

IMPROVING INSTRUCTIONAL EXPLANATIONS IN NETBASED  
COMMUNICATION BETWEEN EXPERTS AND LAYPERSONS

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„Man ist ein Mann seines Faches um den Preis,  
auch das Opfer seines Faches zu sein.“

Friedrich Nietzsche

## OVERVIEW

This dissertation is part of the research project “Das Assessment Tool: Eine Diagnosehilfe für Computer-Experten zur Verbesserung der Effektivität netzbasierter Beratung” [The Assessment Tool: A Method to Support Netbased Communication Between Experts and Laypersons] granted to Dr. Matthias Nückles and Prof. Alexander Renkl by the DFG [German Science Foundation] within the Special Priority Program “Netzbasierte Wissenskommunikation in Gruppen” [Netbased Knowledge Communication in Groups], which was initiated by Prof. Friedrich Hesse, Prof. Ulrich Hoppe, and Prof. Heinz Mandl in 2000.

The Special Priority Program aims to investigate the generic qualities of networked computers as media for knowledge communication. It focuses on the underlying mechanisms of human interaction with technology. In addition, results are used to make recommendations on how to design tools to support netbased communication in groups, for example, with regard to the design of virtual learning environments in higher education or with respect to improvements in work and problem-solving processes related to netbased cooperation forms in organisations (for an overview of the Special Priority Program, see Buder, 2003; Buder & Hesse, 2002, 2004).

Another important area of research within the Special Priority Program addressed in this dissertation focuses on consultation services delivered via the Internet. Today, there is a wide range of online services offered to customers, including, for example, technical support services for hardware and software, online banking services, or medical and psychological health care services (Döring, 2000). Typically, experts in a certain domain of knowledge provide advice to customers, that is, to laypersons who have no or noticeably little knowledge about the subject of advice (Bromme & Rambow, 2001; Nückles & Bromme, 2002). Hence, for advice to be effective, experts should adjust their communication to the specific knowledge background and informational needs of the individual layperson. In computer-mediated communication, however, the evaluation of the communication partner’s knowledge and the continuous construction of a mutual understanding are



considerably more difficult as compared with face-to-face communication (Clark & Brennan, 1991). The communication partners cannot see nor hear each other, and the possibilities to provide immediate feedback are seriously restricted. In addition, due to their rich knowledge base, experts often have difficulty taking into account the layperson's completely different perspective (e.g., Bromme, Rambow, & Nückles, 2001; Hinds, 1999; Nückles, 2001). Despite the increasing need for e-support services (UNCTAD, 2004), their importance for businesses to create competitive advantages (Van Riel, Lemmink, Streuikens, & Liljander, 2004; Wittwer, 2002) as well as their relevance for people's decision-making (Kiesler, Zdaniuk, Lundmark, & Kraut, 2000; Wittwer, Bromme, & Jucks, 2004), research has paid little attention so far to the specific problems of experts conveying their knowledge to laypersons within these services. In particular, there is a lack of studies investigating netbased communication between experts and laypersons specifically from an educational and psycholinguistic perspective, including the question of how experts adapt their explanations to the laypersons' understanding (cf. Bromme, Jucks, & Wagner, 2005).

Therefore, in this dissertation, the difficulties as well as the possibilities of improving netbased communication between experts and laypersons are discussed and examined. More specifically, the dissertation focuses on the question to what extent the accuracy of an expert's model about the layperson's knowledge influences communication in computer support provided via the Internet. In order to investigate this question, a support procedure, a so-called assessment tool, was developed that provides information about a layperson's knowledge background to computer experts. The assessment tool consists of a small Internet-based questionnaire by which laypersons who place a technical support inquiry to an online support are asked to provide several self-assessments of their computer expertise. Thus, the information provided by the assessment tool can be used by the experts to construct a model of their communication partner and to adapt their explanations to the layperson's individual knowledge accordingly. From a practical point of view, the computer helpdesk scenario is used in the experiments of this dissertation to examine the usefulness of a support procedure for netbased advice-giving. From a theoretical perspective, the sce-

nario provides an experimental setting for analysing the importance of adaptation required for effective communication and understanding.

To empirically test the effectiveness of the assessment tool for online advice-giving, several dialogue experiments were conducted within the research project. In all studies, the following experimental setting was used: Experts and laypersons sat in separate rooms and communicated with each other via an asynchronous interface. The experts' task was to provide explanations to laypersons' inquiries regarding diverse computer and Internet issues. In the experiments, the availability as well as the validity of the information about the laypersons' knowledge presented to the experts – by means of the assessment tool – were varied. Overall, results showed that the assessment tool displaying correct information about the layperson's knowledge level resulted in an improved communication between experts and laypersons. Laypersons were better able to process the experts' explanations that were produced with the assessment tool within the frame of their personal understanding, as was indicated by higher learning gains and a reduced need for asking follow-up questions. These findings clearly demonstrated the importance of an accurate model about the layperson's knowledge for providing effective and efficient advice.

Chapter 1 provides the general theoretical background for this dissertation involving a review of the relevant literature relating to netbased communication between experts and laypersons. In chapter 2 to 4, three dialogue experiments are presented that examine different but related aspects of netbased communication between experts and laypersons. The chapters include a theoretical introduction addressing the specific research problem, a presentation of the research questions, the method and results of the experiment as well as a discussion of the findings. Though closely related, each of these chapters is self-contained and can therefore be read independently. Chapter 2 shows that knowledge information about a layperson can be used by experts to specifically adapt their explanations to the layperson's individual needs and thereby to improve their advice-giving. In chapter 3, the detrimental effects on communication are investigated that occur when experts over- or underestimate laypersons' knowledge backgrounds. Chapter 4 presents a think-aloud study that highlights experts' planning processes during the composition of instructional

explanations for laypersons. In addition, it provides an analysis of the adaptive linguistic and semantic features of the experts' explanations. Chapter 5 concludes with a summary of this dissertation, a discussion of the findings, and an outline of future research directions.

## CHAPTER 1

### Theoretical Background

As the World Wide Web offers new possibilities for communication and information exchange across barriers of distance and time, it has become increasingly attractive for organisations to provide computer support to users via the Internet (Van Riel, Lemmink, Streukens, & Liljander, 2004). Today, virtually every large computer company and university computer centre offers helpdesk support, often in a text-based, asynchronous way via electronic mail. The support usually takes the form of advice provided by experts (Loomba, 1996). Experts help users, for example, to make an informed decision about alternative software products, to use hardware and software applications more efficiently, or, in case of problems with the computer or the Internet, they assist them in finding and solving a problem on their own (Goffin & New, 2001).

The advisory success, however, heavily depends on the experts' ability to provide intelligible and informative explanations for laypersons with differing levels of expertise, ranging from beginners to more proficient users (Brodbeck, Zapf, Prümper, & Frese, 1993; Kiesler, Zdaniuk, Lundmark, & Kraut, 2000; Kobsa, 2004). Hence, in order to give effective advice, experts should adapt their communication to the knowledge prerequisites of the individual layperson (Clark & Murphy, 1982). Only then can laypersons process the information within the context of their personal understanding which consequently should facilitate comprehension and learning. A central requirement for experts who communicate with laypersons therefore consists in assessing the laypersons' current level of understanding and customising the instructional explanations accordingly (Clark, 1992, 1996; Nickerson, 1999).

The following section provides an overview of the communication theory developed by Clark (1992, 1996) that is of particular relevance for communication between experts and laypersons, because central to this theory is the establishment of a mutual understanding with respect to the communication partners' background knowledge (section 1.1). The

subsequent section then introduces the factors influencing netbased communication between experts and laypersons (section 1.2). These include the constraints of asynchronous, written communication (section 1.2.1) as well as the cognitive limitations faced by experts when sharing their knowledge with people who have less expertise (section 1.2.2). After this, in section 1.3, the assessment tool is introduced that aims to compensate for the difficulties of netbased expert-layperson communication as outlined in the preceding sections. The chapter concludes with a description of the specific research problems that are addressed in the three experiments presented in chapters 2 to 4 (section 1.4).

## **1.1 Language as Action: The Theory of Common Ground**

Due to the asymmetrical knowledge that exists between experts and laypersons, it is necessary that experts adjust their instructional explanations to the laypersons' specific informational needs (Schober & Brennan, 2003). In doing so, experts enable laypersons to better comprehend and construct an appropriate mental model of the content being explained. In the *theory of common ground* developed by Clark (1992, 1996), adaptation to a person's knowledge level and communicational needs is regarded as being fundamental for the establishment of a mutual understanding, that is, a common ground. According to Clark, "two people's common ground is, in effect, the sum of their mutual, common, or joint knowledge, beliefs, and suppositions" (1996, p. 93). In order to develop a mutual understanding, communication partners – as expressed by the notion of *language-as-action* (Pickering & Garrod, 2004) – jointly coordinate their communication activities by taking into account the other's perspective. The *perspective* may refer to any aspect of a person that is relevant in communication with regard to the establishment of a common ground. It can be conceived of a person's goals, opinions, attitudes, and – more important within the context of this dissertation – the cognitive structures associated with a person's knowledge about the topic of conversation (for a more detailed explication of the term "perspective", see Jucks, 2001; Krauss & Fussell, 1996; Schober 1998). The perspective-taking allows communication partners to assess what is already part of the common ground, that is, what can be assumed to be known to both of them (so-called *commonality assessment*, cf. Hor-

ton & Gerrig, 2005). Hence, the common ground reflects the common knowledge shared by the communication partners as well as their knowledge about what knowledge is not shared between them (Krauss & Fussell).

For people to contribute to communication, they have, following the terminology of Clark's communication model (1992, 1996), to add to their common ground. The collective process that results in an accumulation of the common ground is called *grounding* (Clark & Schaefer, 1989). It consists of *contributions* that are composed of two phases, namely presentations and acceptances. In the *presentation phase*, the speaker presents an utterance to the partner. In the *acceptance phase*, the partner indicates the understanding of that presentation. Clark and Schaefer describe several different methods, so-called *grounding techniques*, that are used to accept or reject the presentation of the speaker. These include backchannel responses such as “hmm”, “ok”, or “right”, nonverbal signs like nodding the head, or the initiation of a next relevant contribution (e.g., asking for additional information).

In order to minimise the effort that both communication partners put into grounding, from the initiation of each contribution to its mutual acceptance, they follow the *principle of least collaborative effort* (Clark & Wilkes-Gibbs, 1986). That is, they strive to use the least amount of joint effort required to achieve their conversational goals (cf. the cooperative principle of communication proposed by Grice, 1975). In order to do so, people draw on their prior beliefs about the partner's knowledge as a basis for creating utterances that meet the partner's individual communicational needs. This process of constructing utterances for particular addressees has been called *audience design* (Clark & Carlson, 1981; Clark & Murphy, 1982) or *recipient design* (Sacks, Schegloff, & Jefferson, 1974): “By ‘recipient design’ we refer to a multitude of respects in which the talk by a party in a conversation is constructed or designed in ways which display an orientation and sensitivity to the particular other(s)” (p. 727). Relying on one's own prior beliefs about the other's knowledge not only reflects a kind of cognitive economy in communication but is also relevant for pragmatic reasons. Ascertaining what is in fact held in common would theoretically result in an iterative formulation of statements, such as “I know that we mutually

know that x because I know that you know that I know that you know ... that x". This chain of reasoning involved in achieving true mutual knowledge is potentially infinite (Schiffer, 1972). Therefore, Clark and Marshall (1981) suggested that communication partners instead infer what is part of the common ground. In order to do so, they can make use of a set of heuristics that involve taking into account information that are copresent to both communication partners. First, *physical copresence* refers to information that is in the shared physical environment of the communication partners. Secondly, *linguistic copresence* refers to information that has been explicitly mentioned in the preceding discourse. Finally, *community membership* refers to information derived from the perceived group membership of the communication partner.

Even though inferring common ground by virtue of the aforementioned copresence heuristics (Clark & Marshall, 1981) is computationally more feasible than engaging in an iterative formulation of mutual knowledge, it still requires the communication partners to develop a fairly detailed model that reflects the knowledge that they assume to be shared with each other. In fact, as Clark and Marshall argue, routine communication with people who are familiar to us is effective because "we carry around rather detailed models of people we know, especially of people we know well" (p. 55). Nevertheless, the metacognitive knowledge about the communication partner, also referred to as *listener model* (Clark & Marshall) or *partner model* (Herrmann & Grabowski, 1994), might be erroneous and biased, thus leading to problems of understanding (Fussell & Krauss, 1992; Schober & Brennan, 2003). As mentioned before, it can only be inferred that a communication partner possesses certain knowledge about the subject under discussion, and as with all inferences, there is always the risk of being wrong. Moreover, it is quite obvious that inferences can never access all the facets of a person's perspective (Polichak & Gerrig, 1998; Schober, 1998). However, with the exception of the postulated copresence heuristics (Clark & Marshall), Clark does not specify in more detail the cognitive-psychological processes involved in the formation of a model about a communication partner (cf. Horton & Gerrig, 2005).

The most commonly used experimental paradigm to study the assumptions underlying Clark's theory of common ground (1992, 1996) is the so-called *referential communication paradigm* in which communication partners communicate directly with each other with one person having information that the other one needs. For example, person A is instructed to describe one item (usually a picture of an object or an abstract design) in an array of items in a way that will allow person B to identify the target item. The experimental setup provides the opportunity to observe the processes by which the communicators coordinate and establish a joint perspective. Therefore, it is particularly suitable for analysing how perspective-taking influences speaker's efforts to adjust their messages to the partner's needs in order to guarantee communication success. There is a huge body of literature showing that in a wide variety of situations communicators in fact adapt their utterances to meet the addressee's specific informational needs (e.g., Brennan & Clark, 1996; Isaacs & Clark, 1987; Lockridge & Brennan, 2002; Nadig & Sedivy, 2003). However, these studies most often focus exclusively on referential communication and the kind of reference typically refers to concrete things or "nonsense" figures. Variables under study are, for example, the reference to proper nouns, the use of deictic formulations, or the coordination of turn-taking. Thus, the tasks used in this paradigm strongly constrain the content of communication. In most cases, therefore, communication does not aim at improving understanding in terms of acquiring knowledge but mainly consists in solving lexical or referential ambiguities that might impede the natural flow of communication (Bromme, Jucks, & Runde, 2005; Krauss & Fussell, 1996; Schober & Brennan, 2003). This is surprising given the fact that adjustments with respect to a partner's communicational needs might occur at virtually all levels of language use, such as "word choice, pronunciation or other articulatory features, syntactic structure, sentence-level top selection, or higher level discourse planning" (Schober & Brennan, p. 140). Nonetheless, little attention has been paid to how communicators, when faced with more complex tasks, adjust their communicative contributions at a more molar, that is, semantic level, as is necessary when, for example, experts communicate with laypersons (see also Bromme, Jucks, & Wagner, 2005). Such more coarse-grained adjustments would allow experts to bridge the gap between their



own specialist knowledge and the laypersons' less sophisticated knowledge and, consequently, would enable laypersons to better understand the information provided.

### 1.1.1 Nickerson's Anchoring-and-Adjustment Model

Central to Clark's theory of common ground (1992, 1996) is the assumption that effective communication only takes place when communication partners are able to appreciate differences between their own and the other's perspective. Following this assumption, Nickerson (1999, 2001) proposes a model in which he, more specifically than Clark, describes the cognitive processes by which communicators arrive at assumptions about their partner's knowledge. His model is composed of three phases: According to the *anchoring-and-adjustment heuristic* proposed by Tversky and Kahneman (1974), in the first phase, one's own knowledge, *model of own knowledge*, serves as an anchor for building a *default model of (a) random other's knowledge*. This is done by taking into account all information about one's own knowledge that can be considered as special or unlikely to be representative of the knowledge of people in general. In the second phase, the default model is then transformed into an *initial model of specific other's knowledge*. As a basis for the derivation of this more person-specific model, clues such as the appearance of the communication partner will be used to make assumptions about the community to which the partner belongs (community membership, cf. Clark & Marshall, 1981). From the presumed membership further information can be derived concerning the knowledge that this group is likely to possess. In addition, one might also draw on knowledge about shared past experiences with the communication partner (so-called *personal knowledge*, Clark & Schaefer, 1987) that might be relevant to the current communication situation. In the final phase, one modifies the *working model of specific other's knowledge* on an ongoing basis in accordance with information obtained when directly interacting with the communication partner. For updating the working model, communication partners can make use of the linguistic and physical copresence heuristic (cf. Clark & Marshall) to infer what is commonly shared in the communication situation. Moreover, they might explicitly engage in asking questions to

address what is already mutually known and what needs further clarification (Horton & Gerrig, 2005).

It is important to note that, according to Nickerson (1999), the three phases of his model need not be completely passed through each time one seeks to assess a communication partner's knowledge. Rather, when communicating with a person who is familiar to us, the already existing initial model about this person can be directly accessed and updated as new individuating information is acquired. In contrast, when strangers meet, one's own knowledge is initially the best predictor of the other person's knowledge. Depending on information obtained to suggest differences between one's own and the partner's knowledge, the assumptions about the partner are then specified and modified on an ongoing basis, as is proposed by Nickerson's model.

### **1.1.2 Levels of Partner Adaptation in Communication**

Which sources of information can be used to transform a default model of a random other person's knowledge into a model of the knowledge of a specific person (Nickerson, 1999), however, heavily depends on the constraints and affordances of the communication medium (for details, see section 1.2.1). For example, when only little information about the communication partner is available, such as in e-mail communication, it is – at least initially – not possible to develop an elaborate model about the partner's knowledge. Instead, only very generic assumptions can be made, for example, as a result of information derived from the partner's community membership. Hence, when designing messages, the communicator can only use these assumptions to customise the level of detail of the information being provided. Conversely, in traditional conversational contexts, communicators can draw upon information from a variety of sources. Thus, it is comparatively easier to take into account the partner's specific informational needs and to adapt the messages to meet the partner's perspective in a number of respects. Schober and Brennan (2003) systemised the different adjustments communicators can make in the following way:

- *No adjustments*: Speakers produce utterances on the basis of their own ease of production without taking into account the communication partner's needs.

- *Generic-partner adjustments*: Speakers produce utterances that the typical user of a language would find easiest to understand, for example, by articulating unpredictable words more clearly.
- *Cultural/community/group-based adjustments*: Speakers produce utterances that a typical member of a community would find easiest to understand, for example, by adopting the jargon of the specific community.
- *Specific-partner adjustments*: Speakers produce utterances that take into account the communication partner's individual needs.

As Schober's and Brennan's taxonomy (2003) suggests, the more information about a communication partner is available, the more a communicator might be able to take into account this information for adapting the utterances to the partner (Clark & Murphy, 1982). However, regardless of the variety of sources that can be used to develop a detailed model about the communication partner, communication is nevertheless likely to fail when communicators are not aware of differences in their perspectives and informational needs (Schober, 1998). This might be particularly detrimental when the topical knowledge between communication partners greatly differs, as is typically the case for communication between experts and laypersons (Nückles & Bromme, 2002). Moreover, when communicators experience a high cognitive load, for example, because the discourse tasks are particularly difficult (von Stutterheim, 1994) or messages have to be produced under time pressure (Clark & Brennan, 1991; Horton & Keysar, 1996), there might be fewer attentional resources available to devote to taking into account the partner's specific needs (Krauss & Fussell, 1996). Hence, a number of factors – the specific characteristics of the communication medium, personal variables, as well as situational circumstances – come into play in communication that might considerably constrain the potential space of partner adaptation.

## 1.2 Factors Influencing the Success of Netbased Communication Between Experts and Laypersons

When providing advice to laypersons via the Internet, experts in particular might be expected to have problems in communicating effectively. Not only the constraints of asynchronous communication might impair experts' construction of an elaborate model about the layperson's knowledge but also their inclination to forget about the exclusiveness of their knowledge may add to their difficulties in considering the layperson's perspective adequately. Therefore, these factors can be assumed to have a considerably negative impact on communication. In the following subsections, these factors are presented in more detail.

### 1.2.1 Constraints and Affordances of Written, Asynchronous Communication

Clark's communication theory (1992, 1996) as well as Nickerson's anchoring-and-adjustment model (1999, 2001) originally refer to face-to-face dyadic conversation. Typically, conversation is regarded as the most fundamental site of language use from which all other discourse forms are derivative (Clark, 1996; Schober & Brennan, 2003). Therefore, communication media are usually described with respect to the features that distinguish them from the ideal of conversational speech (e.g., Clark & Brennan, 1991; Pickering & Garrod, 2004; Whittaker, 2003; Wiley & Schooler, 2001). Clark and Brennan propose a taxonomy according to which communication media can vary along different dimensions that directly influence the ease by which communicators can establish a common ground. These dimensions, also called *constraints on grounding*, are the following:

- *Copresence*: Communicators share the same physical environment.
- *Visibility*: Communicators are visible to each other.
- *Audibility*: Communicators can communicate by speaking and listening.
- *Cotemporality*: One communicator receives at roughly the same time as the other one produces.
- *Simultaneity*: Communicators can send and receive at once and simultaneously.
- *Sequentiality*: The communicators' turns cannot get out of sequence.

- *Reviewability*: Communicators can review their own and the other's messages.
- *Revisability*: Before sending, communicators can revise their messages.

When a communication medium lacks one of these characteristics, grounding techniques are necessary that compensate for the costs resulting from the constraints of the specific medium (Clark & Brennan, 1991). In text-based, asynchronous communication, many of the aforementioned characteristics are virtually unavailable. For example, the lack of *copresence* makes it more difficult for communicators to immediately refer to objects because they do not share a common physical environment. Moreover, communication partners cannot see each other (lack of *visibility*), which makes it particularly difficult for them to quickly assess what is part of the common ground. Due to the written nature of communication, all contributions have to be typed on a computer keyboard (lack of *audibility*). Hence, grounding techniques such as the use of backchannel responses are not available to coordinate communication. People who communicate in a computer-mediated context, for example, via email might theoretically send and receive messages simultaneously (*simultaneity*) as well as interact with each other instantaneously (*cotemporality*). In effect, however, contributions are often only loosely coupled and interrupted by messages from third parties (lack of *sequentiality*).

The lack of all these characteristics in computer-mediated communication might result in considerable difficulties for establishing a mutual understanding (Clark & Brennan, 1991). For example, objects, for the sake of clarity, have to be described more extensively. At the same time, there are higher *production costs* (Clark & Brennan) than in face-to-face communication because every message has to be typed on a computer keyboard which takes more effort and time than speaking or gesturing. For this reason, the decision to actively contribute to communication in computer-mediated contexts more heavily depends on the urgency and relevance of the message in relation to the costs associated with its communication (Reid, Malinek, Stott, & Evans, 1996). Similarly, the correction of already sent messages would be more laborious than in face-to-face communication. Therefore, in order to compensate for the potentially higher *repair costs* (Clark & Brennan), communi-

cators often produce longer messages within each turn but, overall, provide fewer turns as compared with face-to-face communication (e.g., Lebie, Rhoades, & McGrath, 1996; Rosé et al., 2003). Typically, these messages are formulated more carefully (Clark & Brennan) and contain more profuse elaborative descriptions (e.g., Oviatt & Cohen, 1991). This can be attributed to the affordances of written, asynchronous communication because previous messages can be reviewed (*reviewability*) and used to revise one's own contributions (*revisability*). In addition, there is time to plan the messages and to reflect about a communication partner's informational needs. In synchronous communication, however, like face-to-face communication, *delay costs* are high (Clark & Brennan), that is, people are supposed to respond instantly to a message without pausing too long. A delayed response could be interpreted, for example, as impoliteness or inattentiveness.

Overall, the comparison of the constraints and affordances between face-to-face and computer-mediated communication shows that the construction of a detailed model about the communication partner's topical knowledge is more difficult in computer-mediated contexts. The reduced number of communication channels along with the time-delayed communication provides less opportunity to accumulate a stock of information about the communication partner that could be utilised by speakers to formulate intelligible and informative messages. At the same time, however, an accurate partner or listener model (Clark & Marshall, 1981; Herrmann & Grabowski, 1994) is particularly important in computer-mediated communication already from the outset because the reduced possibilities to provide feedback make it more difficult to recognise and correct possibly false assumptions about the communication partner (Fussell & Krauss, 1992; Nickerson, 1999). Hence, in cases where communicators provide information that is not in line with the partner's knowledge background, the partner is more likely to drop out of communication because the costs of communication might be higher than its benefits, particularly when having to type each message on a computer keyboard (Reid et al., 1996). In contrast, when communicators have a good deal of information about their communication partner to develop an elaborate partner model, the affordances of computer-mediated communication – namely the possibilities to thoroughly review and revise one's own contributions – allow them to

plan and design messages that satisfy the partner's particular needs (Schober & Brennan, 2003).

### **1.2.2 Expertise and Communication**

Besides the constraints of computer-mediated communication, the cognitive limitations faced by experts who are urged to share their knowledge with laypersons when giving advice might additionally impair the communication success. Research on expertise studying the acquisition and application of expert performances has shown that experts not only know more than laypersons, but that their knowledge structures are also more tightly organised and interconnected (e.g., Chi, Glaser, & Farr, 1988; Reimann, 1997). 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 (e.g., Patel, Arocha, & Kaufman, 1999).

There is a plethora of scientific knowledge accumulated on the cognitive structure of expert knowledge and experts' skills in problem-solving in various domains, such as chess (e.g., Gobet & Simon, 1996), physics (e.g., Chi, Feltovich, & Glaser, 1981), medicine (e.g., Rikers, Schmidt, & Boshuizen, 2002), psychology (e.g., Leon & Perez, 2001), teaching (e.g., Hogan, Rabinowitz, & Craven, 2003), history (e.g., Wineburg, 1991), politics (e.g., Jones & Read, 2005), or computer science (e.g., Fix, Wiedenbeck, & Scholtz, 1993). These studies typically show that experts, as compared with novices, possess more abstract and elaborate concepts and schemata that facilitate a rapid categorisation of problem situations and the activation of routine problem-solving strategies. For example, in the frequently cited study by Chi et al. (1981), experts in physics used a deeper, more conceptual structure to sort physics problems, whereas novices sorted problems using a superficial structure. Thus, experts represented the problems in a way that immediately allowed for an application of relevant problem-solving strategies. Experts' high performance, however, is not only the result of a quantitative accumulation of knowledge but can be mainly attributed to the processes of knowledge restructuring, which takes place in the course of the development from novice to expert. A mechanism central to this development is, what

Anderson (1987) called, *proceduralisation*, that is, the transition from *declarative knowledge* that concerns factual knowledge to *procedural knowledge* that concerns operative knowledge required to solve problems.

For example, in medicine, students initially acquire knowledge from separate domains such as biology, chemistry, or physics at the beginning of their course of study. The kind of learning is characterised by lines of reasoning consisting of chains of small steps based on detailed but loosely interrelated concepts. Through practice, these concepts will be integrated into a tightly coupled knowledge network that allows for linking together different concepts. The more often direct lines between concepts are activated, for example, through confrontation with clinical cases, the more the concepts are clustered together under a limited number of clinically relevant concepts, thereby skipping intermediate concepts (this process is often referred to as *knowledge encapsulation*; Rikers et al., 2002). Finally, due to the growing clinical experience, the knowledge will be reorganised into so-called *illness scripts* (Feltovich & Barrwos, 1984), that is, knowledge structures that contain information about typical clinical pictures, signs, and symptoms as well as appropriate treatment options. In the ongoing development of expertise, these scripts will be continuously automated, the result being that they are activated as integrated wholes and instantiated by information available in the current case. Thus, in a practical diagnostic situation, the information available in the initial stages of the diagnostic encounter activates an illness script that not only guides the expectations about signs and symptoms but also yields a diagnosis and options for treating the patient's diseases (Reimann, 1997).

The highly elaborate and differentiated knowledge base of experts, however, might create an obstacle in communication with laypersons (Bromme & Rambow, 2001; Nückles, 2001). As exemplified before, key elements of the experts' knowledge that allow them to make a rapid classification of problem situations are often automated to a very high extent and therefore no longer accessible to consciousness and verbalisation. Hence, when experts are asked to explain complex information of their field of expertise to a layperson, this requires them to reconstruct the automated solution steps and decision processes which might be extremely laborious and – depending on the complexity of information – not al-



ways successful. In addition, due to the ready availability of their knowledge (Tversky & Kahneman, 1974), experts might be particularly prone to be dominated by their own perspective and, consequently, are not able to take into account the laypersons' specific needs. The categories and schemata experts use to classify problems are not available to laypersons (cf. Chi et al., 1981) who therefore have no chance to access the experts' perspective. For this reason, the success of communication between experts and laypersons heavily depends on the experts' ability to understand the problem from the laypersons' point of view (Nückles, 2001; Rambow & Bromme, 2000). The fact that this task, however, puts fairly high demands on experts is demonstrated by Billings-Gagliardi, Mazor, and Belanger (2001): "Several of our students have spontaneously commented that after just six months in medical school they have already begun to forget what medical information lay people know" (p. 39). The quotation also shows that problems in communication between experts and laypersons are less a result of experts' lack of rhetorical skills but can be primarily attributed to the very characteristics of their knowledge. When explaining complex information, experts should, however, still make use of appropriate linguistic devices such as examples, analogies, or metaphors in order to link the new information with the laypersons' current understanding and, in so doing, to facilitate the integration of information into their knowledge base (Rambow & Bromme).

### **1.3 The Assessment Tool: A Support Procedure for Netbased Communication Between Experts and Laypersons**

From the preceding discussion of the factors influencing netbased communication between experts and laypersons, it can be concluded that it would be useful to provide computer experts with a support procedure when giving advice to laypersons. In this dissertation, an assessment tool<sup>1</sup> will be proposed and empirically tested that is dedicated to support computer experts in constructing a mental model of a layperson in asynchronous communica-

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<sup>1</sup>The assessment tool will be presented in more detail in the methods sections of each of the following three chapters.

tion. The tool consists of a small Internet-based questionnaire by which laypersons who place a technical support inquiry are asked to provide the computer expert with several self-assessments of their computer expertise<sup>2</sup>. The tool is composed of relatively few question categories making it more practical for routine use in online computer support. If the laypersons were met with too many questions, they would more likely refuse to answer them (cf. Kobsa, Koenemann, & Pohl, 2001).

When computer experts provide online support to laypersons, they are usually in an anonymous communication situation with only little information about the layperson available. Thus, the assessment tool should enable experts to achieve a relatively concise and veridical evaluation of a layperson's knowledge right from the start because it provides them with information about the layperson that normally can only be collected during the course of the interaction process. In this vein, the support procedure helps to compensate for some constraints of written, asynchronous communication (see section 1.2.1) and thereby facilitates the collaborative effort of communication (cf. Clark & Schaefer, 1989). With regard to experts' inclination to forget about the laypersons' perspective (see section 1.2.2), the assessment tool prompts experts to carefully reflect about a layperson's knowledge prerequisites in order to facilitate adaptation to the laypersons' informational needs. However, the assessment tool can only be effective if the medium of communication allows for a careful planning and 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 (Clark & Brennan, 1991).

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<sup>2</sup>Although the assessment tool actually contains laypersons' self-assessments of their computer and Internet expertise to make it more practical for routine use in online support, in all three experiments presented in this dissertation laypersons' computer and Internet expertise was assessed through a standardised knowledge test. This was done because people's self-assessments are normally not perfectly veridical (Glenberg, Sanocki, Epstein, & Morris, 1987; see also chapter 2). Hence, by using an objective assessment procedure, we increased the chances of detecting knowledge differences between the laypersons who participated in the experiments.

## 1.4 Research Questions

The main goal of this dissertation is to empirically study the importance of an accurate mental model about the communication partner in netbased communication between experts and laypersons. To this purpose, the assessment tool has been developed that is supposed to support experts in constructing a mental representation of their communication partner. As outlined at the beginning of this chapter, in Clark's communication theory (1992, 1996) and Nickerson's anchoring-and-adjustment model (1999, 2001), a detailed partner model is regarded as an indispensable prerequisite for effective communication (section 1.1). The construction of an accurate partner model, however, is heavily impaired in netbased communication (section 1.2.1), and experts in particular are often prone to neglect the laypersons' perspective in communication (section 1.2.2). Therefore, the assessment tool aims to overcome these difficulties by providing experts with explicit information about the layperson's background knowledge in the computer and Internet domain (section 1.3).

In this dissertation, three experiments will be presented that examined the effects of the assessment tool both on the processes and outcomes of netbased communication between experts and laypersons. *Experiment 1* investigated the extent to which the assessment tool helped experts to form a mental model of their communication partner and thereby improved communication. *Experiment 2* was conducted to shed light on the particular consequences for communication when experts over- or underestimated the layperson's background knowledge. Finally, experiment 3 was dedicated to the analysis of the planning processes and adaptation strategies that experts applied when designing explanations for laypersons with the help of the assessment tool.

### **1. Are Experts Able to Specifically Adapt Their Explanations to a Layperson's Informational Needs in Computer-Mediated Communication When They are Provided with Information About the Layperson's Knowledge?**

The effectiveness of a prototype version of the assessment tool was already empirically tested in a dialogue experiment by Nückles and Stürz (in press). An asynchronous com-

puter helpdesk scenario was established in which computer experts answered requests of laypersons regarding diverse computer and Internet issues. The assessment tool consisted of laypersons' self-ratings of their computer and Internet expertise. It was visible to the experts during the entire course of the exchange. The results showed that advice-giving was more efficient and effective when computer experts had the assessment tool available as compared with the control condition where experts had no information about the laypersons' knowledge. Laypersons wrote back half as often in response to the experts' explanations and acquired, at the same time, more knowledge than the control group without the assessment tool. Although this experiment showed that providing computer experts with an assessment tool was promising, the question remained unanswered of the mechanisms underlying the assessment tool effect. Therefore, *experiment 1* of this dissertation tested two different theoretical explanations that could account for the finding. According to the *sensitisation explanation*, the assessment tool sensitised and reminded the experts that their communication partner was a layperson with only little knowledge in the computer domain. This might 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 layperson. In contrast, according to the *specific adaptation explanation*, it was assumed that the information displayed in the assessment tool was used by the experts to construct a more accurate mental model about the knowledge of the particular layperson. This should enable them to specifically adapt their explanations to the layperson's individual knowledge level. The testing of these alternative explanations allowed for conclusions regarding the extent to which experts were able to make adjustments to meet their communication partner's needs. Following Schober's and Brennan's taxonomy (2003, see also section 1.1.2), experts would make *group-based adjustments*, that is, adjustments that would benefit all members of a community to a similar extent if the sensitisation explanation was correct. In contrast, if the specific adaptation explanation was true and experts drew on the laypersons' individual knowledge when producing messages, this would indicate that experts were indeed able to make *specific-partner adjustments*.

## **2. What Happens When Experts Over- or Underestimate Laypersons' Knowledge in Computer-Mediated Communication?**

According to Clark's communication theory (1992, 1996) and Nickerson's anchoring-and-adjustment model (1999, 2001), for communication to be effective, it is important to have an accurate mental model about the communication partner. Hence, when communicators arrive at erroneous assumptions about their partner, miscommunication is likely to occur. Particularly in computer-mediated communication, erroneous assumptions can be assumed to cause serious communication failures because the possibilities to give a communication partner feedback are more restricted than in face-to-face settings (Clark & Brennan, 1991, section 1.2.1). Hence, experts must rely more heavily on their prior assumptions about a layperson's knowledge prerequisites. In case they arrive at false beliefs about a layperson's informational needs, these beliefs – without feedback – have lower chances of being recognised and corrected (Fussell & Krauss, 1992). Although prior research has shown that experts indeed tend to over- or underestimate the knowledge of people with less expertise, little attention has been paid to the particular impact of such over- and underestimations on communication. Therefore, *experiment 2* of this dissertation investigated how experts' misjudgements of what laypersons knew affected laypersons' learning from the experts' explanations and how laypersons engaged in question-asking as a strategy to compensate for possible comprehension problems. Of particular interest were the differential effects on laypersons' learning and question-asking depending on whether they were over- or underestimated by experts.

## **3. How do Experts Plan and Produce Explanations in Order to Meet the Laypersons' Specific Informational Needs in Computer-Mediated Communication?**

A serious shortcoming of Clark's communication model (1992, 1996) as well as of research that tests the model's assumptions is that it is often simply assumed that adaptation to a communication partner's informational needs occurs, without trying to understand the process by which it is accomplished in more detail (Schober & Brennan, 2003). Therefore, so far little effort has been put into identifying what communicators think and do when formulating messages for their communication partners. Besides, using preferably the ref-

erential communication task, research on communication has focused nearly exclusively on very simple adjustments communicators make to tailor the utterances to their partner, for example, through the use of the definite or indefinite article to distinguish between given and new information (see section 1.1). Adaptations in dyadic communication that occur at a semantic rather than a lexical level have not been studied yet experimentally. Against this background, *experiment 3* of this dissertation aimed to investigate how experts planned and designed their explanations with the help of the assessment tool in order to provide adaptive explanations to the laypersons. To this purpose, a think-aloud study was conducted to analyse experts' planning processes during the composition of their explanations for the laypersons. In addition, a content analysis was employed to uncover the linguistic and semantic features expert used in order to specifically adjust their explanations to the layperson's individual knowledge level.

## CHAPTER 2

### **Supporting Experts' Adaptation to a Layperson's Knowledge in Computer-Mediated Communication**

Inasmuch as knowledge becomes ever more specialised 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 that 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 communication to the knowledge prerequisites of the layperson (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 categorisation 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) analysed 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 does 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). Given these constraints, the possibilities 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.



## **2.1 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 laypersons via an Internet-based helpdesk, they are in an anonymous communication situation with only little information available about the layperson. Therefore, the procedure should enable the expert to achieve a relatively concise and veridical evaluation of a layperson'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 layperson's knowledge prerequisites in order to facilitate adaptation to the layperson's communicational needs. The better the computer experts' model of the layperson's knowledge is, the better the experts can adapt their explanations to the layperson's knowledge (Clark & Murphy, 1982).

In this chapter, an assessment tool will be empirically tested that supports computer experts in constructing a mental model of the layperson'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 2.1). For example, the laypersons 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 layperson's knowledge level based on a small number of highly relevant information items. The assessment tool provides the expert with information about the layperson right from the start that 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.

### Assessment Tool

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

**Dialog with client:**

**Counselor's answer:**  
Yes, exactly, a browser transforms these commands into corresponding signs and pictorial representations.

**New Client Inquiry:**  
I'm running Internet Explorer 6. Sometimes when I visit websites I get the following alert 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. Therefore, the default security level for this zone is "Medium", which prohibits running sites containing Active X controls. Active X is a feature of the Internet Explorer, a method of installing software on your computer which can install tems or software modifications over the Internet. Active X was developed for the purpose of]

SEND
DELETE

Figure 2.1. Screenshot of the assessment tool as it was available to the computer expert in the experimental conditions with valid and distorted knowledge information.

The assessment tool has already been successfully tested in a web-based dialogue experiment between computer experts and laypersons (Nückles & Stürz, in press). With the assessment tool, the laypersons 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.

In Nickerson's theory (1999), the construction of a mental model of another person's knowledge is conceptualised 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 layperson'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 layperson's knowledge more quickly and accurately than would have been possible without the assessment tool, that is, only on the basis of the layperson'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 layperson's individual knowledge level.

On the other hand, it may be argued that communicative effectiveness was raised not because of the information presented, but simply because the assessment tool increased the expert's awareness of the layperson and counteracted the tendency of de-individuation in Internet-based communication (Gunawardena, 1995). The experts were sensitised to reflect about the layperson'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 layperson. According to this explanation, the assessment tool had a more or less non-specific sensitising effect on the expert. Against this background, the goal of the present experiment was to test whether the availability of specific information about the layperson's knowledge would make a difference at all, that is, support the experts' adaptation and thereby enhance communicative effectiveness and efficiency.

## **2.2 Research Questions and Predictions**

In order to disentangle the effects of sensitisation and specific adaptation, the experimental design used in the dialogue study by Nückles and Stürz (in press) was modified and expanded. Firstly, instead of using self-assessments of computer expertise, that is, subjective information, the assessment tool in the present experiment provided the computer expert with objective information about the layperson's knowledge level as measured by standardised knowledge tests. Although self-assessments have proven to be good predictors of actual 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 layperson's computer knowledge, the power to detect a potential effect of specific adaptation was increased. Secondly, a third experimental condition was included, in addition to a communication condition with the assessment tool and a condition without the assessment tool. The information displayed in this additional condition was randomly drawn from the pool of knowledge data of laypersons who had previously participated in the experiment. The random data condition checked to see whether a distortion of the information about the layperson'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.

### **2.2.1 Sensitisation Hypothesis**

If the assessment tool mainly had a sensitising effect on the computer expert, that is, the information about the layperson 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 layperson and this alone should help them to improve their explanations. Consequently, in the conditions with the assessment tool, the laypersons should acquire substantially more knowledge compared with laypersons in the condition without the assessment tool. Moreover, if the

laypersons 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 explanations. 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.

### **2.2.2 Specific Adaptation Hypothesis**

If the information provided by the assessment tool facilitates the adaptation to a specific layperson's knowledge, both the increase in communicative efficiency and effectiveness should be substantially larger in the condition presenting valid data about the layperson 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 layperson's knowledge and this should impair the expert's adaptation to the layperson's actual knowledge state.

## **2.3 Method**

### **2.3.1 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 2.1). 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 an inquiry. 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 inquiry. The values displayed in the assessment tool were determined through an objective and standardised 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 layperson 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 5-point scales in the assessment tool (cf. Figure 2.1). For example, if a layperson had solved only 1 or 2 items out of the 10 items of the Internet knowledge subtest, this was indicated as a *low* Internet knowledge level. In contrast, if the layperson had solved 9 or 10 items of a subtest, this would be represented in the assessment tool as a *high* knowledge level. In order to assess the layperson'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 5-point rating scale displayed in the assessment tool (see Figure 2.1). Inter-rater reliability was .92.

### 2.3.2 Participants

Sixty computer-experts and 60 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 25.68 years ( $SD = 4.91$ ). 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 interested in the Internet, the students of computer science responded with a mean of 6.38 years ( $SD = 2.12$ ). They reported that on average, they would spend 21.07 hours per week working on the Internet ( $SD = 15.23$ ), which is a large amount of time. When asked to rate their Internet expertise on a 5-point rating-scale ranging from 1 (= *very inexperienced*) to 5 (= *very experienced*), a mean of 4.08 ( $SD = 0.72$ ) resulted. All in all, these values pointed out sufficiently high Internet expertise with regard to the purposes of the present experiment. The majority of the computer experts (60%) had a part-time job as a Web master, system administrator or computer advisor. 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 3.45 ( $SD = 1.05$ ). Hence, the computer experts in this experi-

ment apparently counselled other computer users rather frequently. There were no differences between the three experimental conditions,  $F < 1$ .

The 60 participants serving as laypersons were recruited among students of psychology and of the humanities. They received 15 EURO as compensation for their participation. The somewhat larger amount of money was justified by the extended knowledge tests the laypersons were administered in addition to the communication phase of the experiment. The laypersons' mean age was 23.15 years ( $SD = 2.80$ ). As specific adaptation presupposes that there are laypersons with different levels of prior knowledge the computer experts can adapt to, the students serving as laypersons in the present experiment should cover a wide range of different prior knowledge levels. The results of the general computer knowledge test, as well as the Internet knowledge test (see Assessment Tool section above) showed that this constraint was indeed met. In the general computer knowledge test, the average number of correct responses was 5.33, with a standard deviation of 2.50 and a range of 10. For the Internet knowledge test, a mean of 5.80 resulted, with a standard deviation of 2.33 and a range of 8. Hence, the present sample of laypersons evidently displayed great variability of prior knowledge levels. On average, the students reported that they had been using the Internet for 2.57 years ( $SD = 2.03$ ), and they would spend about 4.41 hours per week working on the Internet ( $SD = 4.91$ ). In rating Internet expertise, a mean of 2.36 resulted ( $SD = .93$ ). Thus, compared to the students of computer science, the students serving as laypersons rated their experience in using the Internet as clearly lower.

### 2.3.3 Design

Computer experts and laypersons 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 layperson's knowledge (in the following labelled *valid AT*), (b) communication without an assessment tool (*no AT*), and (c) communication with an assessment tool displaying random information about the layperson's knowledge (*random AT*). Dependent variables encompassed measures of communicative effectiveness (i.e., the

layperson’s increase in knowledge) and communicative efficiency (i.e., the number of questions asked by the layperson in response to an expert’s explanation).

### 2.3.4 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 layperson how to solve a problem and, additionally, to provide an explanation why the problem occurred in order to help the layperson understand the nature of the problem. Table 2.1 shows the six inquiries that were used in the experiment.

Table 2.1. *Inquiries used in the experiment*

---

With regard to the Internet I have often read the term ‘FTP server’. Could you please explain the notion of a FTP server to me in more detail?

---

Recently I visited a website that told me to wait while ‘Flash is loading’. Could you please tell me what exactly the difference between HTML and Flash is?

---

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’?

---

I’m running Internet Explorer 6. Sometimes, when I visit websites I get the following alert 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 I can get rid of the problem.

---

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.

---

I’m running Internet Explorer 6. Whenever I want 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.

---



### 2.3.5 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.

*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 three 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 inquiries. The students were informed that they were participating in a study on students’ knowledge about computers and the Internet. 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 probably have influenced their communication behaviour during the advisory exchange with the computer expert. Hence, in order to control for such potential effects of self-categorisation, the cognitive framing of the pre-test phase and communication phase of the experiment was kept as distinct as possible. Therefore, after completion of the knowledge test, the experimenters analysed the layperson’s answers in a separate room, where they subsequently entered the results into the assessment tool form (see Assessment Tool section above).

After the assessment of the layperson’s general level of computer and Internet knowledge, the layperson’s prior knowledge with regard to the six inquiries to be discussed in the communication phase was determined. Accordingly, the laypersons were encouraged to try to answer each of the inquiries, if possible. The same procedure was repeated in the post-test phase of the experiment. In this way, it was possible to compute the individual increase in knowledge for each layperson.

*Communication phase.* The experiment simulated an asynchronous hotline consulting service. The computer expert and the layperson sat in different rooms and communicated through a text-based interface, which could be accessed by means of the browser. The layperson’s task was to sequentially direct each one of the six inquiries (cf. Table 2.1)

to the expert by typing the prepared wording of the inquiry into the text form of the interface. The sequence of the inquiries was randomised individually for each dyad of expert and layperson. The expert was asked to answer each inquiry as well as possible. The laypersons were encouraged to write back and ask as many questions as needed or wanted. When both communication partners felt that an inquiry had been answered to a satisfactory degree, they could continue on to the next inquiry.

In the two experimental conditions with the assessment tool, the completed form was visible to the expert during the entire course of the exchange, and was located in the upper part of the screen (see Figure 2.1). In the lower left part of the screen, the layperson's inquiry was presented to the expert and on the right side there was a separate text box for the expert to type in their answer. In the left box, the whole exchange between the interlocutors could be viewed by pulling down the scroll bar (affordance of reviewability, cf. Clark & Brennan, 1991). Communication was asynchronous like in electronic mail because an interlocutor's written message did not become automatically visible on the partner's screen, but was announced by an alert window (lack of cotemporality, cf. Clark & Brennan). In order to view the message, the participant had to press the 'OK'-button in this window.

*Post-test phase.* After the communication phase, the laypersons were again asked to write down, as well as possible, how they would answer each of the six inquiries. After completion of the post-test, the layperson and the expert were debriefed and compensated for their participation.

### **2.3.6 Scoring**

In order to determine a layperson's increase in knowledge, their written attempts to answer the six inquiries collected before and after the communication phase were scored for correctness by two independent raters. Both raters were blind to the experimental conditions. For each answer, up to 3 points could be assigned (0 = *no or wrong answer*, 1 = *partly correct answer*, 2 = *roughly correct answer*, 3 = *completely correct answer*). Agreement

among the raters was determined by the intra-class coefficient. For the mean of the individual ratings a coefficient of 0.92 resulted, indicating excellent inter-rater agreement.

## 2.4 Results

Before the layperson's individual increase in knowledge was computed, it was made sure that the laypersons had no substantial prior knowledge about the inquiries. The mean scores of the laypersons' answers collected before the communication phase clearly ranged below one (4-point rating scale, cf. Table 2.2) indicating that, on average, the laypersons did not know the correct answer to the inquiries prior to the exchange with the computer expert. There were no significant differences between the experimental conditions,  $F < 1$ .

### 2.4.1 Communicative Effectiveness

In order to compute the laypersons' individual increase in knowledge, the mean scores of the laypersons' answers to the six inquiries prior to the communication phase were subtracted from the corresponding mean scores after the communication phase (cf. Table 2.2). The maximum score to be attained was 3 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 sensitisation 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 layperson'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 layperson'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 sensitisation hypothesis and supported the specific adaptation hypothesis. The planned contrast representing the sensitisation hypothesis failed to reach statistical significance,  $F < 1$ , whereas the contrast testing the specific adaptation hypothesis was highly significant,  $F(1, 57) = 9.99$ ,  $p < .01$ ,  $\eta^2 = .15$  (strong effect). Table 2.2 shows that the mean values of the laypersons’ 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 2.2. 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 laypersons’ answers before the communication phase*	0.46 (0.38)	0.68 (0.73)	0.58 (0.50)
Mean scores of the laypersons’ answers after the communication phase*	1.97 (0.71)	1.66 (0.55)	1.37 (0.59)
Mean differences of the laypersons’ increase in knowledge	1.52 (0.81)	0.99 (0.78)	0.80 (0.54)
Total number of questions per expert-layperson exchange	2.15 (1.73)	4.35 (2.98)	4.70 (2.54)
Number of comprehension questions per expert-layperson exchange	1.75 (1.74)	3.80 (2.44)	3.85 (2.13)

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

### 2.4.2 Communicative Efficiency

To obtain a measure of communicative efficiency, the total number of questions the layperson produced in response to the expert's explanations during the whole exchange, that is, throughout the six inquiries was counted. 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 layperson 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 sensitisation 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 sensitisation hypothesis, regardless of whether the total number of questions or the number of comprehension questions was used as the dependent variable,  $F(1, 57) = 1.87, ns$ , and  $F(1, 57) = 2.95, ns$ , 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 with the other experimental conditions (cf. Table 2.2, last two rows). Thus, only the provision of valid information reduced the frequency of questions by which the layperson 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 layperson's knowledge.

## 2.5 Discussion

The present experiment successfully replicated the results of the study conducted by Nückles and Stürz (in press). Both the effectiveness and efficiency of asynchronous helpdesk communication increased when the experts were provided information about the layper-

son's knowledge level by means of an assessment tool. Similar results were obtained, irrespective of whether the displayed information was based on the laypersons' self-assessments, such as in the Nückles and Stürz study, or on more objective and valid data, as they were measured by standardised knowledge tests in the present experiment.

Apart from the replication of the Nückles and Stürz results (in press), the main purpose of the present experiment was, however, to test different theoretical explanations of the assessment tool effect: Does the assessment tool improve the effectiveness and efficiency of asynchronous helpdesk communication mainly because it has a non-specific sensitising effect on the computer expert? Or does the information provided support specific adaptation to the layperson's knowledge level and thereby improve the effectiveness and efficiency of the communication? The results of the present experiment clearly contradicted the sensitisation hypothesis and supported the specific adaptation hypothesis. The laypersons acquired the most knowledge and asked the least questions when the computer expert was presented valid data about the layperson's knowledge level. When the information about the layperson's knowledge was distorted (random data condition), the layperson's knowledge acquisition was impaired. From these results, it can be concluded that it was in fact the individuating information about the layperson's knowledge that led to the increase in communicative effectiveness and efficiency. From the perspective of Nicker-son's anchoring-and-adjustment model (1999), the assessment tool improved the communication between expert and layperson because the information about the layperson'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 layperson's knowledge more quickly and accurately than would have been possible without such individuating information or with distorted information.

### **2.5.1 Practical Implications**

The finding that the assessment tool boosted the provision of adaptive explanations suggests that this idea might also apply to other Internet-based collaborative and instructional settings beyond the helpdesk context. An assessment tool could be especially useful in

asynchronous settings where complex knowledge has to be acquired and communicated, and where the partners differ systematically with regard to their prior knowledge or expertise. Communication between experts and laypersons is just a special type of such a setting. Interdisciplinary cooperation (e.g., Rummel & Spada, 2005) and heterogeneous learning groups, such as human tutoring (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001; VanLehn, Siler, Murray, Yamauchi, & Baggett, 2003), are other prominent examples. There are a growing number of online courses at universities and in further education (e.g., <http://www.uopxonline.com>; <http://www.vhb.org>), in which people with differing educational and professional backgrounds from almost everywhere can enrol and receive instruction. As the tutors and teachers in these courses usually have to provide instructional explanations for people they – at least initially – do not know, an assessment tool could provide valuable information in order to facilitate the task for tutors to adapt their explanations to the learners' knowledge level. In computer science, so-called *awareness tools* have been developed that attempt to support collaborative learning by providing the learners automatic feedback about their interaction process (see Jerman, Soller, & Muehlenbrock, 2001, for a review). Whereas these systems attempt to foster learning by supporting the learners' awareness of the process of collaboration, the assessment tool approach presented in this chapter aims to support learning by making the individual prerequisites of the collaborators, such as their knowledge background, accessible. Thus, in the context of online tutoring, an assessment tool could potentially be a valuable additional device that increases the tutor's awareness of an individual learner's knowledge level and supports adaptation at various stages of the tutoring process.

### **2.5.2 Experts' Adaptation Strategies, Study Limitations, and Suggestions for Further Research**

The purpose of the dialogue study reported in this chapter was to test different theoretical explanations of the assessment tool effect. The results showed that because the assessment tool fostered a specific adaptation to the layperson's knowledge, the communication between expert and layperson increased in effectiveness and efficiency. However, how the experts used the information about the layperson to produce adaptive explanations is less

clear. From Clark's theory of common ground follows that the less knowledge is shared by expert and layperson, the more context information would be needed by the layperson to comprehend an expert's message (cf. Clark, 1992; Clark & Carlson, 1981). Hence, it would be plausible to assume that the experts pursued a linear strategy to integrate the information displayed in the assessment tool into their way of writing explanations. For example, they might have reasoned that "the lower the layperson's knowledge level, the more concrete and extensive my explanations should be" in order to provide the layperson sufficient context for comprehension. These possibilities were explored by computing correlations of the layperson's knowledge level as indicated in the assessment tool with linguistic features of the experts' explanations, such as the extensiveness of the explanations, the number of examples, and the number of technical terms. The only substantial relation that was found was a correlation of  $r = -.32$ ,  $p < .05$ , indicating that the experts indeed used more extensive explanations the lower the layperson's knowledge level was. The result replicates a finding of Bromme and Nückles (2001) who found that computer experts wrote more extensive explanations for a beginner than for an advanced computer user. On the other hand, the correlation in the present experiment was rather low. It cannot help to fully understand the cognitive heuristics the computer experts used to adjust their explanations to the layperson's knowledge level. Thus, beyond the slight tendency to link explanatory extensiveness to the layperson's knowledge level, the experts apparently used the information displayed by the assessment tool to adjust their explanations in more sophisticated and individualised 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 layperson (so-called *pruning*, see Chin, 2000), or would have to be introduced in case it was not known. One can further speculate that the experts combined the information displayed by the assessment tool with the written feedback provided by the layperson in order to calibrate their mental model of the layperson's knowledge. To investigate such hypothetical strategies, follow-up studies would be needed. In particular, thinking-aloud protocols could help to reveal how the experts developed a qualitative represen-



tation of the layperson's knowledge from the quantitative information provided by the assessment tool, and how this qualitative representation was used to generate instructional explanations for the layperson.

Inasmuch as the experts' adaptation strategies represent one side of the coin, the laypersons' comprehension processes represent the other side. Therefore, it is equally important to investigate in more detail the laypersons' cognitive processes when they try to understand the explanations provided by the experts. Thinking-aloud protocols of the laypersons' comprehension processes could help to understand which features of the experts' explanations facilitated or hindered the layperson's acquisition of knowledge. Such an analysis could possibly allow for the identification of features that make an expert's explanation well adapted to a specific knowledge level. Results from these studies could be interesting not only for the design of advice-giving systems (e.g., Chin, 2000) but also for the design of adaptive learning environments, such as intelligent tutoring systems (e.g., Shute & Psocka, 1996).

Nonetheless, although it is not fully clear which adaptation strategies experts used and how the laypersons processed the experts' explanations, the approach to supporting asynchronous communication with an assessment tool has already proven to be successful. The assessment tool effect has been shown to be replicable across experiments (cf. Nückles & Stürz, in press). Furthermore, the present study revealed the crucial mechanism underlying the assessment tool effect: It can be concluded that the assessment tool supports a specific adaptation to a layperson's knowledge level and thereby improves communicative effectiveness and efficiency. These results are both of practical and of theoretical interest. They are of practical interest because consumer satisfaction in Internet-based helpdesk communication could be improved through the application of such a likewise economical and efficient support procedure (Bhattacharjee, 2001). The results are further of theoretical interest, first, because they provide insights into how the calibration of people's mental model about another person's knowledge can be supported, and secondly, because they show that experts can, despite their rich and highly interconnected specialist knowledge, successfully adapt their communication to a layperson's limited domain knowledge.

## CHAPTER 3

### **Effects of Experts’ Over- and Underestimations of Laypersons’ Knowledge on Communication**

Although communication with laypersons has become an integrated part of the professional competence of many experts (Candlin & Candlin, 2002; Nückles & Bromme, 2002), comparatively little is known about how experts share their knowledge with persons who have less expertise (Cramton, 2001; Hinds & Pfeffer, 2003). In the traditional expert-novice paradigm that highlights the differences between experts and novices in their organisation and application of knowledge (Chi, Feltovich, & Glaser, 1981; Simon & Chase, 1973), experts are merely construed as “lonely” problem solvers (Bromme, Nückles, & Rambow, 1999). Their knowledge base and skills under study are confined to the problem domain, that is, to a certain field of expertise, such as medicine (e.g., Rikers, Schmidt, & Boshuizen, 2002), physics (e.g., Larkin, 1981), geography (e.g., Anderson & Leinhardt, 2002), history (e.g., Wineburg, 1991), mathematics (e.g., Stylianou & Silver, 2004), or politics (e.g., Jones & Read, 2005). However, the requirements for experts to effectively convey their knowledge to others are not investigated.

In particular, the task of communicating with laypersons might be cognitively demanding for experts because it urges them to take into account the layperson’s completely different perspective (Bromme, Jucks, & Runde, 2005; Clark, 1992, 1996). Therefore, experts should have quite a precise idea of what a specific layperson does and does not know (Nickerson, 1999). Only on the basis of an accurate model of their communication partner can they provide intelligible information that meets the layperson’s individual needs (Clark & Murphy, 1982; Fussell & Krauss, 1992). Consequently, experts may run the risk of preventing comprehension when they arrive at erroneous assumptions about the layperson’s knowledge and give explanations that are only poorly adapted (Leinhardt, 2001). Consider, for example, a situation in which experts overestimate a layperson’s knowledge and produce explanations that are far too difficult and abstract to understand. As a result, the lay-

person might experience considerable comprehension problems, which interfere with learning. On the other hand, when underestimating a layperson’s abilities, experts might be prone to talk their communication partner down. That is, they provide information that is already known but instead miss, for example, including more elaborate content that may enrich the layperson’s understanding.

Do such erroneous assumptions about laypersons’ knowledge have a similar negative impact on their understanding and learning, regardless of whether laypersons are over- or underestimated by the experts? Or is there a differential effect on laypersons’ understanding as a function of the type of experts’ misjudgements, that is, are explanations that are too difficult with respect to the laypersons’ current level of knowledge more detrimental to their understanding than explanations that are relatively too easy? Moreover, when perceiving comprehension difficulties, can laypersons compensate for them by engaging in question-asking? This chapter is dedicated to provide answers to these questions. We conducted a dialogue experiment in which we examined how experts’ over- and underestimations of laypersons’ knowledge affected learning and understanding. Using an asynchronous computer helpdesk scenario, laypersons received written explanations from computer experts in order to learn fundamentals of computer and Internet technology. The experts were provided with a so-called assessment tool that displayed information about the layperson’s individual level of knowledge in the computer and Internet domain (see Figure 3.1). Experts were instructed to use this information to tailor their explanations to the layperson’s knowledge level. In one experimental condition, the assessment tool displayed valid information about the layperson’s knowledge. In the other two experimental conditions, the displayed information either overestimated or underestimated the layperson’s knowledge relative to the layperson’s true knowledge level. We analysed how the experimental induction of biased assumptions about the layperson’s knowledge affected the communication between experts and laypersons. More specifically, we investigated laypersons’ learning from experts’ explanations and how laypersons engaged in question-asking as a strategy to compensate for their perceived communication problems.

### 3.1 Experts' Estimations of What Laypersons Know

The prevailing view of many theories of language production is that an accurate model about the communication partner is an important prerequisite for effective communication (Barr & Keysar, 2002; Clark 1992, 1996; Clark & Murphy, 1982; Fussell & Krauss, 1992; Horton & Gerrig, 2002; Nickerson, 1999). This is particularly true when the topical knowledge between communication partners greatly differs, as is typically the case for communication between experts and laypersons (Isaacs & Clark, 1987; Pickering & Garrod, 2004; Schober, 1998; Schober & Brennan, 2003). Nevertheless, research so far has paid little attention to the particular effects on communication as a function of experts' estimations of what laypersons know (Hinds & Pfeffer, 2003). This is surprising given the growing body of literature that demonstrates the influences of people's prior knowledge on judgements about others' knowledge (for an overview, see Nickerson, 1999). There is ample empirical evidence that people, in general, are not very good at estimating others' knowledge. They usually tend to view themselves as representative for other people, and thus, impute their own knowledge to others (e.g., Birch & Bloom, 2003; Kelley & Jacoby, 1996; Ross, Greene, & House, 1977).

Accordingly, it might be expected that experts particularly are prone to overestimate a layperson's knowledge. The ready availability (Tversky & Kahneman, 1974) and interconnectedness of their rich knowledge base (Chi et al., 1981) might make it difficult for them to anticipate the limited domain knowledge of a layperson. In a study by Hinds (1999), technical experts who had intense experience in mobile telecommunications were asked to predict the time needed by novices to perform an unfamiliar complex task using a cellular telephone. Results showed that experts systematically overestimated how quickly novices would be able to complete the task. Hinds concluded that to the extent that experts acquired their expertise they began to abstract and simplify their understanding of the tasks. Therefore, the experts failed to recall the complexity of the tasks and how little they knew and how slowly they performed when they were novices. Hinds coined this phenomenon the *curse of expertise*. A related body of research in educational psychology con-

siders the accuracy of tutors' monitoring the understanding of students (Chi, Siler, & Jeong, 2004; Graesser, Person, & Magliano, 1995; Putnam, 1987). Tutors are often knowledgeable in a particular domain but have no formal training in the skills of tutoring (Cohen, Kulik, & Kulik, 1982). In this respect, they are comparable with domain experts who have no didactic expertise, but provide instructions outside educational contexts. For example, Chi et al. (2004) analysed how accurately tutors assessed the extent to which students showed a scientifically correct understanding of biological issues. They found that tutors inflated their judgement toward assuming that students had more complete understanding than they actually did. Hence, tutors overestimated the students' knowledge because they monitored students' understanding from their own perspective instead from the perspective of the students. However, not only experts or tutors with high content knowledge, but even teachers who also possess pedagogical knowledge, that is, knowledge about methods for assessing students' understanding and effective teaching (Borko & Putnam, 1996), may be caught by the *curse of expertise*. Nathan and Koedinger (2000) found that high-school teachers with advanced mathematics education overestimated the accessibility of symbol-based representations for students who were learning introductory algebra. Thus, their judgements of learner difficulty were mainly affected by their own view of student mathematical development, wherein symbolic problem-solving was learned prior to verbal reasoning (see also Nathan & Petrosino, 2003).

Although it seems intuitive that experts, due to their rich domain knowledge, are more likely to overestimate what laypersons know, one may also picture situations in which experts tend to underestimations of laypersons' knowledge. The increasing diversity of skills and abilities laypersons have in our knowledge-based society, ranging from very inexpert to more advanced laypersons, might make it difficult for experts to take into account all the different levels of knowledge laypersons may possess (Maranta, Guggenheim, Gisler, & Pohl, 2003). In particular, when experts are aware of their status as an expert, they may perceive the exclusiveness of their knowledge as a feature that distinguishes them from the community of laypersons. Accordingly, experts may tend to underestimate the communality of specialist knowledge among laypersons. In line with this assumption,

Bromme, Rambow, and Nückles (2001) found that computer experts, as compared with laypersons, generally produced more cautious estimates concerning the commonality of specialist terms from the computer domain among laypersons. When specialist terms were considered that were known by the majority of laypersons, experts, in contrast to laypersons, clearly underestimated laypersons' knowledgeability of these concepts.

Overall, the reported studies provide evidence that experts may be prone to over- as well as underestimations of laypersons' knowledge. However, the particular consequences of such miscalculations for communication and learning have not yet been studied experimentally. Nonetheless, some studies found that experts might have difficulties providing explanations to laypersons at an appropriate level, suggesting experts' inclination to over- and underestimate what laypersons actually know. For example, in the experiment by Hinds, Patterson, and Pfeffer (2001), experts' explanations addressed to a lay audience were more advanced, abstract, and less concrete than those provided by persons with less expertise. As a result, laypersons had considerably more problems in understanding the instructions given by experts. Contrary, Alty and Coombs (1981) who conducted a detailed conversation analysis of face-to-face advisory dialogues collected at diverse computer support services found that experts often included redundant information in their explanations, or paraphrased the same content several times, without noticing that it was already understood by the layperson (see also Erickson & Shultz, 1982). Although these findings demonstrate the weaknesses in experts' ability to provide explanations that meet the laypersons' needs, they do not allow, in a strict sense, for conclusions regarding the accuracy of experts' assumptions about laypersons' knowledge (Fussell & Krauss, 1992). For example, experts might deliberately express themselves in an incomprehensible manner to demonstrate the exclusiveness of their knowledge, or their rhetorical skills are insufficient for translating their writing plans into a well-designed text (Bromme et al., 1999).

However, if experts' over- and underestimations of laypersons' knowledge were indeed a major source of miscommunication, erroneous beliefs should cause serious consequences particularly in computer-mediated communication. When experts give advice via the Internet (e.g., in e-services for computer or medical advice), they are in a relatively

anonymous setting with only little information about a layperson available (Dilts & Lyth, 2000). Because netbased communication through helpdesks is usually text-based and asynchronous, the possibilities for social interaction are seriously restricted. The expert and layperson cannot see nor hear one another, and the limited feedback in computer-mediated communication (Clark & Brennan, 1991) provides less opportunity for an extensive dialogue allowing for follow-up questions and additional explanations. Hence, due to the limited feedback, less information is available that experts could use to form a model of their communication partner. Accordingly, they must rely more heavily on their prior assumptions about the layperson’s knowledge (Bromme et al., 2001). At the same time, however, biased assumptions about another person’s knowledge have lower chances of being recognised and corrected when feedback is more restricted (Clark & Brennan). Therefore, in case experts arrive at false assumptions about a layperson’s informational needs, such assumptions might result in considerable communication problems (Fussell & Krauss, 1992; Nickerson, 1999).

## **3.2 Research Questions and Predictions**

The current study aimed to highlight the impact of experts’ erroneous assumptions about laypersons’ knowledge on computer-mediated communication. To this purpose, laypersons’ learning from experts’ explanations was investigated as well as how laypersons self-regulated potential comprehension difficulties through question-asking. In order to examine the effects of experts’ over- and underestimations on communication, experts’ biased assumptions were experimentally induced. This was done by providing them with invalid information about the layperson’s individual level of knowledge (for details, see Methods section).

### **3.2.1 Knowledge Gain Hypothesis**

Providing experts with valid information about a layperson’s knowledge should result in explanations that were well adapted to the laypersons’ knowledge level. Consequently, their learning should be facilitated. Conversely, providing experts with biased knowledge

information should lead to suboptimal explanations that were only poorly adjusted to the laypersons’ needs. Accordingly, learning should be impaired regardless of whether the laypersons’ knowledge was over- or underestimated. Hence, it was predicted that laypersons should benefit less from the experts’ explanations, as compared with laypersons who received explanations from experts provided with valid information.

### **3.2.2 Question-Asking Hypothesis**

At the same time, both over- and underestimated laypersons should experience a greater discrepancy between the information presented and their own communicational needs (cf. Graesser & McMahan, 1993). This should provoke them to write back to the expert and ask for clarifications or further information more often. In contrast, valid information about the layperson’s knowledge level should help the experts to better adapt their explanations to the layperson’s knowledge. Consequently, the layperson should be more contented and therefore return fewer questions to the expert. Accordingly, it was predicted that laypersons would ask substantially more questions when experts had biased information available, as compared with laypersons who were advised by experts who had valid information.

#### ***Comprehension Question Hypothesis***

Depending on whether laypersons were over- or underestimated, they should ask different types of questions. Experts who were provided with information biased towards overestimation of the layperson’s knowledge should produce explanations that were too complex and difficult to understand. As a result, laypersons should have problems encoding unknown words or adequately representing the semantic structure of experts’ explanations in order to achieve a deep understanding (Kintsch, 1998; Otero & Graesser, 2001). Accordingly, it was predicted that laypersons whose prior knowledge level was overestimated would ask more comprehension questions that were specifically related to the words and statements produced by the experts, as compared with laypersons advised by experts with valid information or information biased towards underestimation.



### ***Information-Seeking Question Hypothesis***

In contrast, providing experts with underestimations of a layperson’s knowledge should result in rather simple explanations, which were not very informative to the layperson. The laypersons might have little problems comprehending the content of these explanations. On the other hand, they would offer the laypersons little opportunity to deepen and extend their understanding, that is, to enrich their mental model of the computer issues with new information (Kintsch, 1998). Hence, laypersons whose knowledge was underestimated should ask more often for additional information not previously stated in the explanations, as compared with laypersons who received explanations from experts with valid information or information biased towards overestimation.

### **3.2.3 Technical Language Hypothesis**

Apart from the predictions concerning the impact of the experts’ assumptions on laypersons’ learning and question-asking, we also analysed the experts’ explanations to the laypersons’ inquiries. Although the main focus of this study was on the laypersons’ learning and question-asking behaviour, the analysis of the experts’ explanations allowed us to explore, at a linguistic level, how the experts used the knowledge information in the assessment tool to design their explanations for the laypersons. To assess the experts’ audience design (Clark & Murphy, 1982), that is, the way experts constructed their explanations with the intention of being understood by the particular layperson, we analysed the technical terms used by the experts (cf. Bromme, Jucks, & Runde, 2005). If experts took into account the knowledge information about the laypersons – as it was indicated by the assessment tool – to tailor their instructions, this should influence their use of technical terms. When the laypersons’ knowledge was overestimated, the experts’ explanations should contain the most technical terms. In contrast, when the laypersons’ knowledge was underestimated, the experts should use – in the interest of being as clear as possible – the fewest technical terms.

### 3.3 Method

#### 3.3.1 Participants

Forty-five computer experts and 45 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 22.50 years ( $SD = 2.07$ ). 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 interested in the Internet, the students of computer science responded with a mean of 6.78 years ( $SD = 2.06$ ). They reported that on average, they would spend 29.23 hours per week working on the Internet ( $SD = 18.22$ ), which is a large amount of time. When asked to rate their Internet skills on a 5-point rating-scale ranging from 1 (= *very inexperienced*) to 5 (= *very experienced*), a mean of 4.27 ( $SD = 0.69$ ) resulted. All in all, these values pointed out sufficiently high Internet expertise with regard to the purposes 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 3.68 ( $SD = 0.83$ ). Hence, the computer experts in this experiment apparently counselled other computer users rather frequently.

The 45 participants serving as laypersons were recruited among students of psychology and of the humanities. They received 15 EURO as compensation for their participation. The somewhat larger amount of money was justified by the extended knowledge tests the laypersons were administered in addition to the communication phase of the experiment. The laypersons’ mean age was 23.60 years ( $SD = 5.65$ ). On average, the students reported that they had been using the Internet for 2.95 years ( $SD = 2.27$ ), and they would spend about 3.29 hours per week working on the Internet ( $SD = 2.74$ ). In rating Internet skills, a mean of 2.71 resulted ( $SD = 0.69$ ). A MANOVA with years of Internet usage, hours of Internet usage per week as well as self-rated Internet skills as dependent measures and participants (expert vs. layperson) as the independent factor showed that laypersons’

Internet expertise was clearly lower than the Internet expertise reported by the experts,  $F(3, 86) = 60.34, p = .001, \eta^2 = .68$  (strong effect).

It was ensured that all students serving as laypersons in the experiment had only a moderately low level of prior knowledge in the computer and Internet domain. This was necessary in order to establish systematic over- and underestimations of laypersons’ knowledge. Moreover, the preselection of laypersons allowed us to control for potential effects of prior knowledge on question-asking. Research has shown that the amount and the quality of the questions people ask typically depend on the knowledge they have in a certain domain (e.g., Otero & Graesser, 2001). In order to determine the laypersons’ prior knowledge in the computer and Internet domain, a standardised knowledge test was administered. The test was based on a multiple-choice test by Richter, Naumann, and Groeben (2000) that was specifically constructed to differentiate among people who are laypersons in this domain. Thus, even someone with high scores on this knowledge test would still have substantially less knowledge than a computer expert. The test consisted of 24 multiple choice items, with 12 items representing the computer knowledge scale and 12 items representing the Internet knowledge scale. Only those laypersons participated in the experiment who correctly solved at least 5 but no more than 8 items on each scale. This range of solved items on each scale was defined as a layperson’s medium knowledge level. Students whose number of correctly solved items was outside this range were not eligible to participate. Accordingly, there were no significant differences in laypersons’ computer and Internet knowledge between the experimental conditions,  $F(2, 42) = 1.76, ns$  (computer knowledge),  $F(2, 42) = 1.72, ns$  (Internet knowledge).

### 3.3.2 Design

For the experiment, computer experts and laypersons were combined into pairs that were randomly assigned to the experimental conditions. A one-factorial between-subject design was used with *assessment tool* as the independent variable comprising three different conditions: (a) communication with an assessment tool displaying valid information about the layperson’s knowledge (in the following labelled *valid data condition*), (b) communication

with an assessment tool displaying information that was biased towards overestimation of the laypersons’ knowledge (*overestimation condition*), and (c) communication with an assessment tool displaying information that was biased towards underestimation of the laypersons’ knowledge (*underestimation condition*). Dependent variables encompassed measures of laypersons’ knowledge gain and question-asking. The layperson’s knowledge gain referred to the increase in knowledge through the dialogue with the computer expert. Their question-asking was operationalised by the number of follow-up questions laypersons returned in response to the expert’s explanations. The follow-up questions were categorised either as comprehension questions or information-seeking questions. A further dependent variable referred to the design of the experts’ answers, that is, their use of technical terms.

### 3.3.3 Materials

#### *The Assessment Tool*

The assessment tool provided the computer experts both with ratings of the laypersons’ general computer knowledge and their Internet knowledge (see Figure 3.1). For each rating, the laypersons’ individual knowledge was displayed on a 6-point scale in the assessment tool, ranging from a *very low* to a *very high* knowledge level. The values displayed in the assessment tool were determined through the computer and Internet knowledge test mentioned before (see Participants section above).

In the valid data condition, the number of items that a layperson solved correctly in the general computer knowledge subtest and in the Internet knowledge subtest was translated into values on the scales in the assessment tool. This was done by dividing the raw score a layperson achieved in each subtest by 2 and indicating the resulting score on the corresponding scale in the assessment tool. For example, if a layperson solved 6 out of the 12 items of the Internet knowledge subtest, this was indicated as a *rather low* Internet knowledge level.

In the biased estimation conditions, over- and underestimations were produced by adding or subtracting, respectively, two points on each scale from the laypersons’ actual

knowledge level. For example, if a layperson actually had a *rather low* knowledge level on the computer knowledge scale, this was indicated as a *very low* knowledge level in the underestimation condition, and as a *high* knowledge level in the overestimation condition.

**Assessment Tool**

**Computer knowledge**  
My knowledge about computers is    very low    low    rather low    **rather high**    high    very high

**Internet knowledge**  
My knowledge about the Internet is    very low    low    rather low    **rather high**    high    very high

**Dialog with client:**

**Counselor's answer:**  
Yes, exactly, a browser transforms these commands into corresponding signs and pictorial representations.

**New Client Inquiry:**  
I'm running Internet Explorer 6. Sometimes when I visit websites I get the following alert 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. Therefore, the default security level for this zone is "Medium", which prohibits running sites containing Active X controls. Active X is a feature of the Internet Explorer, a method of installing software on your computer which can install terms or software modifications over the Internet. Active X was developed for the purpose of

SEND    DELETE

Figure 3.1. Screenshot of the assessment tool as it was available to the computer expert in all three experimental conditions.

### *Inquiries Asked by the Laypersons*

In order to initiate the dialogue with the experts in the communication phase of the experiment, laypersons received six prepared inquiries that they directed one after another to the experts. The inquiries demanded explanations of relevant Internet topics and problems. They were chosen from a pool of 20 inquiries that were constructed and pretested in a preliminary analysis. Three inquiries required the computer expert to explain a technical concept. The other three were more complex. They asked the expert to instruct the layperson how to solve a problem and, additionally, to provide an explanation why the problem occurred in order to help the layperson understand the nature of the problem. The wording of the inquiries was standardised to make the initiation phase of the expert-layperson dialogues comparable across participants and above all, across experimental groups. Each

inquiry was accompanied by one or two additional sentences that provided some background context for the embedded question and thus helped the expert to understand the broader intention of the inquiry. Table 3.1 shows the six inquiries that were used in the experiment.

Table 3.1. *Inquiries laypersons directed to the experts in the experiment*

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With regard to the Internet I have often read the term ‘FTP server’. Could you please explain the notion of a FTP server to me in more detail?
Recently I visited a website that told me to wait while ‘Flash is loading’. Could you please tell me what exactly the difference between HTML and Flash is?
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’?
I’m running Internet Explorer 6. Sometimes, when I visit websites I get the following alert 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 I can get rid of the problem.
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.
I’m running Internet Explorer 6. Whenever I want 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.

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### ***Pre- and Posttest on Laypersons’ Knowledge About the Inquiries***

Laypersons’ knowledge about the inquiries discussed in the communication phase was assessed using a written description measure. Laypersons were asked to try to answer each of the six inquiries before and after the communication phase. Their written answers were scored for correctness and completeness on a 4-point scale, ranging from 0 to 3 points. All points achieved were summed up across the answers to the six inquiries. The maximum score to be obtained was 18 points. Generally, laypersons had no substantial knowledge about the inquiries prior to the communication. On average, they only obtained 0.97 out of

18 points ( $SD = 1.59$ ) There were no significant differences between the experimental conditions,  $F(2, 42) = 1.29, ns$ .

### 3.3.4 Procedure

The pairs 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.

*Pre-test phase.* At the beginning of the pre-test phase, the students serving as laypersons were asked to complete the computer and Internet knowledge test. After completion, the experimenters analysed the tests in a separate room, where they subsequently entered the results into the assessment tool form (see Assessment Tool section before). After the assessment of the layperson’s general level of computer and Internet knowledge, the layperson’s prior knowledge with regard to the six inquiries to be discussed in the communication phase was determined. Accordingly, the laypersons were encouraged to try to answer each of the inquiries, if possible.

*Communication phase.* In the communication phase, the computer expert and the layperson sat in different rooms and communicated through a text-based interface, which could be accessed by means of the browser. The layperson’s task was to sequentially direct each one of the six inquiries (cf. Table 3.1) to the expert by typing the prepared wording of the inquiry into the text form of the interface. The sequence of the inquiries was randomised individually for each dyad of expert and layperson. The expert was asked to answer each inquiry as well as possible. The laypersons were free to write back and ask as many follow-up questions as needed or wanted. When both communication partners felt that an inquiry had been answered to a satisfactory degree, they could continue on to the next inquiry.

In all three experimental conditions, the assessment tool with information about the laypersons’ knowledge was incorporated into the interface and visible on the experts’ screen. The assessment tool was located in the upper part of the screen (see Figure 3.1). Experts were informed that the layperson’s knowledge had been determined in advance

and that they should try to bear in mind the information when answering the layperson’s inquiries. In the lower left part of the screen, the layperson’s inquiry was presented to the expert and on the right side there was a separate text box for the expert to type in their answer. Communication was asynchronous like in electronic mail because a written message did not become automatically visible on the partner’s screen, but was announced by an alert window. In order to view the message, the participant had to press the ‘OK’-button in this window. Note that the asynchronous, written communication prevented the experts and laypersons from communicating nonverbally. As research has shown, gaze direction, gestures, and facial expressions communicate significant information communication partners can use to derive assumptions about the other’s cognitive and motivational state (e.g., Fox, 1993). Hence, in the experiment, the only information about the laypersons the experts had available and they could use to customise their instructional explanations was the knowledge data presented in the assessment tool.

*Post-test phase.* After the communication phase, the laypersons were again asked to write down, as well as possible, how they would answer each of the six inquiries. In this way, it was possible to compute 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.

### **3.3.5 Analysis and Coding**

#### ***Laypersons’ Questions***

The recorded dialogues between experts and laypersons were analysed for all follow-up questions laypersons asked in response to an expert’s explanation. The questions were assigned to one of the following two question categories:

- 1) *Comprehension questions.* This category was scored when the question addressed comprehension problems specifically related to particular words or statements produced by the experts. For example, an expert explained the technical concept ‘Secure Shell’ and used the terms ‘command line’ and ‘UNIX’ for illustration. The layperson asked in response to the expert’s explanation: “What does it mean to execute a com-



mand line in UNIX?”. Hence, these questions sought information necessary to develop an adequate textbase or situation model from the expert’s explanations (cf. Otero & Graesser, 2001).

- 2) *Information-seeking questions.* This category referred to questions that required experts to provide laypersons with additional or new information that was not previously stated in the experts’ explanations. For example, an expert explained the basic differences between the Internet protocols HTTP and FTP. The layperson expressed the need for further information by asking: “What are the advantages of FTP over HTTP?”. Thus, these questions aimed at adding new or more elaborate information to the layperson’s already existing situation model (cf. Otero & Graesser, 2001).

Two independent judges counted and coded all laypersons’ follow-up questions. They were blind to the experimental conditions. In the cases of disagreement between the two judges, the final coding was determined through discussion. Inter-rater agreement was very good ( $\kappa = 0.91$ , cf. Fleiss, 1981).

### ***Technical Language of Experts’ Explanations***

In order to analyse the experts’ use of technical language, we coded the experts’ explanations for technical terms. This linguistic measure has been shown to be a sensitive indicator for the experts’ audience design in communication with laypersons (Bromme et al., 2005). In this study, technical terms were used by experts, for example, as part of a definition (e.g., “HTML is a programming language”), to instantiate a superordinate category (e.g., “a common browser software is Mozilla”), or to introduce subordinate concepts (e.g., “movies are part of Flash animations”). For the analysis, a list was made containing all the technical terms produced by the experts. Only those expressions were coded as technical terms that were listed in the computer glossary of the book *Computerlexikon* (Schulze, 2003). However, computer terms listed in the glossary that have already become everyday terms (e.g., mouse, computer screen) were not coded as technical terms. To identify the technical terms experts used in their answers to the laypersons’ questions, two judges

coded all explanations. They were blind to the experimental conditions. A total of 264 technical terms resulted. Inter-rater agreement was excellent ( $\kappa = 0.99$ , cf. Fleiss, 1981).

### **3.4 Results**

In this study, an alpha level of .05 was used for all statistical tests.

#### **3.4.1 Laypersons’ Knowledge Gain**

In order to examine laypersons’ knowledge gain, their learning from the experts’ explanations was analysed. To this purpose, the mean scores of their answers to the six inquiries prior to the communication phase were subtracted from the corresponding mean scores after the communication phase.

Following the knowledge gain hypothesis, in those conditions where the experts were presented biased information, the laypersons should acquire less knowledge than the laypersons in the valid data condition. This prediction was represented by the following contrast: valid data condition: 1, overestimation condition:  $-0.5$ , underestimation condition:  $-0.5$ . The results of the contrast analysis supported this prediction,  $F(1, 42) = 4.83$ ,  $p = .03$ ,  $\eta^2 = .10$  (medium to strong effect). Table 3.2 shows the mean values of the laypersons’ increase in knowledge. As predicted, the largest knowledge gain occurred in the valid data condition, whereas in both conditions in which the laypersons’ knowledge was over- or underestimated, their knowledge acquisition was impaired.

#### **3.4.2 Laypersons’ Questions**

To analyse how the information about the laypersons’ knowledge level affected their question-asking, the total number of follow-up questions a layperson produced in response to the expert’s explanations was counted. Following the question-asking hypothesis, laypersons should ask more questions in response to an expert’s explanation if the expert had biased information about the layperson’s knowledge level than if the information was valid. This prediction was represented by the following contrast: valid data condition: 1, overestimation condition:  $-0.5$ , underestimation condition:  $-0.5$ . The results confirmed the

question-asking hypothesis,  $F(1, 42) = 5.86$ ,  $p = 0.02$ ,  $\eta^2 = .12$  (strong effect). As Table 3.2 shows, laypersons directed significantly more questions to the experts when their knowledge was over- or underestimated compared with the number of laypersons’ questions in the valid data condition. The laypersons in the biased estimation conditions returned at least twice as often questions to their expert advisors than the laypersons in the valid data condition.

Table 3.2. Means and standard deviations (in parentheses) of the experiment’s dependent variables

Dependent variable	Experimental condition		
	Valid data condition	Overestimation condition	Underestimation condition
Mean difference of the laypersons’ increase in knowledge	8.47 (3.54)	6.23 (2.69)	6.37 (3.06)
Total number of follow-up questions during the expert-layperson exchange	1.40 (1.12)	3.80 (3.47)	2.87 (2.42)
Number of comprehension questions during the expert-layperson exchange	0.67 (0.82)	2.40 (2.47)	0.87 (1.19)
Number of information-seeking questions during the expert-layperson exchange	0.73 (2.51)	1.40 (2.20)	2.00 (1.77)
Number of technical terms in the experts’ explanations	15.60 (7.21)	19.87 (13.19)	11.13 (6.01)

### ***Types of Questions Asked by the Laypersons***

To examine the differential impact on question-asking as a function of experts’ over- and underestimations of laypersons’ knowledge, we distinguished between comprehension questions and information-seeking questions. This analysis should reveal if laypersons, depending on whether their knowledge was over- or underestimated, asked different types

of questions in order to compensate for their perceived difficulties with the experts’ explanations.

Following the comprehension question hypothesis, laypersons whose knowledge was overestimated should ask more comprehension questions than the laypersons in the valid data condition or underestimation condition. This prediction was represented by the following contrast: valid data condition:  $-0.5$ , overestimation condition:  $1$ , underestimation condition:  $-0.5$ . The results of the contrast analysis clearly supported this prediction,  $F(1, 42) = 9.77$ ,  $p = .003$ ,  $\eta^2 = .19$  (strong effect). Laypersons in the overestimation condition produced more than twice as many comprehension questions as laypersons in the other experimental conditions (see Table 3.2).

Following the information-seeking question hypothesis, laypersons whose knowledge level was underestimated should produce more information-seeking questions, that is, questions that demanded additional information, than the laypersons in the valid data condition or overestimation condition. Accordingly, a planned contrast with the following weights was computed: valid data condition:  $-0.5$ , overestimation condition:  $-0.5$ , underestimation condition:  $1$ . This contrast, however, just failed statistical significance,  $F(1, 42) = 3.20$ ,  $p = .08$ ,  $\eta^2 = .07$  (medium effect). Table 3.2 shows that – as predicted – information-seeking questions occurred most frequently in the underestimation condition. However, despite their comprehension problems, laypersons whose knowledge was overestimated also asked the experts for further information.

### **3.4.3 Technical Language of the Experts’ Explanations**

In addition to the analyses of laypersons’ learning and question-asking, we examined the technical language of the experts’ explanations to the six inquiries. This analysis allowed us to test how the assessment tool influenced the expert’s design of their explanations as a function of the validity of the knowledge information presented. To this purpose, the technical terms used by the experts were counted and summed up across the explanations to the laypersons’ questions. Following the technical language hypothesis, laypersons whose knowledge level was underestimated should receive explanations that contained the fewest

technical terms. In contrast, experts in the overestimation condition should produce the most technical explanations. This prediction was represented by the following contrast: valid data condition: 0, overestimation condition: 0.5, underestimation condition: -0.5. The results confirmed the technical language hypothesis,  $F(1, 42) = 6.54$ ,  $p = .01$ ,  $\eta^2 = .14$  (strong effect). As Table 3.2 shows, the experts’ explanations produced for laypersons whose knowledge was overestimated contained substantially more technical terms than those explanations addressed to laypersons in the underestimation condition.

### 3.5 Discussion

This study showed that the accuracy of information about a layperson’s knowledge was important for communication to be effective. When experts had valid information about laypersons’ domain knowledge, laypersons asked the fewest questions and acquired the most knowledge. In contrast, when experts were provided with biased information, the laypersons profited less from the explanations. Regardless of whether the laypersons were over- or underestimated, their knowledge acquisition was impaired to a similar extent, and they asked significantly more questions. In addition, we also found an influence of the knowledge information on how the experts designed their explanations. The use of technical terms was highest when the laypersons’ knowledge was overestimated. Conversely, experts reduced their use of technical language for advice-giving when laypersons were underestimated. This predicted pattern of results was obtained although the induced estimation biases were rather discreet in order to prevent the experts from becoming suspicious: For example, if a layperson’s real computer knowledge level was *rather low*, this was indicated in the assessment tool as a *very low* level.

Apart from this, the dialogue experiment also gave insights into the differences in laypersons’ question-asking behaviour as a function of experts’ over- and underestimations. When the laypersons’ knowledge was overestimated, the experts’ explanations substantially raised the number of comprehension questions asked. Conversely, laypersons whose computer knowledge was underestimated asked very few comprehension questions, indicating that the explanations they received from the experts apparently caused very little

trouble in understanding. At the same time, the number of information-seeking questions was highest in the underestimation condition. This suggests that the experts' explanations were apparently less than optimally informative for the laypersons in this condition. However, with regard to laypersons' information-seeking, our empirical results are less clear because contrary to our expectations there were also a substantial number of information-seeking questions in the overestimation condition. Obviously, laypersons whose knowledge was overestimated not only sought to resolve their comprehension problems but also demanded additional information to enrich and extend their understanding of the topic. One may speculate that non-cognitive variables played an important role in the laypersons' behaviour. It is possible that laypersons in the overestimation condition received slightly too complex and demanding explanations causing comprehension problems. On the other hand, the laypersons nevertheless might have perceived these explanations as stimulating, which could explain the higher number of information-seeking questions as compared with the valid data condition. Further research is needed to clarify this issue.

Nonetheless, although the laypersons in the biased estimation conditions obviously experienced different communication problems and engaged in different types of questions to compensate for these problems, they were not fully able to overcome their perceived difficulties. Despite the increased incidence of laypersons' questions in the biased estimation conditions, they acquired less knowledge than the laypersons in the valid data condition. Different factors could contribute to explaining this result. Given the overall low frequency of questions asked by laypersons, one might assume that laypersons did not sufficiently engage in question-asking behaviour to compensate for their knowledge deficits. Remember that the laypersons were free to ask follow-up questions and not instructed to do so. Under these self-regulated conditions, combined with the high costs of message production in netbased settings, that is, typing the questions on a keyboard (Clark & Brennan, 1991), laypersons might have put generally less effort in question-asking, although this would have been beneficial to them (cf. Graesser & McMahan, 1993). Additionally, it is possible that laypersons exhibited rather poor metacognitive behaviour and settled for monitoring only the surface code of the experts' explanations (e.g., the technical terms

used; Otero & Graesser, 2001). To address these issues, further studies are needed in which laypersons’ comprehension processes are explored in more detail through think-aloud protocols.

The fact that experts’ explanations for laypersons who were underestimated were similarly detrimental to learning as explanations composed for laypersons who were overestimated might seem, at first glance, somewhat counterintuitive. It could be argued that providing simple and understandable information may not necessarily impair learning because explanations that are made easy to read and comprehend should have no substantial negative effects. Indeed, the laypersons in the underestimation condition did learn from the experts’ explanations. Nonetheless, the experts obviously did not provide enough new information to help the laypersons expand their already existing understanding to a similar extent as was possible for the laypersons in the valid data condition. This indicates that global and undifferentiated strategies such as “keep it simple, stupid” are not always beneficial. As our findings suggest, such oversimplified explanations might be even as detrimental to learning as was the provision of explanations that were too difficult and complex for the laypersons. Hence, in order to facilitate understanding and learning in an optimal fashion, one should adjust the level of complexity and informativeness of one’s explanations in accordance with the layperson’s knowledge prerequisites. Interestingly, this is in line with results found in research on text revision. This research deals with the question of how to make instructional texts more understandable with respect to a learner’s current level of understanding in order to facilitate learning. Typically, readers with different levels of prior knowledge are presented with texts that are systematically varied in their level of difficulty (e.g., McNamara, Kintsch, Songer, & Kintsch, 1996). As a main result, these studies usually find that the match between the background knowledge of readers and the difficulty of text information is crucial for learning (e.g., Voss & Silfies, 1996; Wolfe et al., 1998). Readers whose prior knowledge does not overlap enough with the information provided by a text often lack a deep understanding of the content. Equally, when readers’ knowledge overlaps too much with the text content, their learning is also impaired. Thus, from these studies – in accordance with the present study – it can be concluded that only

those texts or explanations are optimal for learning that provide the learners with the opportunity to link the text content with their prior knowledge, but still contain enough new information to extend their already existing knowledge. The results of the present dialogue experiment extend the findings of the text revision studies to computer-based communication settings where learners (i.e., the laypersons) acquire knowledge through reading their communication partner's (i.e., the expert's) written explanations. Hence, they demonstrate that the detrimental impact of instructional texts that are not adjusted to a learner's knowledge not only occur in monological settings, as investigated in the traditional text revision studies, but can be also found in interactive instructional settings. In addition to the text revision studies, however, the present findings also show that the negative effects of poorly adapted explanations do persist even when learners can take an active role in self-regulating their understanding, for example, through question-asking.

More broadly, the findings of the current study could also be suggestive for other instructional settings where people greatly differ in the extent to which they have knowledge about a domain. For example, in human tutoring, there is evidence that tutor-generated explanations often do not support students' learning (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001; VanLehn, Siler, Murray, Yamauchi, & Baggett, 2003). One might speculate that students' problems in learning from tutor explanations also result from tutors' miscalculations of what a student actually knows, as was outlined at the beginning of the chapter (Chi et al., 2004). Like domain experts, tutors might lack the ability to correctly diagnose a learner's needs and to customise their instructional explanations accordingly. This might have particularly negative effects when the content being taught is completely unfamiliar to learners, and learning cannot be successfully accomplished by engaging in other, more self-guided learning activities such as generating self-explanations (Chi et al., 2001; Merrill, Reiser, Merrill, & Landes, 1995). In these cases, explanations that do not meet the learner's individual needs might lead to considerable comprehension breakdowns and cause frustration on the part of the learner. Therefore, it seems of particular importance to support tutors' adaptation to the learner's needs. As the present study suggests, provid-



ing tutors with explicit information about a learner’s current knowledge level might be a good starting point to improve human tutoring, at least in computer-mediated contexts.

## CHAPTER 4

### Experts' Planning Processes and Adaptation Strategies in Communication With Laypersons

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 & 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 & Kahneman, 1974) and inter-connectedness of the experts' knowledge (Chi, Glaser, & Farr, 1988) may interfere with the task of taking into account the limited knowledge of a layperson.

Inasmuch 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. Wittwer, Nückles, and Renkl (2004) tested this hypothesis using an asynchronous computer helpdesk scenario. In their experimental study (see also chapter 2), computer experts answered inquiries of laypersons via an asynchronous communication interface. In preparing their explanations, the experts were either presented valid information about the layperson's computer knowledge, no information, or distorted information. Wittwer et al. found that the laypersons learned the most and asked the fewest questions, when the computer expert was presented valid data about the layper-

son's knowledge level. When the information about the layperson was distorted, the laypersons learned the least and asked the most questions. Wittwer 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, Wittwer et al. successfully replicated and extended the results of a previous experiment (Nückles & Stürz, in press).

In the following, the term *layperson* is used to refer to people with varying levels of knowledge in the computer and Internet domain clearly below the expert level. We prefer to use the term *layperson* instead of *novice* because a novice is typically someone who wants to become an expert in a certain domain of expertise. In our context, laypersons seek advice from a computer expert in order to better understand a concrete computer problem and to extend their knowledge (Nückles & Stürz, in press). However, in doing so, laypersons usually do not intend to become a computer expert, although their aim is to better understand or to use the computer more effectively (see also Patel, Arocha, & Kaufman, 1999, who proposed a similar distinction between novice and layperson). 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 jobs.

The studies of Wittwer et al. (2004) and of Nückles and Stürz (in press) 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 & Flower, 1980; Hayes & Nash, 1996)? How did they tailor their explanations to the individual knowledge prerequisites and informational needs of their lay audience (Clark & Murphy, 1982; Nückles & 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 analysed using thinking-aloud protocols (Ericsson & Simon, 1993; Janssen, van Waes, & van den Bergh, 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 are both of theoretical and practical interest. They are of theoretical interest 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, Rambow, & Nückles, 2001; Nückles & 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 & Smith, 1991; Hoffmann, 1992; Rikers, Schmidt, & Boshuizen, 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, Nückles, & Rambow, 1999).

The results of this study could also be of practical interest for the development of computer systems that use personalisation techniques to improve the quality of web-based information services (e.g., online help or advice-giving systems). Normally, such systems acquire data about a specific user (e.g., knowledge, interests, preferences) in order to tailor the content of information to a user's particular needs (for example, additional explanations for very inexpert users, Boyle & Encarnacion, 1994). However, although such adaptation strategies are frequently employed in computer systems (for an overview, see Brusilovsky, 2001; Kobsa, Koenemann, & Pohl, 2001), 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, Karat, Karat, Brodie, & Vergo, 2003; du Boulay & Luckin, 2001). Thus, the results of the present study could be

promising for developing and improving automated personalisation techniques, particularly those used in advice-giving systems.

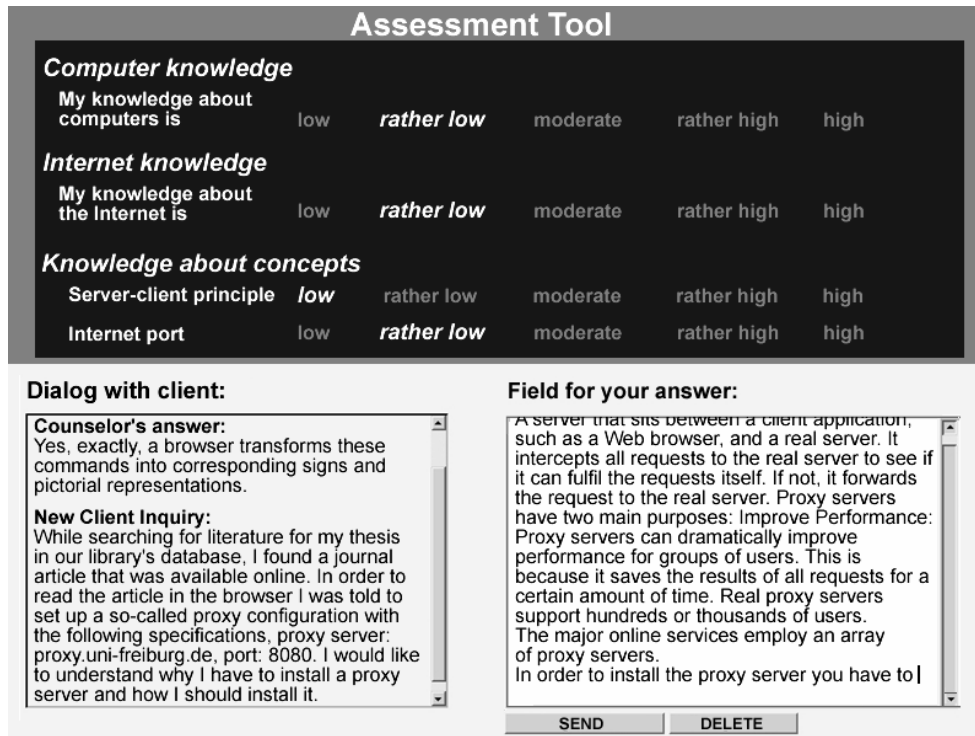


Figure 4.1. Screenshot of the assessment tool as it was available to the computer expert in the experimental condition with the assessment tool.

For the present study of experts' cognitive processes and message design, the same asynchronous computer helpdesk scenario was used that had previously been employed by Wittwer et al. (2004). Again, the scenario required computer experts to compose instructional explanations of diverse computer and Internet issues in response to inquiries 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 4.1). 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.

## **4.1 Experts' Planning and Translating of Answers to Laypersons' Inquiries**

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 type of writing activity. The costs of message production are higher than in verbal communication because every message has to be typed on a keyboard (Clark & 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 & Brennan). Thus, asynchronous communication allows for the careful planning of a message before it is sent. There is time to reflect about a communication partner's background knowledge and communicational needs.

Inasmuch as asynchronous communication is a writing activity, the taxonomy of planning types proposed by Hayes and Nash (1996) can be applied to conceptualise 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 inquiry, then I will think about the answer."). Text planning is focused on what is being written, 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, 1993) that capture the most important features of the topic. The names of the topics may be thought of as "pointers" to packages of information in the author's memory (Hayes & 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 con-

ceive 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 program 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 used this information to decide which concepts and relations were known or not known by the layperson, and which of them they wished to include in their explanation. Consider an expert's answer model that is represented by a conceptual network comprising ten specialist concepts. If the layperson has a high prior knowledge level, he or she may know the rough 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. With regard to the three concepts that 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 the ten concepts. In this case, the expert would have to decide for seven of the concepts whether to include them in the answer and – if included – how to introduce them. Consequently, more pruning decisions would be required if the layperson had a low prior knowledge level than if they had a high 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, experimental condition should moderate (cf. Baron & 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 & 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 characterising and contextual information that enables the layperson to relate the new information to their prior knowledge and to their 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 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.

## **4.2 Adaptive Features of Experts' Answers to Laypersons' Inquiries**

Provided that information about a layperson's knowledge constrains both the conceptual planning and language planning of experts (Hayes & Nash, 1996), their written answers to laypersons' inquiries 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 such technical concepts considered indispensable for constructing the answer. Hence, the lower a layperson's knowledge level, the more the experts might focus on a few relevant concepts in their explanations to make sure that they can provide enough context to warrant the layperson's comprehension. In doing so, the experts would follow the principle of optimal design (Clark, Schreuder, & Buttrick, 1983), which states that communicators seek to provide sufficient context to facilitate a recipient's comprehension as much as necessary in order to design messages that are optimal for each recipient (Horton & 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, their cognitive effort invested in the translation of these technical concepts into explanations that are intelligible to a layperson. In contrast, the higher a layperson's knowledge level, the more technical concepts the experts could use in their answer without having to think a lot about how to paraphrase and characterise 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 characterise and contextualise the meaning of technical concepts, for example, by use of analogies or illustration of the practical relevance of concepts. This interaction effect, however, should only be observed in the communication condition with the assessment tool because only in this condition were the experts presented information about the layperson that made the layperson's knowledge level explicit.

Nückles (2001) as well as Bromme, Jucks, and Runde (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 behavioural 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 but not the explanations themselves was investigated. Bromme et al. (2005) analysed 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 generalised to communication settings with real recipients who can provide feedback. For example, Schober (1993) found that communicators showed less audience design (Clark & 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.

### **4.3 Research Questions and Hypotheses: Overview**

#### **1. Does the Assessment Tool Increase the Effectiveness and Efficiency of Communication?**

The principal goal of the present study was to highlight the cognitive planning processes and linguistic means by which the experts adapted their explanations to a layperson's knowledge level. However, before it makes sense to ask how the experts used the information displayed in the assessment tool, it has to be established that the information about the layperson helped the experts to improve their communication. Therefore, we first investigated whether the results of the Wittwer et al. study (2004) could be replicated by the cur-

rent 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).

## **2. Does the Assessment Tool Increase the Experts' Awareness of the Layperson's Knowledge Background?**

Compared with face-to-face communication, in asynchronous communication there is less information available 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 & 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*).

## **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 was, 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 was, 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 experimental condition (i.e., with versus without the assessment tool) to be a moderator (cf. Baron & 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. Does the Information About the Layperson's Knowledge Level Influence the Way the Experts Designed Their Answers to the Layperson's Inquiries?**

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. Wittwer et al., 2004, and chapter 2). 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 non-specific sensitising effect of the assessment tool, instead of a specific adaptation to the layperson's knowledge. A non-specific sensitising 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 research question 3), we expected experimental condition (i.e., with versus without the assessment tool) to be a moderator, that is, the hypothesised interaction between the type of explanatory statements and the layperson's knowledge level should only occur in the communication condition with the assessment tool.

## 4.4 Method

### 4.4.1 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 4.1). 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 an inquiry. 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 inquiry. 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 average layperson – definitely above average. The displayed values in the assessment tool were determined through an objective and standardised assessment procedure. To this purpose, an updated and shortened version of the computer and Internet knowledge test developed by Richter, Naumann, and Groeben (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. 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 scores a layperson achieved in the test by 2. For example, if a layperson solved only 1 or 2 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 4.1). The layperson's knowledge regarding the

meaning of the specialist terms relevant to the inquiries 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.

#### 4.4.2 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 24.00 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 counselled 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 somewhat larger amount of money was justified by the extended knowledge tests the laypersons were administered 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 as well as 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,  $F(3, 68) = 41.07, p < .001, \eta^2 = .64$  (strong effect).

Because the present study tested hypotheses concerning correlations with the laypersons' knowledge level, the students serving as laypersons should cover a wide range of different prior knowledge levels to allow for such correlations. The results of the general computer knowledge test as well as of the Internet knowledge test (see Assessment Tool section above) 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 9 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 8 items. Hence, the present sample of laypersons evidently displayed sufficient variability of prior knowledge levels.

#### 4.4.3 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 inquiries, 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).

#### 4.4.4 Materials

A pool of 20 inquiries was constructed that demanded explanations of relevant computer topics and problems. Twenty computer experts rated how familiar they were with each of the inquiries 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 inquiries were selected for the experiment. This procedure guaranteed that in the communication phase of the experiment, the computer experts would encounter inquiries for which they would be able to give appropriate answers. The inquiries required the computer expert to explain a technical concept or to provide an explanation why a particular technical problem occurred in order to help the layperson understand the nature of the problem (cf. Table 4.1).

Table 4.1. *Inquiries used in the experiment*

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Recently I visited a website that told me to wait while ‘Flash is loading’. Could you please tell me what exactly the difference between HTML and Flash is?

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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’?

---

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.

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#### 4.4.5 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.

*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 inquiries. Additionally, we asked the laypersons to try to answer each of the inquiries. 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 dialogue 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 4.1). The reliability for the mean of the two raters, as determined by the intra-class coefficient was .92, which indicates excellent inter-rater agreement. Third, we encouraged the laypersons to answer each of the inquiries 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 3 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 ( $r = .90$ ). An inspection of the mean scores of the laypersons' answers showed values close to zero indicating that, on average, they did not know the correct answer to the inquiries prior to the exchange with the computer expert (cf. Table 4.2). There were no significant differences between the experimental conditions,  $t(34) = 0.64, ns$ .

*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 inquiries verbatim to the expert by typing the prepared wording of the inquiry into the text form of the interface. The experts were asked to answer each inquiry 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 warm up thinking aloud, they were asked to verbalise their thoughts while figuring out the correct sequence of pictures in a picture story. The experts' verbalisations were digitally recorded on a notebook equipped with an 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.

*Post-test phase.* After the communication phase, the laypersons were again asked to write down their knowledge about each of the three inquiries. 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.

#### **4.4.6 Coding of the Experts' Think-Aloud Protocols and the Experts' Answers to the Laypersons' Inquiries**

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' inquiries. Nückles and Stürz (in press) 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 inquiry 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.

### ***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 inquiry, 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' 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 characterise 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 that 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  $\kappa = 0.91$ ).

### ***Coding of the Experts' Answers to the Laypersons' Inquiries***

For the analysis of the experts' adaptation strategies, another coding scheme was developed that aimed to identify the linguistic and semantic features of the experts' answers. The coding scheme consisted of two levels of judgements. The first level assigned one of 14 inductively found categories that allowed for an exhaustive classification of each statement in the experts' answers. The coding scheme specified for each statement the linguistic features used in order to describe or explain the separate aspects of a technical concept. Statements at this level were assigned to categories such as instantiation, part-whole relationship, simile, difference, or categorisation. At an abstract level, these 14 categories fit in four more abstract classes that were organised 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.") were categorised 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 superordinate concept ("HTML is a text formatting language.").

3. *Characteristics of technical concepts.* On this dimension, attributes that specifically characterise 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 were 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 purpose, we used a procedure originally suggested by Erkens, Kanselaar, Prangma, and Jaspers (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 organisational 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.

## 4.5 Results

### 4.5.1 Did the Assessment Tool Increase the Effectiveness and Efficiency of 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).

The laypersons’ individual knowledge gain was computed by subtracting the mean scores of their own answers to the inquiries before the communication phase from the corresponding mean scores collected after the communication phase (cf. Table 4.2). To

Table 4.2. *Laypersons’ knowledge about the inquiries 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	
	With the assessment tool <i>n</i> = 18	Without the assessment tool <i>n</i> = 18
Mean scores of the laypersons’ answers to the inquiries before the communication phase*	0.15 (0.24)	0.22 (0.43)
Mean scores of the laypersons’ answers to the inquiries 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 3 points could be assigned (0 = no or wrong answer, 1 = partly correct answer, 2 = roughly correct answer, 3 = completely correct answer).

analyse the impact of the assessment tool on the effectiveness and efficiency of the communication, a multivariate analysis of variance 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 assessment

tool) was the independent measure. This MANOVA was highly significant,  $F(2, 33) = 12.03$ ,  $p < .001$ ,  $\eta^2 = .42$  (large effect). Separate ANOVAs showed that the laypersons achieved a significantly larger knowledge gain,  $F(1, 34) = 8.25$ ,  $p < .01$ ,  $\eta^2 = .20$  (large effect), and posted significantly fewer comprehension questions,  $F(1, 34) = 7.95$ ,  $p < .01$ ,  $\eta^2 = .19$  (large effect), in the condition with the assessment tool compared with the condition where the experts answered the laypersons' inquiries without the assessment tool. Thus, our hypotheses regarding communicative effectiveness and efficiency were confirmed. At the same time, the results of the Wittwer et al. study (2004; see also chapter 2) 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' inquiries.

#### **4.5.2 Did the Assessment Tool Increase the Experts' Awareness of the Layperson's Knowledge Background?**

Table 4.3 (second and third columns) shows the mean frequencies and standard deviations of the different types of planning statements. A multivariate analysis of variance 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,  $F(5, 30) = 6.06$ ,  $p = .001$ ,  $\eta^2 = .50$  (large effect). 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,  $F(1, 34) = 23.89$ ,  $p < .001$ ,  $\eta^2 = .41$  (large effect). Hence, the recipient model hypothesis was confirmed: The computer experts who were presented information about the layperson's knowledge better attempted to get 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:  $F(1, 34) = 2.09, ns$ ).

Table 4.3. *Frequencies of types of planning statements and correlations with the layperson’s knowledge level*

Types of planning processes	Mean number of planning statements (standard deviations in parentheses)		Correlation with the layperson’s knowledge level	
	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)	-.63**	.12
Construction of an answer model	6.50 (3.85)	6.28 (0.48)	-.22	.22
Construction of a recipient model	4.06 (2.05)	1.50 (0.85)	.27	.22
Pruning	3.07 (2.69)	2.54 (1.49)	-.49*	-.09
Translation	3.56 (1.83)	2.74 (1.54)	-.71**	.28

Note. \*\* $p < .01$ , \* $p < .05$ .

#### 4.5.3 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 4.1) 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  $r = .55, p < .001$ , to  $r = .77, p < .001$ ). 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 Procedure section). A  $t$ -test for independent samples showed that the laypersons had a similar average knowledge level in both experimental conditions,  $t(34) = 0.80, p = .430$  (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,  $F(1, 34) = 0.04, p = .952$ . Thus, the statistical chances to detect correlations with the layperson's knowledge level were comparable between the experimental conditions.

Table 4.3 (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 versus 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 & Kenny, 1986; Cohen & Cohen, 1983): We computed a multivariate analysis of variance 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,  $F(2, 31) = 6.17, p < .01, \eta^2 = .29$  (large effect). Subsequent univariate tests showed that this interaction effect was somewhat less pronounced for the number of pruning statements,  $F(2, 32) = 3.13, p < .09, \eta^2 = .09$  (medium effect) as compared with the number of translation statements,  $F(2, 32) = 12.74, p < .01, \eta^2 = .29$  (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.

*Influence of the layperson's knowledge level on the experts' process planning.* Apart from these theoretically expected relationships, there was also 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 & Cohen, 1983), we obtained a significant result,  $F(1, 32) = 6.58, p < .05, \eta^2 = .17$  (large effect). The negative sign of the correlation coefficient in Table 4.3 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 reread the inquiry 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 concep-

tual model of their answer but, on a more general, that is, non-content level, they intensified the regulation of their writing processes.

#### 4.5.4 Did the Information About the Layperson’s Knowledge Level Influence the Way the Experts Designed Their Answers to the Layperson’s Inquiries?

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 non-specific sensitising effect of the assessment tool rather than a specific adaptation to the layperson’s knowledge. To check for such a non-specific sensitising effect, 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 4.4 shows the mean proportions and standard deviations of the four types of statements. As expected, there were no significant differences between

Table 4.4. *Average proportion of types of explanatory statements of an expert’s answers*

Types of explanatory statements and length of an expert’s answer	Means and standard deviations (in parentheses) listed separately for experimental conditions	
	With the assessment tool <i>n</i> = 18	Without the assessment tool <i>n</i> = 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)

the experimental conditions. The mean values and standard deviations of the different types of statements were virtually identical. Accordingly, both the multivariate test,  $F(3, 32) = 0.39, p = .549$ , and the separate ANOVAs for each type of statement clearly failed to reach statistical significance, all  $F_s < 1$ . Note that the multivariate test still remains non-significant, even if the alpha level is raised to 30% in order to avoid inflation of type two errors.

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 4.4), we decided to combine them with statements specifying characteristics of technical concepts into one category, in the following called “characteristics and contextual information”. The correlation coefficients are separately displayed for the experimental conditions in Table 4.5. As predicted by the adaptive features hypothesis, there was a significant posi-

Table 4.5. *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 <i>n</i> = 18	Without the assessment tool <i>n</i> = 18
Processes and events related to technical concepts	.60**	-.30
Definitions of technical concepts	-.18	.20
Characteristics of technical concepts and contextual information	-.49*	.13

Note. \*\* $p < .01$ , \* $p < .05$ .

tive 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 characteristics and contextual informa-

tion was significantly negative (cf. Table 4.5). 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 characterise 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 illustrated by the left graph in Figure 4.2. To test whether this interaction was statistically reliable, we conducted – separately for each experimental condition – an analysis of variance with type of explanatory statements (i.e., “processes and events” versus “characteristics and contextual information”) as a repeated measures factor. The layperson’s knowledge level represented a continuous independent variable (cf. Baron & Kenny, 1986; Cohen & 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 the information about the layperson’s knowledge level

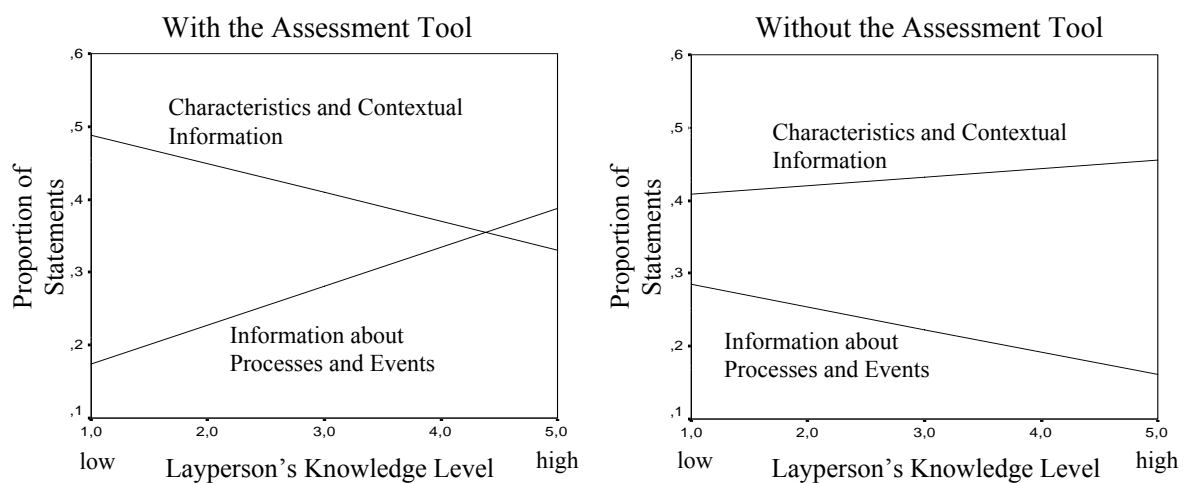


Figure 4.2. Interaction between type of explanatory statements and the layperson’s knowledge level plotted separately for the experimental conditions.

available,  $F(1, 16) = 9.71$ ,  $p < .01$ ,  $\eta^2 = .38$  (large effect). In the condition without the assessment tool (see right graph, Figure 4.2), there was no significant interaction,  $F(1, 16) = 1.13$ ,  $p = .303$ . 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 layper-

son's knowledge level,  $F(1, 32) = 7.23$ ,  $p < .05$ ,  $\eta^2 = .18$  (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.

## **4.6 Discussion**

The present study showed that providing computer experts with information about a layperson's knowledge background made their advisory dialogue 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, 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 optimise their learning. Thus, the present results replicate and confirm the findings of Wittwer et al. (2004; see also chapter 2) as well as of Nückles and Stürz (in press). More importantly, the current study offers valuable insights into the cognitive processes and the linguistic means the experts employed to adjust their answers to the layperson.

### **4.6.1 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 were presented information about the layperson's knowledge better attempted to get an idea 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 & 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 probably 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 non-significant 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 4.3).

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 non-content level, that is, the level of process planning by which the experts regulated their writing processes (Hayes & Nash, 1996). Together, these results provide evidence for the different planning processes (i.e., process planning, conceptual planning and language planning) as they were hypothesised 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 inquiry, 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; 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 that Horton and Keysar report in favour of their theory has seriously been questioned (Polichak & 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.

#### **4.6.2 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' inquiries showed no significant differences between the experimental conditions (cf. Table 4.4). Hence, the raised communicative effectiveness and efficiency of the experts' answers in the condition with the assessment tool cannot simply be attributed to a non-specific sensitising effect of the assessment tool (cf. Wittwer et al., 2004). 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 predicted 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 effect 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 & Gerrig, 2002). According to this logic, "optimal" answers for laypersons with a low level of knowledge would concentrate on a few technical concepts that are thoroughly characterised 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 characterising information – in order to make the answer as informative for the layperson as possible.

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: Inasmuch 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 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. (2005) 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.

### **4.6.3 Practical Implications**

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 better able to process the experts' explanations that were produced with the assessment tool within the frame of their personal understanding 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 more personalised advice that was tailored to their individual needs (Kobsa et al., 2001). Providing effective and personalised 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 & Lyth, 2000). Hence, an assessment tool could be fruitfully employed in online computer support services in order to improve, via personalisation of the advice provided, customer satisfaction and retention (Mohr & Bitner, 1991; Rust & 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, Abraham, Jenkins, & Fallowfield, 2003; Hack, Degner, & Dyck, 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 similarly have beneficial outcomes.

Moreover, the present findings of how experts adopt different types of explanatory statements for the purpose of tailoring their explanations to a layperson's knowledge could

be also interesting for the design of automated personalisation techniques used by computer systems in web-based information services. There is a huge body of research dedicated to the question of how information can be optimally adapted to the user's special needs, for example, in order to improve information retrieval or learning (e.g., Brusilovsky, 2001; Dillon & Gabbard, 1998; Graesser, Person, Harter, & TRG, 2001; Kobsa et al., 2001). It is notable, however, that research on user modelling for human-computer dialogues is seldom guided by naturalistic observations of human interactions (Carroll & McKendree, 1987; du Boulay & Luckin, 2001) nor is the effectiveness of implemented personalisation techniques frequently tested empirically (Alpert et al., 2003). Hence, the observation of human experts' adaptation strategies and the experimental testing of their effects on the user's side, as exemplified by the present study, could also serve as a methodology for deriving effective personalisation techniques that can be employed in automated advice-giving or online help systems.

## CHAPTER 5

### General Discussion

#### 5.1 Summary and Discussion of Results

The overarching goal of the dissertation was to empirically test a support procedure for computer experts who give advice to laypersons in online computer support services. Based on the difficulties for effective advice-giving that result from the constraints of computer-mediated communication as well as from the experts' inclination to forget about the exclusiveness of their specialist knowledge, an assessment tool was developed to support experts in constructing a mental model about the layperson's knowledge in the computer and Internet domain. Three experiments were conducted to examine the effectiveness of the assessment tool and thereby the importance of a partner model for advice-giving. *Experiment 1*, presented in chapter 2, focused on the mechanisms underlying the assessment tool effect: Did the assessment tool improve communication between experts and laypersons mainly because it enabled experts to produce generally well-written explanations that benefited laypersons' understanding regardless of their individual knowledge level? Or did the information provided by the assessment tool support experts in adapting their explanations specifically to the layperson's knowledge level and thereby improve communication? Drawing on empirical evidence that experts tend to over- and underestimate what laypersons know in their field of expertise, *experiment 2*, presented in chapter 3, analysed the impact of such over- and underestimations on communication. To do so, experts were presented with information that either over- or underestimated the laypersons' knowledge in the computer domain: Did such over- and underestimations have a similar influence on communication, or did they affect laypersons' learning and question-asking differently? Finally, *experiment 3*, presented in chapter 4, was dedicated to shed light on the question of how experts used the knowledge information about the layperson provided by the assessment tool in order to plan and produce explanations that met the laypersons' specific needs. Thus, the study further helped to contribute to our understanding of the as-

assessment tool effect by delving more deeply into experts' planning processes and adaptation strategies.

Overall, the three experiments showed that netbased communication between experts and laypersons could be substantially improved by means of the assessment tool. Laypersons acquired significantly more knowledge from explanations that were written by experts who had the assessment tool with information about the layperson's knowledge level available, as compared with laypersons whose expert was provided with no or distorted information about the layperson. At the same time, the laypersons were better able to immediately comprehend the experts' explanations, as was indicated by the lower frequency of follow-up questions asked in response to the experts' initial explanations. The replication of the assessment tool effect in all three studies strengthens the robustness of our findings and demonstrates that the assessment tool indeed proves to be a suitable method to overcome the difficulties experts might face when providing advice to laypersons via the Internet.

### 5.1.1 Experiment 1

With regard to a theoretical explanation that could account for the assessment tool effect, *experiment 1* provided first valuable insights. The study showed that communication between experts and laypersons was substantially improved when experts were provided with valid information about the layperson's knowledge level by means of the assessment tool. Conversely, in cases where experts were presented distorted information about the layperson, this considerably impaired communication success. From these findings, it could be concluded that the assessment tool not only sensitised the experts for the laypersons' needs but also allowed for a specific adaptation to their individual knowledge state. Hence, the assessment tool enabled experts to construct a relatively accurate mental model about the laypersons' knowledge on the basis of which they could customise their explanations accordingly (Nickerson, 1999, 2001). Following Schober's and Brennan's taxonomy (2003; for details, see also chapter 1) that distinguishes different levels of adjustment communicators can make in order to design their messages, the findings of *experiment 1* suggest that

experts were capable of making *specific-partner adjustments* that took into account the laypersons' individual communicational needs. Hence, when formulating messages, experts who were provided with the assessment tool not only considered their communication partner as a typical member of the group of "laypersons" that usually share a certain amount of knowledge with each other (*cultural/community/group-based adjustments*, cf. Schober & Brennan) but also differentiated – within this social category – between different levels of knowledge the laypersons possessed. This result validates and extends the findings of previous research on expert-layperson communication. Bromme, Jucks, and Runde (2005) showed that medical experts varied the content of information conveyed to their – fictitious – communication partner, depending on the partner's community membership. The experts mentioned advanced topics more often when they wrote messages to a medical colleague. In contrast, their explanations contained more practical tips when their communication partner was a layperson in the field of medicine. According to the taxonomy proposed by Schober and Brennan, experts in the study by Bromme et al. made *community-based adjustments* in order to produce messages that were in accordance with the communication partner's community-related knowledge (medical expert vs. medical layperson). In addition to these findings, *experiment 1* of this dissertation showed that experts were able to make even more fine-tuned adjustments that matched the layperson's individual knowledge state (for similar findings in monological settings, see Bromme & Nückles, 2001; Nückles, 2001).

However, although the experiment demonstrated a specific adaptation of the experts' explanations to the laypersons, indications for this adaptation were primarily found for the outcomes of communication, that is, the laypersons' knowledge gain and the number of follow-up questions they asked in response to the experts' explanations. It was, however, less clear how the knowledge information about the laypersons provided by the assessment tool directly influenced experts' explanations at a linguistic and semantic level. Moreover, the study gave insight into the detrimental effects on communication when experts obviously constructed a biased mental model about the layperson's knowledge, as was induced through the provision of distorted knowledge information in one experimental condition. In



order to realise the distortion of information, this information was randomly drawn from the pool of knowledge data of laypersons who had previously participated in the experiment. Hence, experts received information about the laypersons' knowledge that either over- or underestimated their true knowledge level. However, the amount of these over- and underestimations (i.e., the difference between the layperson's true knowledge level and the knowledge level that was displayed in the assessment tool) was not held constant nor was the type of the induced bias (i.e., over- or underestimation of the layperson's true knowledge level) experimentally varied. Due to the lack of controlling for these factors, it was not possible to systematically separate the possible differential effects of experts' over- and underestimations on laypersons' understanding and question-asking behaviour. These study limitations were addressed by the subsequent experiments presented in this dissertation.

### **5.1.2 Experiment 2**

Having shown in the first experiment that – in line with Clark's theory of common ground (1992, 1996) and Nickerson's anchoring-and-adjustment model (1999, 2001) – an accurate model about the communication partner was important for successful communication, *experiment 2* provided more detailed insights into what happened when experts over- or underestimated the laypersons' background knowledge. Despite the empirical evidence that experts, due to their rich knowledge base, tend to over- or underestimations of laypersons' knowledge (Bromme, Rambow, & Nückles, 2001; Hinds, 1999), research so far has paid little attention to the consequences of such misjudgements for communication. In fact, it is well documented that experts often have problems in providing explanations to laypersons at an appropriate level (e.g., Alty & Coombs, 1981; Erickson & Shultz, 1982; Hinds, Patterson, & Pfeffer, 2001). However, this observation does not allow for the conclusion that experts' erroneous assumptions about the laypersons' knowledge are the determining factor for the reported communication failures (cf. Fussell & Krauss, 1992; Krauss & Fussell, 1996). As sketched out in chapter 1, there might be other factors such as time pressure, the complexity of information being communicated, or even the unwillingness to provide un-

derstandable explanations that can be predominant in the communication situation and therefore prevent experts from assessing the partner's perspective (Krauss & Fussell; Schober & Brennan, 2003). Thus, in order to investigate possible communication problems between experts and laypersons that can be clearly attributed to experts' erroneous assumptions about the layperson's knowledge, it is necessary to examine those assumptions independent of the message produced (Fussell & Krauss). In *experiment 2*, this was realised by using the assessment tool in order to induce systematic biases in experts' beliefs about the layperson's knowledge level. Due to the salience of the knowledge information displayed in the assessment tool and its relevance for the task to provide effective advice (cf. Hanna & Tanenhaus, 2004), experts were expected – in line with the findings of the first experiment of the dissertation – to use the information to construct a model about the layperson that, consequently, should constrain the production and formulation of their explanations. Results showed that both over- and underestimations of the layperson's knowledge indeed affected communication considerably. Laypersons who were over- or underestimated by the experts acquired significantly less knowledge than laypersons whose experts were provided with valid knowledge information. In addition, these laypersons asked more questions in order to compensate for their perceived communication problems. Depending on whether laypersons were over- or underestimated by experts, a differential effect was found for the types of questions laypersons asked. Laypersons who were overestimated directed primarily comprehension questions to the experts, whereas laypersons who were underestimated asked the experts in particular for additional information previously not stated in their explanations. The differences in laypersons' question-asking behaviour suggest that experts in the overestimation condition produced too difficult explanations resulting in comprehension breakdowns on the part of the laypersons. Conversely, laypersons in the underestimation condition had only little problems comprehending the experts' explanations. However, at the same time, these explanations offered them only little new information that would have been beneficial to their learning. It is remarkable to note that, apart from the different types of questions laypersons in the biased estimation conditions asked, their knowledge acquisition was impaired to a similar extent. This finding clearly demon-

strates that an inaccurate partner model can considerably impair the effectiveness of communication, and that this is true regardless of whether the partner model is biased towards an over- or an underestimation of what the communication partner does actually know.

Besides, the study also showed how experts varied the use of technical terms in their explanations as a function of the background knowledge they assumed laypersons to have. Experts who overestimated the layperson's knowledge used the most technical terms in their explanations, whereas experts who underestimated the laypersons produced explanations that contained the fewest technical terms. Hence, the use of technical terms was a sensitive indicator for the experts' audience design (cf. Bromme et al., 2005). However, this relatively simple measure alone, of course, could not fully help to understand how the experts customised their explanations in order to make the complex technical information understandable for laypersons with different knowledge prerequisites. It is plausible to assume that experts applied even more sophisticated strategies to tailor the information to the layperson's individual needs.

### 5.1.3 Experiment 3

Therefore, the goal of *experiment 3* was to focus on the specific features of the experts' explanations that made them adapt to a particular layperson's knowledge level. In addition, to better understand how experts produced their explanations with the help of the assessment tool, their planning processes during the composition of their explanations were examined. The analyses revealed a complex picture of how experts transformed their initial ideas for providing an answer to the laypersons' inquiries into a well worked-out explanation. Experts who were presented information about the layperson's knowledge generally attempted more intensely to get an idea of the layperson's particular level of expertise as compared with experts who had no assessment tool available. However, depending on the layperson's knowledge in the computer and Internet domain, experts varied the effort they put into the planning of their explanations. The lower the layperson's knowledge was, the more the experts thought about how to carry out the writing task, reflected on the technical concepts the layperson might know, and the more they stated how to translate the technical

concepts into appropriate expository formats. These findings demonstrate that experts' planning processes were guided by no means exclusively by their own perspective but rather took into account the laypersons' needs in a multitude of ways. The content analysis of the experts' explanations added to this picture. Experts adopted different types of explanatory statements for the purpose of tailoring their explanations to a layperson's individual knowledge level. When communicating with a layperson who had only little prior knowledge, experts reduced the number of technical concepts being explained but, at the same time, described these concepts more thoroughly through the use of similes, analogies or additional information that illustrated the personal relevance of a concept to the layperson. Conversely, the explanations experts produced for laypersons with a higher knowledge level contained more technical but less contextual information. Hence, in applying this adaptation strategy, experts designed messages that aimed at satisfying the individual needs of laypersons with different knowledge backgrounds.

Overall, the think-aloud study validates and extends the findings of the first two experiments presented in this dissertation. The analysis of the experts' planning processes verified that experts used the knowledge information about the layperson displayed in the assessment tool to construct a mental model about the layperson (Nickerson, 1999). Moreover, the content analysis of the experts' explanations revealed the sophisticated manner in which experts adjusted their explanations in order to meet the laypersons' particular needs. Thus, in addition to the findings of *experiment 1* and *2* that demonstrated a specific adaptation effect mainly with regard to the outcomes of the communication process (i.e., laypersons' learning and question-asking), *experiment 3* showed how this adaptation affected the design of the experts' explanations at a linguistic and semantic level.

## **5.2 Directions for Further Research**

### **5.2.1 Validation of the Experts' Adaptation Strategies**

The content analysis of the experts' explanations conducted in *experiment 3* of the dissertation uncovered the adaptation strategies experts applied in order to provide explanations to laypersons that met their individual needs. The variation of the different explanatory types

of statements for the purpose of conveying individualised information to laypersons with different knowledge backgrounds is similar to designing instructional texts in educational psychology (e.g., McNamara & Kintsch, 1996; McNamara, Kintsch, Songer, & Kintsch, 1996). As already briefly described in chapter 3, text revision studies deal with the question of how to improve instructional texts by focusing particularly on knowledge activation and inference-making that both play an important role for learning from texts (Graesser, Singer, & Trabasso, 1994; Kintsch, 1998). In these studies, text characteristics are usually manipulated in order to analyse their effects on the readers' understanding. Following this approach, Britton and Gülgöz (1991), for example, reduced the need for readers to make inferences when reading a text by increasing the overlap among arguments provided in the text (e.g., making implicit referents explicit). As a result, the revised text substantially facilitated readers' comprehension (for similar results, see Beck, McKeown, Sinatra, & Loxterman, 1991; Linderholm et al., 2001; Vidal-Abarca & Sanjose, 1998). However, research has also shown that this traditional approach does not always lead to optimal learning. For example, McNamara et al. (1996; McNamara & Kintsch) as well as Voss and Silfies (1996) found that texts can be too easy for students with a relatively high degree of prior knowledge (see also the findings of *experiment 2* in this dissertation). When such students read a text in two different versions, the text version that was more difficult to comprehend (i.e., less coherent) resulted in better learning outcomes. Conversely, students with only little prior knowledge clearly benefited from reading the more coherent text. These findings suggest that the higher level of text difficulty induced the students who had a high knowledge level to more actively process the textual information by making more and deeper connections of the text concepts with related concepts in their long-term memory. In contrast, due to the higher redundancy between the students' prior knowledge and the information provided by the easy texts, these texts were not challenging enough, thus resulting only in passive processing and lower comprehension. The interaction between the background knowledge of the reader and the characteristics of the text itself demonstrates that optimal learning from a text is best accomplished when readers who vary in their prior

knowledge of the text topic are provided with texts whose complexity is in accordance with the reader's specific knowledge prerequisites.

With regard to the text characteristics being varied, the focus of the text revision studies is usually on information that is provided to readers in order to reduce or enhance their inferential activity required for establishing coherence. Thus, the information might refer to any type of inference that research on text comprehension has catalogued (for an overview, see Graesser et al., 1994; Graesser, León, & Otero, 2002). For example, pronouns might be substituted for proper nouns in order to facilitate the reference to a previous text constituent (e.g., *John* likes to play tennis with Tom. *John* (instead of *he*) also likes to go out at the weekend; so-called *anaphoric inferences* or *bridging inferences*). In a similar vein, information can be added in order to fill in breaks in the causal coherence of a text (so-called *explanation-based inferences* or *predictive inferences*). For example, a historical event might be explained more elaborately through the provision of additional information about the causal antecedents and consequences of this event (for an example, see Gilabert, Martínez, & Vidal-Abarca, 2005).

In contrast to the text revision studies that – despite the modifications with regard to readers' inference-making – hold the amount and type of information provided by a text relatively constant, *experiment 3* of this dissertation demonstrated that even more content-related modifications of a text (i.e., the experts' written explanations) can also be beneficial to learning. As shown, in order to provide individualised support to laypersons, experts established a wide range of explanations on the same topic that differed in the amount of technical and contextual information presented to the particular layperson. Given these findings, it would be interesting to apply the experts' adaptation strategy as a heuristic for revising instructional texts in the computer domain. Following this strategy, instructional texts for computer users with only little experience would contain mainly basic technical information that would be illustrated through the additional use of contextual information. In contrast, more proficient users would receive instructional texts that would provide them with more information about technical concepts without the need to highlight their contextual meaning to a greater extent. Analogous to the reported text revision studies, experi-

ments could be conducted that analyse the effectiveness of instructional texts – constructed in this manner – for readers with different levels of computer expertise. Results of such studies would not only validate the findings of the think-aloud study but also make a substantial contribution to research on text comprehension, particularly with regard to learning from texts in technical domains (Goldman & Wolfe, 2001).

### **5.2.2 How did the Laypersons Process the Adaptive Explanations Produced With the Assessment Tool?**

The three experiments presented in this dissertation demonstrated that the assessment tool substantially improved laypersons' learning from the experts' explanations. However, what remained less clear was the question whether the higher knowledge gain of the laypersons in the assessment tool condition could be explained by a deeper understanding or just by a better reproduction of the experts' explanations. The learning test that was used in all three experiments to analyse laypersons' knowledge acquisition contained only items that required the laypersons to provide an answer to the inquiries they previously directed to the experts in the communication phase. The laypersons, however, were not asked to give answers to transfer or inference questions that would have assessed their ability to apply the newly acquired knowledge to a novel situation. Such application of knowledge could have been regarded as an indication of deep-level knowledge (e.g., de Jong & Ferguson-Hessler, 1996). Thus, in a strict sense, the experiments do not allow for conclusions regarding the level of processing laypersons exhibited when reading the experts' explanations.

In order to better understand the differences in how laypersons might have processed the adaptive explanations produced by experts with the help of the assessment tool, one might draw upon Kintsch's model of text comprehension (1998). According to this model, text comprehension can be conceptualised as a process by which readers integrate encountered information from a text into a coherent and well-integrated mental representation. This involves creating representations at three different levels. At the surface level (a), words and phrases are encoded. At the textbase level (b), the semantic and rhetorical structure of the text is represented in the form of propositions. At the deepest level (c), a so-called situation model is elaborated, a model of what the text is about, that integrates the

readers' prior knowledge with information provided by the text. Hence, the situation model allows readers to generate inferences and thereby to construct new knowledge.

Accordingly, one could argue that the adaptive explanations produced by experts who had the assessment tool available facilitated laypersons' representation of the text, particularly their encoding of words and phrases, because experts might have thoroughly explained technical terms or instead avoided using them at all. Laypersons who received explanations that were not adapted to their individual needs, however, might have had more difficulties in representing experts' explanations at the surface or textbase level, because words were unknown to them or the text was not clearly written. According to this explanation, laypersons' knowledge acquisition in the assessment tool condition was increased because they were better able to remember and reproduce words and propositions extracted from the experts' explanations. Nevertheless, their representations might have been exclusively confined to a more appropriate textbase level that did not imply a deeper understanding, that is, a situation model.

On the other hand, one might assume that the adaptive explanations not only facilitated laypersons' reproduction of the information but also enabled them to engage in active processes that led to an improved comprehension and a deepened understanding. Because the explanations produced with the assessment tool were more in tune with the laypersons' knowledge prerequisites, this might have reduced possible comprehension problems at the surface and textbase level and, thus, left more room for generating inferences at the situation model level. In contrast, due to the fact that laypersons in the other experimental conditions were provided with explanations that were not tailored to their specific communicational needs, they might have been more frequently obliged to monitor the surface code and the textbase level of the experts' explanations. This might have prevented them from constructing a situation model that would have benefited their understanding.

In order to test these assumptions, further studies are necessary that examine whether the provision of adapted explanations in fact help laypersons to acquire knowledge in a way that makes it useful for application in many situations. In addition, think-aloud studies could be a valuable means to reveal laypersons' comprehension processes, including those



learning activities that are applied to acquire a deep understanding, such as self-explaining and self-monitoring (Chi, De Leeuw, Chiu, & LaVancher, 1994; Renkl, 1997).

### **5.2.3 The Assessment Tool as a Support Procedure for Human Tutoring**

In chapter 2 and 3 of this dissertation it was argued that the findings of the experiments could also be suggestive for other instructional settings where people greatly differ in the extent to which they have knowledge about a domain. In particular, there are striking similarities between expert-layperson communication and human tutoring. In both instructional settings, the “teaching” person often possesses no pedagogical knowledge (Borko & Putnam, 1996), that is, knowledge about methods for assessing students’ understanding and providing explanations at an appropriate level (e.g., Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001; Cohen, Kulik, & Kulik, 1982). In addition, both the expert and the tutor frequently interact, in contrast to teachers, with the learner in a one-to-one fashion. Therefore, it is particularly important to draw out the learner’s thought process in order to tailor the instructional explanations to the learners’ needs. Apart from experts’ and tutors’ difficulties in diagnosing what the learner actually knows (Bromme et al., 2001; Chi, Siler, & Jeong, 2004; Hinds, 1999), communication and tutoring might be even aggravated in computer-mediated contexts because fewer sources of information are available that experts and tutors might use to assess the learner’s understanding (Siler & VanLehn, 2003). Given these constraints along with the empirical evidence that tutor-generated explanations often do not foster student’s learning (Chi et al., 2001; VanLehn, Siler, Murray, Yamauchi, & Baggett, 2003), it might be useful to provide tutors with an assessment tool that supports them in constructing an accurate mental model about the student’s knowledge prerequisites. Accordingly, when tutors provide more effective instructional explanations that are adapted to the student’s particular needs, this might have a number of beneficial outcomes, making instructional explanations a valuable complement to other, more self-guided learning activities such as self-explaining (Renkl, 2002). First, instructional explanations as compared with self-explanations are often preferred by learners, as has been shown, for example, by Schworm and Renkl (2002) and Alevan and Koedinger (2000). Therefore, it

seems reasonable to satisfy the learners' needs by providing them, at least to a certain extent, with instructional explanations. This recommendation is in line with the observation that tutor-generated explanations often are prevalent in human tutoring (Chi et al., 2001), particularly in computer-mediated contexts (Shah, Evens, Michael, & Rovick, 2002). Secondly, instructional explanations given by tutors are in the great majority of cases correct. In contrast, self-explanations can be incorrect, the result being that wrong knowledge is learned (Conati & VanLehn, 2000). Thirdly, instructional explanations can help students to detect inconsistencies in their own understanding and thus prevent them from being caught by an *illusion of understanding* that might inhibit further learning (Chi et al., 1994). And finally, when learning new material, students might have comprehension impasses that they cannot resolve on their own. Thus, instructional explanations might compensate for these difficulties by providing additional information that fills gaps in the students' understanding (Wittrock, 1990).

However, despite the similarities between expert-layperson communication and human tutoring, attention has to be paid to the differences between both instructional settings that might limit the generalisability of the assessment tool findings to human tutoring. In contrast to human tutoring, expert-layperson communication takes place outside an educational context. That is, laypersons do not strive to acquire the scientific knowledge that experts possess (Bromme & Rambow, 2001). Instead, their primary concern is that experts help them to solve their problems on their own or provide them with information that supports them in their decision-making (Kerres & Jechle, 2000). Hence, learning is usually not the main focus in communication between experts and layperson. Conversely, human tutoring is normally embedded within formal educational institutions that teach students knowledge and skills in diverse domains. Therefore, tutors are often faced with the task of providing support that enables students to develop and apply scientifically correct knowledge (Chi et al., 2004). In order to do so, tutor and student have to delve into a knowledge domain more deeply than would be possible or necessary in communication between experts and laypersons. Thus, whereas experts might have some liberty to decide what and how to communicate to suit the laypersons' needs (remember that experts in the think-

aloud study considerably varied the amount of technical information presented to the laypersons as a function of their knowledge level), tutors are urged to cover certain concepts, questions, cases and problems within a particular lesson. Moreover, due to the greater complexity of information tutors must convey in order to enable students to acquire a deep understanding of the relationships between concepts in a domain, it might be speculated that also different or additional adaptation strategies are required to successfully fulfil this task. In order to test the effectiveness of the assessment tool for human tutoring, we are currently running an experiment in which we analyse how students acquire knowledge in clinical psychology with the help of a tutor. Results might show whether the assessment tool is also an appropriate measure to foster learning in instructional settings where students are confronted with more complex learning material. In addition, the findings would suggest if the application of an assessment tool is confined to the computer field or could also be applied to other domains such as clinical psychology.

#### **5.2.4 Do Experts With Didactic Experience Need an Assessment Tool in Order to Give Effective Advice?**

The findings reported in this dissertation suggest that the assessment tool successfully compensated for the factors that might impair the advisory success. As described in chapter 1, these factors include the constraints of asynchronous, text-based communication and the experts' inclination to forget about the exclusiveness of their rich knowledge base. However, in a strict sense, the findings of the reported studies do not allow to sort out the assessment tool effect in more detail. That is, did the assessment tool mainly compensate for the constraints of netbased communication or for the experts' cognitive limitations faced when conveying their knowledge to people with less expertise? Or did the assessment tool instead affect both factors to a similar extent? To answer this question, further studies are needed that systematically vary the level of experience that experts have in providing effective advice to laypersons. Remember that although experts in all three experiments presented in this dissertation advised laypersons quite frequently, they had no formal training in the skills of advice-giving. Such skills might, for example, include knowledge about laypersons' starting points (i.e., their already existing conceptions, but also their miscon-

ceptions in the computer domain) as well as knowledge about effective routes for bridging the gap between the experts' specialist knowledge and the less sophisticated knowledge of laypersons. Despite the empirical evidence that experts indeed were able to adapt their explanations to the laypersons' specific needs when supported by means of the assessment tool, it might be hypothesised that they would even have done a better job if they had been trained in advice-giving.

Therefore, it would be interesting to investigate whether experts with a high expertise in advice-giving would even need the assessment tool in order to provide effective explanations to laypersons via the Internet. If those experts were equally good at advice-giving independent of whether they were presented information about the layperson's knowledge level or not, this would indicate that the assessment tool in the studies reported in this dissertation had primarily a positive impact on the experts' cognitive limitations to adequately considering the laypersons' perspective. In contrast, if the assessment tool helped even experts with didactic skills to provide better advice, this would demonstrate that the constraints of netbased communication in the present studies were indeed the determining factor for experts' difficulties taking into account the laypersons' informational needs. Hence, studies that would analyse the effectiveness of the experts' explanations for advice-giving as a function of the level of experts' didactic skills and the availability of an assessment tool would help to contribute to our understanding how the assessment tool might differently compensate for the problems resulting from the constraints of netbased communication and the experts' inclination towards egocentric thinking.

### **5.3 In Closing**

Although experts are well known for their difficulties in conveying their own specialist knowledge to people with less expertise, this dissertation provided clear evidence that they are not inevitably caught by a *curse of expertise*. In contrast, the three experiments presented in the dissertation showed that experts, despite their rich and highly integrated specialist knowledge, are capable of considering a layperson's completely different perspective in a number of respects. When provided with explicit information about the layper-

sons' background knowledge, experts attempted to adapt their explanations to the layperson's particular needs in order to individualise their communicative contributions. In so doing, they facilitated laypersons' understanding and learning: Laypersons not only had considerably less comprehension problems during communication with the experts but also acquired a substantial amount of knowledge about technical concepts that were previously unknown to them. In addition, the dissertation shed light on the communication problems that occur when experts form a flawed mental model about their communication partner and thus tend to over- or underestimate their knowledge state. The experiment on experts' over- and underestimations is the first study to empirically show the negative impact on communication when erroneous assumptions about the communication partner are the determining factor in message production. The think-aloud study presented in this dissertation further deepens and extends previous research on communication by verifying that partner adaptation occurring at a semantic rather than only at a lexical level is an important prerequisite for effective communication between experts and laypersons. Furthermore, the analysis of experts' cognitive processes yielded insights in how experts – when planning and designing explanations for laypersons – were able to keep track of the limited domain knowledge state of their communication partner in a way that was separate from their own specialist knowledge. Altogether, these results substantiate Clark's communication theory (1992, 1996) as well as Nickerson's anchoring-and-adjustment model (1999) and underscore that a mental model about the communication partner should be regarded as an essential element in theories of language production – at least when the knowledge between the communication partners greatly differs.

Besides these theoretical considerations, the empirical findings show that the assessment tool is a promising and parsimonious approach to support Internet-based communication between experts and laypersons. Thus, the tool could be a valuable supplement to e-commerce systems in the Internet. The vigorous competition in the online marketplace forces online firms more and more to implement business strategies that serve customers as individuals. This trend towards personalisation offers new opportunities for companies to differentiate themselves from more standardised services and to create competitive advan-

tages in the global marketplace. Research has already documented the advantages of personalisation techniques in the Internet for customer satisfaction. Websites that integrate human experts in the process of information- and advice-giving might benefit from an assessment tool because it provides additional value to customers and their experience of being treated as individuals.

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