirers to solve their problem by themselves, for example, when new and complex software has to be learned or an unexpected technical problem with the computer suddenly occurs. The advisory success heavily depends on the experts' ability to provide intelligible and informative explanations for inquirers with differing levels of experience, ranging from very inexperienced to more advanced users (Chin, 2000; Kiesler, Zdaniuk, Lundmark, & Kraut, 2000). Thus, in order to give effective and satisfactory advice, experts should adapt their commu-

nication to the knowledge prerequisites of the client (Clark & Murphy, 1982). Both from an educational (e.g., Renkl, 2002) and psycholinguistic perspective (e.g., Clark, 1996), adaptation to a communication partner's prior knowledge is regarded as fundamental for comprehension and learning.

Research on expertise has shown that experts, as compared to novices, possess an extensive and highly differentiated knowledge base that facilitates a rapid categorization of problem situations and the activation of routine problem solving strategies (Chi, Glaser, & Farr, 1988). However, these very characteristics of expert knowledge might interfere with the task of taking into account the limited domain knowledge of a layperson. Hinds (1999) called this phenomenon the 'curse of expertise'. She reported two experimental studies in which experts systematically underestimated the difficulties laypersons faced when performing a complex task. Alty and Coombs (1981) analyzed face-to-face advisory dialogues between computer experts and clients. They found that the computer experts rarely attempted to ascertain the clients' prior knowledge and rarely monitored the clients' comprehension of their explanations. As a result, the clients often did not understand the advice given. From these studies it can be concluded that in order to assure effective advice, experts should be supported in taking into account the knowledge prerequisites and comprehension of the client.

In face-to-face communication, the communication partners can use a variety of situational and interactional cues to monitor their interlocutor's comprehension moment by moment and thereby refine and update their mental model of what the other person knows or does not know (Clark, 1996; Nickerson, 1999). In Internet-based counselling, however, the evaluation of an interlocutor's knowledge and the continuous construction of a mutual understanding are considerably more difficult when compared with face-to-face communication (Clark & Brennan, 1991). First, in asynchronous communication, nonverbal feedback is virtually impossible because the interlocutors cannot see nor hear one another. Second, the costs of message production are higher than in verbal communication because every message has to be typed on a keyboard. Third, there is no set sequentiality between a message and its reply, because the interlocutors' turn taking may be interrupted by messages from third parties, which can impair comprehension (Clark & Brennan, 1991). Given these constraints, the pos-

sibilities to establish a mutual understanding are clearly more restricted as compared with face-to-face communication. On the other hand, asynchronous communication also offers affordances that can facilitate adaptation to a communication partner. It allows for a careful planning and revision of a message before it is sent. There is time to reflect about a communication partner's background knowledge and communicational needs.

### The Assessment Tool - A Measure to Support Asynchronous Communication

From the preceding discussion it can be concluded that it would be useful to provide helpdesk experts with a support procedure that compensates for the constraints of asynchronous communication on the one hand, and takes advantage of the affordances on the other hand. When computer experts communicate with clients via an Internet-based helpdesk, they are in an anonymous communication situation with only little information available about the client. Therefore, the procedure should enable the expert to achieve a relatively concise and veridical evaluation of a client's knowledge state right from the start, because the lack of nonverbal feedback, the raised production costs and the limited sequentiality impede the continuous construction of a mutual understanding considerably. With regard to experts' inclination to forget about the exclusiveness of their knowledge, the procedure should encourage them to carefully reflect about a client's knowledge prerequisites in order to facilitate adaptation to the client's communicational needs. The better the computer experts' model of the client's knowledge is, the better the experts can adapt their explanations to the client's knowledge (Clark & Murphy, 1982).

In this paper, an assessment tool will be empirically tested that supports computer experts in constructing a mental model of the client's knowledge state in asynchronous communication (see also Nückles, Wittwer, & Renkl, 2003). The tool consists of a small Internet-based questionnaire by which users who place a technical support inquiry are asked to provide the expert with several self-assessments of their computer expertise (cf. Figure 1). For example, the clients are asked to rate their general level of computer knowledge as well as their knowledge of concrete specialist terms semantically relevant to the topic addressed by their inquiry. The assessment tool can be especially useful to the expert if it enables them to form a picture of the client's knowledge level based on a small number of highly relevant information items. The assessment tool provides the expert with information about the client right from the start, which normally can only be collected during the course of the interaction process. Consequently, it should facilitate the collaborative effort of communication (Clark, 1996). However, the assessment tool can only be effective if the medium of communication allows for careful planning and the revision of one's communicational contributions. Therefore, the assessment tool seems to be especially suitable for asynchronous, written communication because there is time for reflection and revision before a message is sent.

Computer knowledge				
My knowledge about computer is	low	rather low	<b>moderate</b>	rather high high
Internet knowledge				
My knowledge about the Internet is	low	<b>rather low</b>	moderate	rather high high
Knowledge about concepts				
Trusted Zone	low	<b>rather low</b>	moderate	rather high high
Applet	low	<b>rather low</b>	moderate	rather high high

Dialog with client

Sometimes when I visit websites I get the following message: „Your current security settings prohibit running Active X controls on the page. As a result, the page may not display correctly.“ I would like to understand why this happens and how can I get rid of the problem.

Field for your answer

The Internet Explorer divides internet addresses into four zones the most important of which is the "Internet Zone". As almost every single site you ever visit will be in this zone, you should pay particular attention to what its security settings are.

SEND DELETE

Figure 1: Screenshot of the assessment tool available to the computer expert.

The assessment tool has already been successfully tested in a web-based dialogue experiment between computer experts and clients (Nückles & Stürz, in press). With the assessment tool, the clients acquired significantly more knowledge than the control group without the assessment tool (increased communicative effectiveness). At the same time, they wrote back only half as often in response to the experts' explanations (increased communicative efficiency). Although the study demonstrated that the assessment tool approach was successful, it is unclear which mechanisms led to the increase in communicative effectiveness and efficiency. There are two main theoretical explanations that may account for these findings.

### Theoretical Explanations of the Assessment Tool Effect

In Nickerson's theory (1999), the construction of a mental model of another person's knowledge is conceptualized as an anchoring and adjustment process (Tversky & Kahneman, 1974), where one's model of one's own knowledge serves as a default model of what a random other person knows. This default model is transformed, as individuating information is acquired, into models of specific other individuals. Accordingly, one could argue that the assessment tool presented individuating information about the client's knowledge level that provided the computer expert with a relatively specific anchor right from the start of the advisory dialogue. This enabled the expert to calibrate their mental model of the client's knowledge more quickly and accurately than would have been possible without the assessment tool, that is, only on the basis of the client's written questions and comments. According to this explanation, communicative effectiveness was raised because the assessment tool provided the expert with specific information that helped them to adapt to the client's individual knowledge level.

On the other hand, it may be argued that communicative effectiveness was raised *not* because of the *information* pre-

sented, but simply because the assessment tool increased the expert's awareness of the client and counteracted the tendency of de-individuation in Internet-based communication (Gunawardena, 1995). The experts were sensitized to reflect about the client's knowledge, for example which computer concepts are *typically* known by laypersons and which are not. This may have helped them to produce explanations that were more intelligible or informative for the *typical* layperson, irrespective of the *specific* knowledge level of an individual client. According to this explanation, the assessment tool had a more or less non-specific sensitizing effect on the expert. Against this background, the goal of the present experiment was to test whether the availability of *specific* information about the client's knowledge would make a difference at all, that is, support the experts' adaptation and thereby enhance communicative effectiveness and efficiency.

To this purpose, we modified the experimental design employed by Nückles and Stürz (in press). First, instead of using self-assessments, the assessment tool in this experiment provided the expert with objective information about the client's knowledge. Although self-assessments have proven to be good predictors of computer expertise (cf. Richter, Naumann, & Groeben, 2000; Vu, Hanley, Strybel, & Proctor, 2000), they still are not completely valid. Therefore, by using objective data about the client's computer knowledge, we increased the power for detecting a potential effect of specific adaptation. Secondly, a third experimental condition was included, in addition to a communication condition with the assessment tool and a condition without assessment tool. The information displayed in this additional condition was randomly drawn from the pool of knowledge data of clients who had previously participated in the experiment. The random data condition checked to see whether a distortion of the information about the client's knowledge level would impair the communication process. Consequently, the inclusion of this experimental condition would enable us to evaluate whether the *specific information* displayed by the assessment tool would influence the adaptivity of the experts' explanations.

## Predictions

**Sensitization hypothesis.** If the assessment tool mainly had a sensitizing effect on the computer expert, that is, the information about the client was of little surplus value, it should make no difference whether the displayed information was valid or distorted. Accordingly, the mere presence of an assessment tool is supposed to increase the experts' awareness of the client and this alone should help them to improve their explanations. Consequently, in the conditions *with* the assessment tool the clients should acquire substantially more knowledge compared with clients in the condition *without* the assessment tool. Moreover, if the clients received explanations that were more intelligible and more informative compared with the condition without the assessment tool, they should experience less comprehension problems and should be more satisfied with the explana-

tions. Hence, this should lessen their need of writing back in response to an expert's explanation. Consequently, the frequency of questions, and more specifically, the frequency of comprehension questions should be reduced in both conditions with the assessment tool.

**Specific adaptation hypothesis.** If the information provided by the assessment tool facilitates the adaptation to a specific client's knowledge, both the increase in communicative efficiency and effectiveness should be substantially larger in the condition presenting valid data about the client as compared with the other conditions. In contrast, communicative effectiveness and efficiency should be the lowest in the random data condition, because the distorted information should result in a biased mental model of the client's knowledge and this should impair the expert's adaptation to the client's actual knowledge state to some degree.

## Method

**The assessment tool.** The assessment tool provided the computer experts both with ratings of the client's general computer knowledge and their Internet knowledge (see Figure 1). Apart from these global evaluations, it was also displayed to what extent the client already knew the meaning of two specialist concepts semantically relevant to the understanding of the problem addressed by an inquiry. Thus, the experts had the possibility to adapt their explanations both to the client's general knowledge background and, on a more concrete level, to their prior knowledge regarding a specific inquiry. The values displayed in the assessment tool were determined through an objective and standardized assessment procedure. To this purpose, an updated version of the computer and Internet knowledge test developed by Richter et al. (2000) was constructed and pre-tested on 40 humanities students. In the experiment, the number of items that a client had solved correctly in the general computer knowledge subtest (10 items) and in the Internet knowledge subtest (10 items) was translated into values on the corresponding five-point scales in the assessment tool (cf. Figure 1). For example, if a client had solved only one or two items out of the ten items of the Internet knowledge subtest, this was indicated as a *low* Internet knowledge level. In contrast, if the client had solved nine or ten items of a subtest, this would be represented in the assessment tool as a *high* knowledge level. To assess the client's knowledgeability regarding the specialist concepts they were asked to describe the meaning of each of the concepts. Two raters independently scored the written descriptions for correctness by using the five-point rating scale displayed in the assessment tool (see Figure 1). Inter-rater reliability was .92.

**Participants.** 60 computer experts and 60 clients participated in the experiment. Computer experts were recruited among advanced students of computer science. The laypersons serving as clients were recruited among students of psychology and the humanities. The results of the knowledge tests showed that the clients covered a wide range of

different knowledge levels. In the general computer knowledge test, a mean of 5.33 correctly solved items was obtained with a standard deviation of 2.50 and a range of 10 items. In the Internet knowledge test, the clients were able to solve 5.80 items on average with a standard deviation of 2.33 and a range of 8 items. Thus, there was ample opportunity for the experts to adapt their explanations to clients with different prior knowledge levels.

**Design.** Computer experts and clients were combined into dyads that were randomly assigned to the experimental conditions. A one-factorial between-subjects design was used comprising three different conditions: (a) communication with an assessment tool displaying valid information about the client's knowledge (in the following labeled 'valid AT'), (b) communication without assessment tool ('no AT'), and (c) communication with an assessment tool displaying random information about the client's knowledge ('random AT'). Dependent variables encompassed measures of communicative effectiveness (i.e., the client's increase in knowledge) and communicative efficiency (i.e., the number of questions asked by the client in response to an expert's explanation).

**Materials.** A pool of 20 inquiries was constructed that demanded explanations of relevant Internet topics and problems. Based on expert ratings regarding the familiarity and relevance of the inquiries, six of them were selected for the experiment. Three inquiries required the computer expert to explain a technical concept. The other three were more complex. They asked the expert to instruct the client how to solve a problem and, additionally, to provide an explanation why the problem occurred in order to help the client understand the nature of the problem (e.g., "I'm running Internet Explorer 6. Whenever I try to print a website consisting of several frames, my printer only prints out one frame. I would like to understand why this happens and what I can do so that the frames are printed out all at once?").

**Procedure.** In the beginning of the experiment, the students serving as clients were administered the general computer knowledge test, the Internet knowledge test, and the concept description task. In addition, their prior knowledge about the six inquiries to be discussed in the communication phase was determined. The students were encouraged to try to answer each of the inquiries if possible. They were informed that they were participating in a study on students' knowledge about computers and the Internet. Thus, it was made certain that the students had no reason to assume that their test results would later be relevant to the communication phase of the experiment. This was important because otherwise the students' self-perceptions of their test performance might have influenced their behavior during the advisory exchange with the computer expert. In the communication phase, the expert and client sat in different rooms and communicated through a text-based interface. The client's task was to sequentially direct each one of the

prepared six inquiries verbatim to the expert by typing the prepared wording of the inquiry into the text form of the interface. The expert was asked to answer each inquiry as well as possible. The clients 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. When the client asked a new inquiry, the assessment tool was automatically updated with regard to the client's knowledge about the specialist concepts relevant to the current inquiry (see Figure 1). After the communication phase, the clients were again asked to write down their knowledge about each of the six inquiries. In this way, it was possible to calculate the individual increase in knowledge for each client (cf. Table 1).

## Results

Before the client's individual increase in knowledge was computed, it was made sure that the clients had no substantial prior knowledge about the inquiries. The mean scores of the clients' answers collected *before* the communication phase clearly ranged below one (4-point rating scale, cf. Table 1) indicating that, on average, the clients did not know the correct answer to the inquiries prior to the exchange with the computer expert. There were no differences between the experimental conditions,  $F < 1$ .

**Communicative effectiveness.** In order to compute the clients' individual increase in knowledge, the mean scores of the clients' answers to the six inquiries prior to the communication phase were subtracted from the corresponding mean scores after the communication phase (cf. Table 1). The maximum score to be attained was three points. An ANOVA performed on the individual difference scores revealed an overall effect of experimental condition,  $F(2, 57) = 5.37, p < .01, \eta^2 = .16$  (strong effect). Following the sensitization hypothesis, a substantial increase in knowledge should be observed in the conditions with an assessment tool but *not* in the condition without an assessment tool. The validity of the displayed information should make no difference. This prediction was represented by the following contrast: valid data: 1, random data: 1, no assessment tool: -2.

Following the specific adaptation hypothesis, the information displayed by the assessment tool should indeed make a difference: The client's increase in knowledge should be larger in the valid data condition compared with the condition without the assessment tool and the random data condition. The smallest knowledge increase would be expected in the random data condition, because the distorted information should impair the expert's adaptation to the client's knowledge level. This linear trend hypothesis was represented by the following contrast weights: valid data: 1, no assessment tool: 0, random data: -1.

The results of the contrast analysis clearly contradicted the sensitization hypothesis and supported the specific adaptation hypothesis. The planned contrast representing the sensitization hypothesis failed to reach statistical signifi-

cance,  $F < 1$ , whereas the contrast testing the specific adaptation hypothesis was highly significant,  $F(1, 57) = 9.99, p < .01, \eta^2 = .15$  (strong effect). Table 1 shows that the mean values of the clients' increase in knowledge evidently displayed the predicted linear trend with the largest increase in knowledge occurring in the valid data condition and the smallest in the random data condition.

Table 1: Means and standard deviations (in parentheses) of the dependent variables of the experiment.

Dependent Variable	Experimental Condition		
	Valid AT	No AT	Random AT
Mean scores of the clients' answers <i>before</i> the communication phase*	0.46 (0.38)	0.68 (0.73)	0.58 (0.50)
Mean scores of the clients' answers <i>after</i> the communication phase*	1.97 (0.71)	1.66 (0.55)	1.37 (0.59)
Mean differences of the clients' increase in knowledge	1.52 (0.81)	0.99 (0.78)	0.80 (0.54)
Total number of questions per expert-client exchange	2.15 (1.73)	4.35 (2.98)	4.70 (2.54)
Number of comprehension questions per expert-client exchange	1.75 (1.74)	3.80 (2.44)	3.85 (2.13)

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

**Communicative efficiency.** To obtain a measure of communicative efficiency, we counted the total number of questions the client produced in response to the expert's explanations during the whole exchange, that is, throughout the six inquiries. An ANOVA performed on the total number of questions revealed a significant overall effect of experimental condition,  $F(2, 57) = 6.27, p < .01, \eta^2 = .18$  (strong effect). When the analysis was restricted to the frequency of comprehension questions, that is, to those questions by which the client explicitly articulated a comprehension problem, a similar result was obtained,  $F(2, 57) = 6.36, p < .01, \eta^2 = .18$  (strong effect). To test the sensitization hypothesis and the specific adaptation hypothesis, planned contrasts were computed with the contrast weights reported above. As before, the data analyses yielded no support for the sensitization hypothesis, regardless of whether the total number of questions or the number of comprehension questions was used as the dependent variable,  $F(2, 57) = 1.87, ns$ , and  $F(2, 57) = 2.95, ns$ , respectively. On the other hand, the specific adaptation hypothesis was also confirmed with regard to communicative *efficiency*. The linear contrast was significant when the total number of questions was considered,  $F(1, 57) = 10.67, p < .01, \eta^2 = .16$  (strong effect), and

also when the analysis was restricted to the comprehension questions,  $F(1, 57) = 9.76, p < .01, \eta^2 = .15$  (strong effect). With valid data in the assessment tool, the laypersons wrote back only about half as often in response to an expert's explanation as compared to the other experimental conditions (cf. Table 1, last two rows). Thus, only the provision of valid information reduced the frequency of questions by which the client explicitly articulated a comprehension problem or asked for further information. On the other hand, most of the questions occurred in the condition that presented distorted information about the client's knowledge.

## Discussion

The dialogue experiment presented in this paper replicates the results found in a previous study (Nückles & Stürz, in press). The approach to support asynchronous communication between computer experts and laypersons by means of an assessment tool has indeed proven to be successful. More importantly, the present findings also allow for conclusions about the mechanisms that led to the increase in communicative effectiveness and efficiency. The clients acquired the most knowledge and asked the fewest questions when the computer expert was presented *valid* data about the client's knowledge. When the information was distorted, the client's knowledge acquisition was impaired. The clients in the random data condition profited the least from the experts' explanations and asked the most questions. These results clearly contradicted the sensitization hypothesis and supported the specific adaptation hypothesis. Thus, it can be concluded that it was in fact the *individuating information* about the client's knowledge that led to the increase in communicative efficiency and effectiveness. From the perspective of Nickerson's anchoring and adjustment model (Nickerson, 1999) the assessment tool improved the communication between expert and client because the information about the client's knowledge provided the computer expert with a *specific* anchor right from the start of the counselling process. This enabled the expert to calibrate their mental model about the client's knowledge more quickly and accurately than would have been possible without such individuating information or with distorted information.

The present findings show that the assessment tool fostered specific adaptation to the clients' knowledge. It is still unclear *how* the experts exactly used the information about the client to produce adaptive explanations. It is plausible to assume that the experts used a 'linear strategy'. For example, they might have reasoned that 'the lower the client's knowledge level, the more extensive my explanations should be' in order to provide the client sufficient context for comprehension (cf. Clark, 1996). Indeed, we found such a correlation between the extensiveness of the experts' explanations and the client's displayed knowledge level ( $r = -.32, p < .05$ ). Still, the correlation was rather low. It cannot help to fully understand the cognitive heuristics the computer experts used to adjust their explanations to the client's knowledge. Thus, beyond the tendency to link explanatory

extensiveness to the client's knowledge level, the experts apparently used the information displayed by the assessment tool to adjust their explanations in more sophisticated and individualized ways. One possibility is that the experts referred to the information in the assessment tool to make decisions during the planning phase of an explanation, for example, whether a technical term they intended to use in their answer would already be known by the client, or would have to be introduced in case it was not known (so-called 'pruning', see Chin, 2000). To explore such possibilities, we are currently running a 'think-aloud' study in which we are investigating how the experts developed a qualitative representation of the client's knowledge from the quantitative information provided by the assessment tool and how this qualitative representation was used to generate instructional explanations for the client. In addition, 'thinking aloud' protocols of the client's comprehension processes could help to identify features of the expert's explanations that hinder or enhance the clients' understanding. The identification of features that make an expert's explanation well adapted to a specific knowledge level could be interesting both for the design of advice-giving systems (e.g., Chin, 2000) and intelligent tutoring systems (e.g., Dede, 1986).

The finding that information about a client's knowledge fostered the provision of adaptive instructional explanations might also be suggestive of ways in which Internet-based collaborative settings other than helpdesk communication could be supported. In the realm of distance learning, many universities offer online courses where students of diverse educational backgrounds and with a wide range of different knowledge participate. As the tutors in these courses have to provide instructional explanations for people they – at least initially – do not know, an assessment tool could provide valuable information that may help the tutors to adapt their explanations to the learners' knowledge level. Hence, an assessment tool might also be an appropriate method to support online tutoring (Siler & VanLehn, in press).

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