The Impact of External Representations on Providing Online Instructions

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Abstract

In the following paper, we report on two studies which test for possible detrimental effects of external representations in a scenario where experts respond to email inquiries in medical advice. Based on research on expert-layperson-communication we assume that experts' extensive and highly integrated knowledge of their own domain makes it very difficult for them to comprehend the completely different perspective of a layperson. Such an immersion into one's own, privileged knowledge is exacerbated through the availability of external representations (e.g. diagrams of body functions). We hypothesize that especially visualizations which make the subject matter immediately evident for the expert, have such a detrimental effect. Varying the complexity of an external representation, only available to the expert, we established furthermore that an "easier", that is, a less complex illustration, produces less audience-designed answers than a much more demanding and complex illustration.

Introduction

Most research on learning from external representations focuses on individual learning, concentrating, for example, on the integration of text and graphics when acquiring science or technology concepts (Glenberg & Langston, 1992; Carney & Levin, 2002). Recently, a second (so far, smaller) strand of research has emerged focusing on *shared* external representations in interactions, for example in computer mediated collaborative learning (see, for example, Suthers & Hundhausen, 2003; Conole, Dyke, Oliver, & Seale, 2004) and communication (Healey, Swoboda, Umata, & Katagiri, 2002). This research interest has been accelerated by the fact that external representations are much easier to access, copy and distribute in computer-mediated- than in face-to-face communication. Computer-mediated-communication also entails *instructing* using *non-shared* external representations. Examples of such situations are hotline settings where experts respond to inquiries. In such scenarios, experts often have access to data bases, including graphic representations, which are intended to support their responses. This scenario has not been the focus of research until now, but it is nevertheless an interesting case for identifying the impact of non-shared external representations on communication in any instructional context.

In the following paper, we report on two studies which test for possible detrimental effects of external representations in such a scenario where experts respond to email inquiries. Why do we suggest that there are detrimental effects? Research on expertise provides evidence that experts not only know more than laypersons, but they also have a different way of structuring their domain-specific knowledge. Training and experience mould people's perception regarding what is important in their work, so that they view it in a specific way. There is substantial evidence that experts have difficulty in adapting their advice to the informational needs of laypersons. One can assume that experts' extensive and highly integrated knowledge of their own domain makes it very difficult for them to comprehend the completely different perspective of a layperson. This was termed 'the curse of expertise' by Hinds (1999), whose experimental study demonstrates that experts underestimate the difficulties novices face when performing a complex task (also see Bromme, Rambow, & Nückles, 2001; Hinds, Patterson, & Pfeffer, 2001, for studies on similar expertise effects). Particularly in the medical field, many research findings indicate that experts do not orientate their explanations towards laypersons' ability to understand what they hear or read (Bromme, Jucks, & Wagner, in press; Boyle, 1970).

Keysar, Barr, and Horton (1998) have demonstrated that even in everyday situations, people use '*privileged information'*, i.e. information that is only available to themselves and not to their communication partner. When experts instruct non-experts, their expert knowledge (for example of medical issues) can be regarded as privileged information per se. In computer-mediated-communication however, we assume that such an immersion into one's own, privileged knowledge is exacerbated through the availability of external representations (e.g. diagrams of body functions). We hypothesize that especially visualizations which make the subject matter immediately evident for the expert, have such a detrimental effect *(privileged information hypothesis)*. Hence, the *first aim of our experiments* is to explore the impact of external representations on expert adaptation to a layperson audience.

For our study we selected the field of online medical advice, and thus a situation in which experts respond to written requests by writing emails to the person who has sent a question. In such settings, the expert often has no further information, beyond the question itself, available about the sender and, because feedback is either lacking (if there is a one-turn interaction) or at least time-delayed, adaptation to the knowledge level becomes both very important and very difficult. In cases where the speaker takes into account the partner's level of knowledge when planning and formulating a response, Clark and Murphy (1982) used the term *audience design.*

One could argue that experts who are knowledgeable in their own field, but have no further educational training, have difficulties in providing any audience design at all. In other words, they reproduce their knowledge in a non-adapted way, just as it is represented in their mental model, by means for example of technical language and by organizing their message according to their own knowledge structures.

It could, therefore, be argued that (possible) detrimental effects of non-shared visualizations would not only result from assumed immersion into expert knowledge, but would reflect a general lack of ability to adapt their answers to different audiences. Therefore, in our experiments, we not only vary the availability of external representations, but also the target audience. In our experiments, we require experts to answer requests from laypersons as well as requests from co-experts (i.e. a person who has overlapping background knowledge on the subject matter). By doing so, we can determine whether our experts adapt to different audiences at all. Clark and Murphy (1982) argue that speech partners apply certain heuristics to help them adapt their messages to the knowledge of their interlocutors. These heuristics enable an economical structuring of communicational contributions (in accordance with the maxim of quantity proposed by Grice, 1989). Knowledge presumed to be common ground does not have to be explained again. One heuristic is particularly relevant to the experiments described below. It derives from the perceived group membership of the communication partner (*community membership heuristic),* the criteria being age, sex, nationality and, very important in this regard, the perceived level of expertise of the communication partner (Isaacs & Clark, 1987; Clark & Marshall, 1981). We assume that experts apply this heuristic when they give online instructions and communicate their knowledge differently to a less and a more knowledgeable addressee *(community membership hypothesis)*. In our experiments, our expert-participants respond to requests written by (fictitious) persons, that are either introduced as co-experts or laypersons.

Hence, we address the following two questions: 1) do experts adapt to the recipient's knowledge status (co-expert vs. layperson) and 2) do graphic illustrations impact on the way answers are formulated?

Experiment 1

Method

Participants. A sample of advanced pharmacy students from German universities participated in the experiment. On average, participants were in their 4th year of university education (M = 7.09 semester, SD = 1.31) and between 21 and 37 years of age (M = 25.47, SD = 3.16). 68 % of our sample was female. Furthermore, we administered a test of pharmaceutical-medical knowledge which matched the topic of the explanatory task. On average, the participants answered 16 out of 18 items correctly (SD = 1.32). It should be noted that in our context the concept of 'expert' is used in contrast to laypersons, not to novices, unlike many studies where experts and novices *within* medicine are compared (for a more detailed discussion of this distinction see Bromme, Rambow, & Nückles, 2001). Therefore it was possible to run this study with advanced medical students as 'experts'. In the context of our research, the domain-related knowledge is critical.

Materials. ***Inquiries***. The participants worked with an inquiry that was introduced to them as written by a layperson on the topic of laxatives, and with an inquiry introduced as written by a co-expert in another field (medicine instead of pharmacy) on the same topic. The topic of laxatives and especially their misuse is frequently the subject matter of communication between pharmacists and their patients and can, therefore, be seen as relevant to expert-layperson communication in health-related areas. The inquiry from the fictitious medical expert was identical in content, but more specialized terminology was used than in the inquiry from the layperson, so that the text of the inquiry matched the information on expertise status. After receiving the inquiry, participants were asked to explain to the respective addressees the link between the use of laxatives and potassium deficiency and its effects.

External representations. The *graphic illustration* – used in the appropriate experimental condition – showed the relationship between the use of laxatives and potassium deficiency. It was necessary for the depiction to be clear enough for the expert to identify the relevant information. On the other hand, we had to ensure that laypersons without prior knowledge, did not profit from it unduly. This was ensured in a preceding experiment with laypersons. Figure 1 shows the illustration.

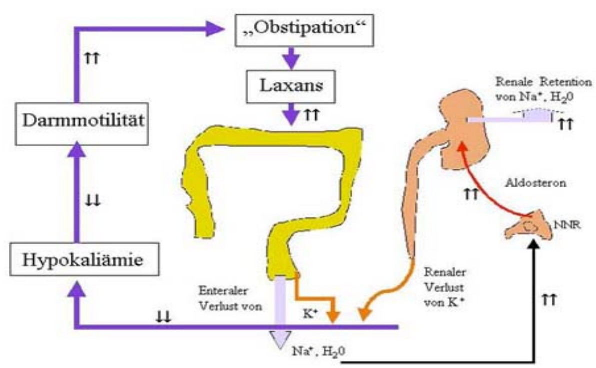

Figure 1: Illustration on the topic of laxatives.

As a further experimental condition, experts were given a *list of key words* which contained the same terms in the same sequence (starting with Obstipation) as those depicted in the illustration. This condition without a graphic representation ensures that the specialist concepts relevant to the explanatory task were salient in a similar manner.

Design and Procedure. The entire experiment was conducted online using an internet browser. The data bank program FileMaker® was used to store the data. The experimental environment was closed, i.e. only people who had received an invitation could take part. A 2 x 2 factorial design was used, whereby the factor 'addressee' was carried out in a within-subject-design (2 levels) and the external representation was manipulated in a between-subject-design.[1] Table 1 provides information about the experimental design.

The experimental environment consisted of web pages that could only be viewed in a predetermined sequence. First, a brief introduction to the task was given. Participants were told, that the goal of the study is to analyze the communicative behavior of experts in email situations. They were not informed about the different experimental conditions. Participants were asked to answer several questions about their computer and internet use before they proceeded to answer the two inquiries. Once the first answer was completed and sent, it was no longer possible either to review or to edit it.

Table 1: Experimental design.

	Addressee	
External representation	layperson	medical expert
Illustration	$n = 17$	
Bullet list of keywords	$n = 17$	

The experiment ended with the domain-specific knowledge test, some demographic questions and questions about participants' attitudes to online health counseling. The average participation time was 45 minutes.

Dependent variables. The answers given by the experts were analyzed by means of a content analysis. Linguistic structural characteristics of the texts were used to determine the audience design of the experts. In so doing, we based our work on variables that had been used in the psycholinguistic studies on audience design mentioned earlier in this paper. We also included variables from instructional psychology. It can be assumed that these structural characteristics are relevant to recipients' text understanding (e.g. using examples, cf. Reimann, 1997). Experts' answers were examined in terms of the following parameters:

Number of words. The total number of words used by experts in the explanatory phase was counted.

Use of medical language (ML) terms. Many medical concepts (at least those covered within such hotline scenarios) can be put in different kinds of words: the specialist term with a Greek or Latin origin and a German translation, which is commonly used by laypeople. For example, 'Laxans' for laxatives and the German 'translation' 'Abführmittel' (The German language has more of such commonly used non-technical terms than for example the English language.). Therefore one can differentiate between a more technical use of language/words and a more 'common' one. This is very significant to our research context, because it signaled whether a layperson's perspective was used. A bullet list was made of all the specialist terms used in the answers from the experts. There were 43 terms in all, 21 of which were used in the explanations to both, laypersons and medical experts, with an average usage rate of at least 10 %. We analyzed how often the terms were used in the answers to both groups of addressees. For further differentiation, these 21 terms were distinguished with respect to specialist terms already contained in the material and those which were not contained in the material. 12 terms were identified as already present in the material. These appeared in the external representations and/or in the inquiries. Experts introduced the remaining 9 terms of their own accord.

Use of direct address. The number of times the expert addressed his explanation directly to the (fictitious) recipient was counted by counting the pronouns indicating a direct reference to the patient as the recipient of the written answer (e.g. you, yours).

Both, the amount of ML terms and the use of direct address were assessed by going through a definite list of words. Hence, no interrater agreement was measured.

Content of the answers. In addition to examining the use of words, we used content analysis to answer the question: what did the experts write about? The explanatory task was the same for both addressees. Nevertheless, experts had some scope with regard to the choice of *content* for the reply. In total, 28 themes were identified which could be divided into three categories: 13 themes were classified as *behavioral tips*, 9 as *closely related* to the explanatory task and the remaining 6 as *broadly related* to the explanatory task. Thus, information about a chemical laxative being better than a vegetable laxative is considered a tip, while information about potassium being important for preventing obstipation is classified as an argument closely related to the explanatory task. On the other hand, information that laxatives help food pass through the digestive system quickly, while not allowing the body to absorb potassium, is considered to be only broadly related to the explanatory task. The interrater agreement was $r = .74$ for themes broadly related to the explanatory task, $r = .81$ for themes closely related to the explanatory task and $r = .84$ for classification of behavioral tips.

Examples. An example was identified when the expert used certain expressions (e.g. "for example" or "like") in combination with descriptions that referred to different instances of the same category object (e.g. listings of different drugs, certain foods). Interrater reliability for the total number of examples in answers was $r = .70$.

Perceived helpfulness of external representation. At the end of the experiment, experts rated on a five point scale (from 1 = "not at all" to 5 = "very") how helpful they perceived the given material to be for explaining the subject matter. This question was presented twice, once with regard to answering the layperson's inquiry and the second time with regard to the answer in the co-expert's inquiry.

Results

Groups did not differ with regard to age, gender and knowledge about the topic, all $t(32) < 1.40$, *ns*.

[1] In both, the first and the second experiment, a third independent condition was assigned to a further group of participants providing them with the same but *shared* illustration. This condition is not described here, as it was used to gather data that falls outside the scope of this article. The data are reported elsewhere (Jucks, Bromme, & Runde, 2003). The theoretical background to the entire research project is described in Bromme, Jucks, and Runde (2005).

Using all six groups of dependent variables, both main effects yielded significant differences, both $F(9, 24) > 2.90$, $p < .05$. The addressee by representational form interaction was not significant, $F(9, 25) = 0.79$, *ns*. Univariate analyses for both main effects provide the following result pattern:

With the exception of information that is closely related to the inquiry, expert-participants answered the query from the layperson differently to that from a medical expert. The layperson received more words, more direct address, more examples, more behavior-related tips, less information that is more broadly related to the content of the inquiry and fewer medical terms (both those that had been used in the materials and those that had been not) than medical experts, all $F(1, 32) > 9.40$, $p < .001$.

Furthermore, experts perceived the external representation to be more helpful in answering the medical expert's inquiry ($M = 4.35$, $SD = 0.77$) than answering the layperson's inquiry ($M = 2.94$, $SD = 1.37$), $F(1, 32) = 35.86$, $p < .001$.

Answering the queries having the illustration at hand versus having the bullet list at hand, yielded differences only with regard to three content-indicators: experts in the condition 'illustration' gave more information that is closely related to the inquiry, provided their recipient with fewer behavior-related tips and fewer examples than experts with the bullet list, all $F(1, 32) > 6.20$, $p < .05$. Furthermore, experts perceived the illustration to be more helpful in explaining the topic ($M = 4.03$, $SE = .19$) than the 'bullet list of keywords' ($M = 3.27$, $SE = .19$), $F(1, 32) = 8.24$, $p < .01$. No further differences occurred, all $F(1, 32) < 2.40$, ns.

Discussion

Did experts apply the community membership heuristic? The results show that participants adapted their explanations significantly, according to the knowledge they expected from a layperson or a medical expert. When giving an explanation to a layperson, they used fewer specialist terms than when addressing a medical expert. Besides, in their replies to the layperson, experts explained issues in more detail, using more direct address and illustrative examples than in their explanations to medical experts. Concerning the selection of topics, experts also adapted to the (fictitious) recipient. The layperson received more behavior-related tips and fewer broadly related, additional specialist information about bio-chemical processes than medical experts. Only with respect to the use of themes closely related to the task itself, no distinction was made between laypersons and medical experts. These themes formed the core of the explanatory task and left, therefore, little 'room for manoeuvre'.

Did the illustration impact on expert's instructions? The comparison shows a considerable impact of the external representation format on the content referred to. Experts who had a illustration available when replying to the inquiries (even though the illustration was not available to the recipient), used significantly fewer examples than experts who had a bullet list of key words to work with. In addition, more 'themes closely related' to the explanatory task were addressed when experts had an illustration, rather than a bullet list of key words. This suggests that experts in the condition 'illustration' quite clearly turned to the illustration when selecting content, 'ticking off' the items of information one by one. Hence, the representation format had a very substantial impact on the explanations, even when the explanatory task remained the same.

Nevertheless, it can be ruled out that the illustration required more effort of the experts and produced more cognitive load than the bullet list of keywords. Those topics that are broadly related to the explanatory task as well the number of medical terms yielded no differences between the two conditions. The variables 'use of direct address' and 'length of explanations', also yielded no differences between the various external representation formats.

So far, the results of Experiment 1 allow the following interpretation: the comparison between explanations written for a layperson and those written for a co-expert reveals clearly that our participants are able to adapt their answers to different audiences. Nevertheless their explanations became more 'expert'-like when written with a scientific illustration on hand. Hence, their addressee-orientation decreases. Paradoxically our expert-participants regarded the illustration as more helpful in communicating with their recipients than the bullet list of keywords. It seems that they suffered from an insider bias, and accordingly concluded that what is easy for them to understand is also transparent to a less knowledgeable person.

One could argue that the illustration was 'tempting' as it was relatively easy to understand at least for experts. Does a more 'scientific' illustration also focus experts on the subject matter and reduce their addressee-orientation? Study 2 was conducted in order to answer this question using a more complex illustration.

Experiment 2

Method

Participants. A new sample of advanced pharmacy students from German universities participated in the experiment. On average, participants were in their 5^{th} year of university education ($M = 8.50$ semester, $SD = 0.55$) and between 24 and 33 years of age ($M = 26.91$, $SD = 2.69$). A total of 46 % of our sample was female. On average, the participants answered 16 of 18 items from the domain-specific test correctly ($SD = 1.14$). Data from 35 persons was used for the following analysis. Eighteen were randomly assigned to the condition 'illustration' and seventeen to the condition 'bullet list of keywords'.

Materials. ***Inquiries***. The same inquiries were used as in the first experiment. ***External representations***. Again, the graphic illustrations – used in the appropriate experimental condition – illustrated the relationship between the use of laxatives and potassium deficiency.

In contrast to the illustration used in Experiment 1, in this experiment, the illustration was more demanding in form and content (see Figure 2). The first half of the illustration depicts those aspects that are relevant to the explanatory task. The bottom part of the illustration shows aspects that have no direct relevance to the explanatory task. The rationale behind choosing this illustration is to increase the ambiguity and therefore, the necessity to decide exactly what contents should be explained. This illustration was also 'translated' into a list of key words.

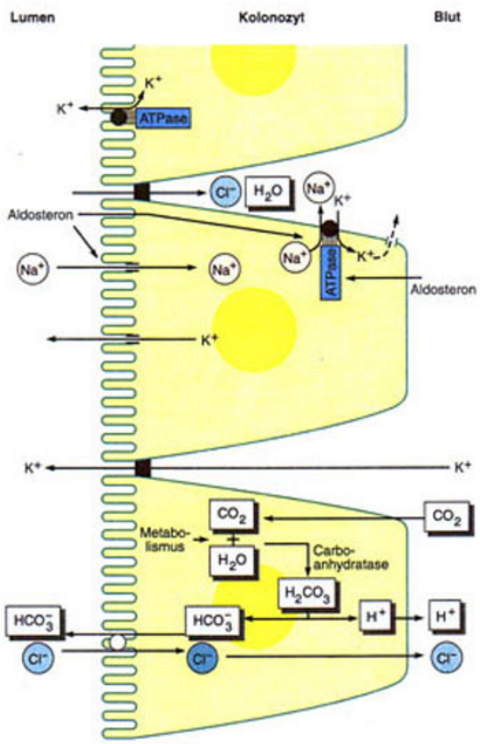

Figure 2: Demanding illustration on the topic of laxatives

The experimental design, procedure, and dependent variables were administered identically in Experiments 1 and 2.

Results

The groups did not differ with regard to age, gender and knowledge of the topic, all $t(33) < 2.00$, *ns*.

Using all six groups of dependent variables, both main effects yielded significant differences, both $F(9, 25) > 2.90$, $p < .05$. The addressee by representation form interaction was not significant, $F(9, 25) = 1.59$, *ns*. Univariate analyses for both main effects provide the following result pattern:

Expert-participants answered the query of the layperson differently than the query of the medical expert. The layperson received more words, more direct address, more examples, more behavior-related tips, and fewer medical terms (both those that had been used in the materials and those that had been not), all $F(1, 33) > 4.72$, $p < .05$. With regard to information that is closely related and information that is more broadly related to the content of the inquiry no differences occurred on the factor addressee, both $F(1, 33) < 3.00$, *ns*.

Experts perceived the external representation to be more helpful in answering the medical expert's inquiry ($M = 3.29$, $SD = 1.05$) than in answering the layperson's inquiry ($M = 1.94$, $SD = 0.91$), $F(1, 33) = 58.82$, $p < .001$.

Answering the queries with the illustration, versus having the bullet list on hand, provided differences only with regard to two content-indicators: With regard to information that is broadly related to the inquiry and behavior-related tips no differences occurred between the two representation forms, both $F(1, 33) > 3.20$, $p < .10$.

Furthermore, experts perceived the bullet list to be more helpful for explaining the topic ($M = 3.00$, $SE = .18$) than the illustration ($M = 2.25$, $SE = .17$), $F(1, 33) = 9.48$, $p < .001$. No further differences occurred, all $F(1, 33) < 2.18$, *ns*.

Discussion of study 2

Regarding the community membership hypothesis, the results correspond exactly to the results of Experiment 1. Again, experts answering an inquiry from a layperson used fewer specialist terms, experts explained issues in more detail, used more direct address and illustrative examples than in their explanations to medical experts. Furthermore, they provided the layperson with more behavior-related tips.

With respect to the privileged information hypothesis, the results are different from those in Experiment 1. Again, the illustration had a different impact on experts' answers than the bullet list of keywords. In contrast to Experiment 1, experts perceived the illustration provided in Experiment 2 to be less helpful in answering the inquiries than the bullet list of keywords. Furthermore, they provided the lay addressee with more behavior-related tips when they had the illustration rather than the bullet list. Hence, the conclusion can be drawn that experts perceive how demanding the illustration is and thus devote additional effort to answering the inquiries in a comprehensible manner.

General discussion

In the two experiments, an online instructional setting between experts and their recipients was modeled. Both experiments clearly indicate that medical experts adapt their answers to their recipients' needs. Our expert-participants provided the lay recipient with less technical and more illustrated information than the expert from a different, but related field. Hence, community membership of the recipient was considered in answering the two queries.

Furthermore, both experiments provide evidence that scientific illustrations exert a particular impact on the form and content of replies. In Experiment 1, experts – in the appropriate experimental condition – had an illustration that they regarded as helpful in explaining the subject matter. This illustration, although containing scientific information, is more straightforward and directly focused on the relevant issues than the second illustration. The latter was, again from experts' own perspective, perceived as *not* helpful for answering the inquiries. Strikingly, content analyses provide evidence of the opposite effect. With the 'helpful' illustration on hand, experts seemed to have "left their lay addressee behind". They went into more detail than necessary, leaving out examples and behavior-related tips in contrast to those experts who worked with the bullet list of keywords.

Although our participants adapted their explanations to the respective knowledge level of the addressee, when writing with an illustration the answers became more expert-like. In contrast, working with the 'unhelpful' illustration, experts provided their audience with more behavior-related tips and less additional information which is only broadly related to the subject matter than experts using the bullet list.

A possible explanation of the differences is that the same underlying cognitive mechanism becomes relevant: once experts focus on the illustration, and perceive it as useful for their job, they get involved, use it, and it impacts directly on the answer. If they immediately "see" how demanding the material is and perceive the illustration to be unhelpful, they counteract the impact of the illustration by providing a comprehensible and comprehensive explanation. Hence, the availability of an illustration that looks rather easy to experts while they instruct, could be rather detrimental.

It has to be emphasized that the 'expert-like' style of answering the questions is characterized by a stronger focus on the physiological mechanisms, in other words on the critical biological and chemical concepts necessary to understand how laxatives work. Under certain circumstances it might be desirable for medical experts to focus on such science-based explanations, even when answering laypersons' questions. Such a focus on *explaining* science concepts instead of delivering mere instructions about how to behave as a patient and instead of delivering treatments without any justification might be preferable under certain circumstances (Runde, Bromme & Jucks, submitted). Nevertheless, such a focus should be the result of a purposeful decision of the expert and it should not simply be triggered by the availability of a non-shared external representation.

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