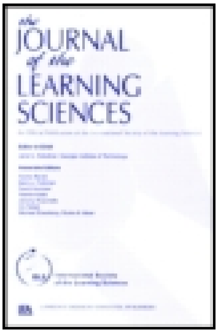

Journal of the Learning Sciences
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hlns20

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Published online: 17 Nov 2009.

THE JOURNAL OF THE LEARNING SCIENCES, *14*(2), 201–241

Learning to Collaborate: An Instructional Approach to Promoting Collaborative Problem Solving in Computer-Mediated Settings

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Effective collaboration in computer-mediated settings among spatially distributed people is a precondition for success in many new learning and working contexts but it is hard to achieve. We have developed two instructional approaches to improve collaboration in such settings by promoting people's capabilities to collaborate in a fruitful way and furthering their understanding of what characterizes good collaboration. The rationale is that strategies necessary for a good and effective computer-mediated collaboration may be conveyed to people by exposing them to an elaborated worked-out collaboration example (observational learning) or by giving them the opportunity to learn from scripted collaborative problem-solving. An experimental study was conducted that compared learning from observing a worked-out collaboration example with the learning effects of scripted collaborative problem-solving, the effects of unscripted collaborative problem-solving, and a control condition without a learning phase. The experimental design provided clearly separated phases for the instructional treatments (learning phase) and for applying and testing the acquired skills (application phase). Both observing a worked-out collaboration example and collaborating with a script during the learning phase showed positive effects on process and outcome of the second collaboration in the application phase.

The dynamically evolving technological solutions for computer-mediated communication have brought about new possibilities for collaboration among spatially distributed people. In working contexts such as remote surgery, web design, or the

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assessment of cases in international law firms, the use of technology for remote collaboration is on the increase (Leskovac, 1998; Nardi, Kuchinsky, Whittaker, Leichner & Schwarz, 1997; Whittaker, 1995). In consequence, computer-mediated collaboration has moved into the focus of technological, organizational, and – more recently – educational and psychological research (Koschmann, 1996; Koschmann, Hall & Miyake, 2002).

However, although computer-mediated collaboration provides great opportunities for joint problem-solving across barriers of time and distance, the successful use of such settings cannot be taken trivially. Difficulties arise concerning the coordination of the joint solution of the task at hand (i.e. with regard to work coordination such as managing time, division of labor, and integrating individual contributions; Daly, 1993; Hiltz, Johnson & Turoff, 1986, Hermann, Rummel & Spada, 2001) as well as the communication (turn-taking, giving feedback, mutual understanding; McKinlay, Procter, Masting, Woodburn, & Arnott, 1994; O'Conaill & Whittaker, 1997). Without adequate support, collaborating partners often fail to complete their joint task or find that it requires too much time and effort (Anderson et al., 1997; Galegher, Kraut & Egido, 1990; Olson et al., 1993; Straus & McGrath, 1994).

The development of effective support measures depends upon the following questions: What constitutes good collaboration in computer-mediated settings? And how can such collaboration be achieved? It is the assumption of this article that people's capabilities for good collaboration through appropriate forms of instruction can be promoted.

To test the effectiveness of the instructional measures we propose, an experimental study was conducted. Learning effects resulting from observing a worked-out collaboration example were compared to those of scripted collaborative problem-solving, the learning effects of unscripted collaborative problem-solving, and a control condition without a learning phase.

REMOTE COLLABORATION

A Scenario

Picture the following scenario: A medical doctor and a psychologist are asked to collaborate on solving a complicated clinical case. As the case involves both a physical illness, multiple sclerosis, and psychopathological symptoms, the assessment requires the two individuals to make use of their complementary expertise. Their joint task is to formulate a report that includes a detailed diagnosis for the patient and a proposal of a suitable therapy. The two experts are not able to meet in person as they work at distant locations and cannot afford the time to meet. Instead, they have decided to take advantage of a desktop videoconferencing system that has recently been implemented at both of their institutions.

The challenges of this type of scenario include solving a complex task collaboratively on the basis of complementary domain knowledge of the collaborating partners, and the difficulties of communicating and collaborating in a computer-mediated setting. In the following, we will discuss these challenges in more detail. We will describe the technical setting, define what is meant by "collaboration", and outline why support is necessary. Finally, we will describe the characteristics of a good collaboration in this and similar working contexts.

Characteristics of Desktop Videoconferences

Desktop videoconferencing systems constitute one particular instance of remote computer-mediated collaboration (Finn, 1997). In a desktop videoconference, participants in different locations each sit at their individual computers and communicate with one another via an audio-video connection. On the computer screen they can see video pictures of the remote partners. These are captured by a small camera on top or to the side of the computer screen. There is also an audio channel. In addition, these systems often include shared applications (e.g. Word documents, Excel spreadsheets, or visualization tools; Whittaker, Geelhoed & Robinson, 1993). The shared applications offer the possibility for joint manipulation of objects, data, or documents in a workspace that is visible and accessible for all participants simultaneously (Dillenbourg & Traum, 1999; Gürer, Kozma & Millán, 1999; Whittaker et al., 1993).

The Collaborative Task

How can we characterize the collaboration required in the given type of scenario? Following the discussion by Dillenbourg (1999, p. 9 ff), three dimensions characterize a collaborative situation. The first dimension is *symmetry*, which Dillenbourg further divides into symmetry of possible actions, symmetry of knowledge, and symmetry of status. In this scenario, the desktop-videoconference setting sets the stage for symmetry of action. Both partners can equally hear and talk to each other; both have equal access to a shared text editor as well as to individual text editors. Symmetry of knowledge and status is also given as each of the two partners is an expert in his respective domain. As we have described above, the collaboration in this scenario rests on the "complementary expertise" of the partners. In other words, although they possess different knowledge, the level of their "knowledgeability" is symmetric.

The second dimension of a collaborative situation that Dillenbourg (1999, p. 10) describes is that the partners have *common goals* – as opposed to conflicting goals that would characterize a competitive situation. Common overarching goals, however, do not preclude diverging opinions at the subgoal level. The repeated negotiation of shared goals over the course of a collaboration is part of constructing and maintaining common ground. In the present scenario, the overarching common goal is to come to a diagnosis and develop a therapy plan for the patient under scrutiny. However, the subgoals of how to get there have to be set and negotiated by the partners.

The third constitutive dimension of a collaborative situation according to Dillenbourg (1999, p. 11) is the *division of labor* among the partners. This dimension has sometimes been used to distinguish between "cooperation" and "collaboration". *Cooperation* has been described as including a division of labor, the parallel independent solution of subtasks, and the combination of individual contributions in a joint product. *Collaboration*, however, has been defined as doing the work together. Following this distinction makes it hard to decide where to place our type of scenario. On the one hand, it is cooperative in that both partners will contribute to the joint solution in different ways due to their complementary expertise. At some points, a division of labor and individual work on subtasks will be inevitable. On the other hand, one could also define the task as collaborative because the partners will maintain an immediate interactive contact over the videoconference for the entire time. Without collaboration, a joint solution integrating both the medical and the psychological perspective would be impossible. In fact, Dillenbourg argues that the distinction between cooperation and collaboration according to the criterion of division of labor is somewhat arbitrary. In accordance with his arguments, we use the terms *cooperation* and *collaboration* synonymously.

Constraints and Challenges: Why Support is Necessary

Extensive research has shown that the success of collaborative efforts does not occur by itself (Johnson & Johnson, 1992; McGrath, 1984; Salomon & Globerson, 1989). Without systematic support, people differ greatly in the way in which they collaborate, depending on a variety of interacting conditions like group size, group composition, collaborative task, or the media used for communication (Dillenbourg, Baker, Blaye & O'Malley, 1995). Some groups collaborate quite efficiently and with good success even when left to their own devices. However, the majority of collaborations only succeed with adequate support.

In addition to this very general argument, two more particular aspects of the present scenario call for the support of the collaborating partners. Collaboration is particularly difficult in the case of "complementary expertise" of the collaborating partners, as in the scenario outlined above. In fact, such collaboration is considered to be the key to a successful exploration of complex phenomena, where taking into account only one perspective would fall short (Gibbons et al., 1994; Ploetzner, Fehse, Kneser & Spada, 1999). However, at the same time, interdisciplinary collaboration is not an easy undertaking (Lewis & Sycara; 1993; Bromme 2000). Problems known to be symptomatic for collaborative learning and problem-solving in general, for example, instantiating and sustaining "convergence" (Roschelle

& Teasley, 1995), coordinating the collaboration (Barron, 2000; Malone & Crowston, 1990), and pooling unshared knowledge (Stasser & Titus, 1985) apply to an even greater extent to interdisciplinary collaboration (Stasser, Stewart & Wittenbaum, 1995). A well-balanced proportion of individual and joint work phases is of central importance for the quality of the problem-solving process (Hermann et al., 2001). Allowing enough time for individual work is crucial to ensure that the partners can bring their individual domain knowledge to bear.

The second aspect concerns the nature of the computer-mediated setting. Depending on the quality of the audio and video transmission, videoconferencing systems appear to offer something approximating face-to-face conditions for collaboration. However, research in video-mediated communication has shown that communicational behavior in video-conference settings is different to that in real face-to-face settings (Anderson et al., 1997; O'Conaill & Whittaker, 1997). Even with a good technical quality the exchange of nonverbal cues is impeded and eye contact is usually impossible so that any collaborative activity requires additional and more explicit effort (Anderson et al., 1997). This concerns, for example, the processes of grounding (Clark & Brennan, 1991), turn-taking, or giving feedback. O'Conaill and Whittaker (1997) concluded that in video-mediated collaboration, explicit coordination of the communicative process requires extra effort.

In view of the challenges outlined above, the collaboration, and specifically its coordination, need to be supported to ensure well-coordinated, efficient work. Before we discuss possible ways of providing such support, however, it is necessary to define what a desirable collaboration in the given scenario might look like.

CHARACTERISTICS OF A GOOD COLLABORATION

All approaches to facilitate successful collaboration are in need of sound evidence concerning what aspects characterize a good collaboration. Such information is important for designing support measures and for evaluating their effects. However, up to now, research on computer-mediated collaboration has been lacking in theory. As a comprehensive theory is missing, we have integrated empirical findings from different strands of research in our attempt to define relevant characteristics of a good collaboration.

On a "macro" level, the coordination of the joint work is of great importance (managing time, dividing labor, pooling unshared knowledge, balancing individual and joint work phases, integrating individual contributions). On a "micro" level, crucial aspects of a good collaboration relate to the communication (mutual understanding, feedback, turn-taking). With regard to the type of task at hand, domain-specific requirements of a good joint solution can be identified. In the following, these three levels of good collaboration will be described in more detail and specified for the scenario at hand.

Macro Level: Coordination

To ensure efficient work in the present scenario, it is crucial to coordinate the collaborative process in an appropriate way (Barron, 2000; Olson, Malone & Smith, 2001; Malone & Crowston, 1990). Coordination has to serve several goals here: to specify the objectives of the work and reach a shared task alignment, to arrange the division of tasks between the partners, to manage their temporal synchronization, and to establish a chronological order of activities. Further, a central goal of the coordination is to ensure the consistency of the joint work product, which means integrating partial solutions of the partners. Particularly in the case of complementary expertise of the partners the question of joint and individual working phases has to be considered (Hermann et al., 2001). On the one hand, allowing enough time for individual work is of great importance to ensure that the partners can incorporate their disciplinary domain knowledge. On the other hand, joint work phases with fruitful discussion of individual opinions are indispensable to ensure the exchange of unshared information. A well-balanced proportion of individual and joint work phases is crucial for a successful collaboration.

Micro Level: Communication on the Basis of Complementary Expertise

Establishing and sustaining mutual understanding is a constant challenge in communication, a phenomenon widely known as "grounding" (Baker, Hansen, Joinier & Traum, 1999; Clark & Brennan, 1991). When collaborating partners come from different disciplinary backgrounds, the establishment of a common ground with regard to central concepts is particularly important, yet also particularly difficult. To avoid misunderstandings, it is vital to use the partner as a source for clarifications and to ask appropriate (comprehensible and relevant) questions.

Asking questions is also of central importance to foster the exchange of unshared information. The pooling of unshared information (accessible only to individual members of the group) is one of the crucial aspects of successful collaborative problem-solving and decision-making (Larson, Christensen, Franz & Abbott, 1998; Stasser & Titus, 1985). The failure of collaborating partners to pool their unshared knowledge resources is highly destructive in a situation where the group members mutually depend on each other's knowledge to successfully complete the group task (Johnson & Johnson, 1992). Such a situation arises in the present scenario through the distribution of complementary expertise in the dyad.

Asking appropriate questions and giving answers at a corresponding level of complexity, however, is no simple task (King, 1994; Ploetzner, Dillenbourg, Preier & Traum, 1999). In particular, research on "audience design" in expert-layperson communication (Clark & Murphy, 1982; Jucks, Bromme & Runde, 2003) has revealed that experts tend to underestimate the complexity of the subject and of their explanations. The pitfalls of an "illusion of evidence" (Jucks et al., 2003) have to be avoided when tailoring one's explanations to the knowledge of the partner. The importance of adjusting the level of questions (information asked for) and answers (information provided) is further supported by results summarized by Webb (1989). Only explanations at an appropriate level of elaboration can be of any help to the questioner.

Finally, the way in which two people regulate turn-taking during their communication affects the quality of the collaboration (Sacks, Schlegloff & Jefferson, 1974). The smoother the transitions among speakers, and the less the communication is interrupted by simultaneous talk, the better. Especially in computer-mediated communication settings, explicitly handing over a turn can be a good way of compensating for the reduced possibilities to transmit nonverbal information.

Domain-Specific Demands for a Good Joint Solution

In solving psychiatric cases with combined psychological and physical pathology, specific successful "expert" procedures should be considered (Caspar, 1997). First of all, the diagnosis and planning of an adequate therapy need to be sequenced. Further, within each of the two components, certain procedures have to be followed. It is important to justify the diagnosis from the case description, by describing how it relates to the symptoms listed. For the therapy plan it is important to carefully consider the goals of the therapy before planning concrete measures and methods. In addition, potential difficulties that could affect the success of the therapy need to be discussed. It is again crucial to take into account the complementary expertise within the dyad. A psychologist might interpret a symptom like constant fatigue as an indicator for a diagnosis of depression, although a medical doctor might recognize it as a side effect of some pharmacological treatment. In sum, it is important to enable both partners to utilize their relevant disciplinary knowledge, while at the same time ensuring the consistency of the joint work product.

Exemplary Collaboration

On the basis of the aforementioned considerations, an exemplary collaboration pattern was developed that takes into account processes relevant for a successful collaboration on the task at hand. This exemplary collaboration allowed the determination of elements of good collaboration to be facilitated by instructional measures. It can be outlined as follows:

Overall, a successful collaborative problem-solving process for the present task (solution of psychiatric cases) requires roughly three parts. These include aspects of good collaboration from all three levels (macro, micro, and domain-specific):

In an *initial* phase, the partners coordinate their collaboration both temporally and with regard to content. First, they define the objectives of their task. Then, they take some time to look at the case description once more and formulate questions. Next, they collect information, and mutually ask and try to answer questions about both the case and the joint task – thereby taking advantage of their complementary expertise and using their partner as a resource for clarification. In this phase they also determine the joint course of action. This phase is crucial for an instantiation of mutual understanding, conceptual convergence, and shared task alignment.

The *main part* of the collaboration consists of two subtasks: the development of a joint solution on the diagnosis and the therapy plan. During both subtasks, a four-step pattern should be followed. To start with, an individual work phase should occur, enabling both partners to bring in their disciplinary knowledge. Following this, the individual ideas should be discussed, ensuring the exchange of unshared information. During the discussion, reciprocal understanding needs to be monitored. After the discussion, the individual proposals have to be revised. The partial solutions are then integrated into the joint solution text, and a draft of the joint work product results.

A *final phase* of the collaboration has the goal of ensuring the consistency of the joint work product. The partners revise the joint solution and make final changes.

Figure 1 represents the activity pattern of this exemplary collaboration. The pattern can be divided into 12 phases, which relate to the three parts of the exemplary collaboration described earlier.

Initial phase	1.	short initial coordination: define objectives of task
	2.	scan case description for potential problems with understanding, formulate questions to the partner
	3.	mutually answer questions, coordination: determine course of action (content, time, roles)
Main phase	4.	individually work on **diagnosis**, take individual notes
	5.	exchange notes, discuss individual ideas
	6.	revise individual solutions and formulate final solution for diagnosis
	7.	copy individual parts of solution (diagnosis) in shared editor, integrate
	8.	formulate goals for the **therapy**
	9.	individually work on therapy plan (division of labor!), take individual notes
	10.	exchange notes, discuss individual ideas
	11.	revise individual solutions and formulate final solution for therapy
Final phase	12.	copy individual parts of solution (therapy) in shared editor, integrate, final check of entire joint solution

FIGURE 1 Exemplary collaboration.

Although the diagram does not depict the "micro" aspects of collaboration on the communicative level, it does show the pattern of activities on the macro level. For example, one can see the alternation of individual and joint work phases during the collaboration. As stated above, especially in the case of a complementary knowledge background of the collaborating partners, a well-balanced proportion of phases of joint and individual work is crucial for the success of the collaboration. Each should take up approximately half of the total amount of time.

After having described relevant aspects of a good collaboration, the next step is to search for ways to achieve such interactions.

INSTRUCTIONAL APPROACHES TO PROMOTE COMPUTER-MEDIATED COLLABORATION

So far, most efforts to support computer-mediated collaborative problem-solving and learning have concentrated on direct, online support strategies, for example by shaping certain aspects of the collaborative situation (e.g. the interface), or by structuring the interaction by means of a cooperation script (for an overview, see O'Donnell, 1999). However, these support strategies have been short-term interventions mostly directed towards achieving immediate effects on the outcome of a single collaboration. By contrast, we think that an *instructional approach* could provide a promising way of improving collaboration and its outcome by promoting people's capabilities to collaborate in a fruitful way and furthering their understanding of what characterizes good collaboration. We see a promising approach in following a situated learning perspective (Collins, Brown & Newman, 1989; Greeno and MMAP, 1998; Lave & Wenger, 1991) and introducing collaborators to the "craft of collaborating" by immersing them in a corresponding learning environment, in other words by involving them in "guided" collaborative activities. The idea of a situated approach is that the learning situation should resemble the application situation as closely as possible.

Observational Learning From Worked-Out Examples of Collaborative Problem Solving

One instructional strategy is for people to observe the model of a successful computer-mediated collaborative solution of a problem. We call such a model a "worked-out collaboration example". While observing, people should reflect on the solution steps of the worked-out example and on the behavior of the collaborating partners. Elaborating on what they see in the model can help people to learn what aspects they need to pay attention to during their own collaboration.

Why do we expect a worked-out collaboration example to be a promising instructional means and how should it be designed to offer optimal opportunities for learning? Reimann (1997), Renkl (1997), VanLehn (1996) and others have emphasized that individual learning from worked-out examples can be a successful way of acquiring cognitive skills. Worked-out examples in physics or mathematics consist of a formulation of the problem, a description of the solution steps, and the solution itself. This type of learning is primarily based on the self-explanation of the solution steps (Chi, Bassok, Lewis, Reimann & Glaser; 1989). Sweller and Cooper (1985) have provided evidence that learning from worked-out examples is often more effective than learning by problem-solving due to cognitive overload caused by the demands of unguided problem-solving. In sum, the strengths of worked-out examples are to reduce cognitive load, to focus learners' attention on relevant aspects of the problem-solving process, and to foster the acquisition of adequate problem-solving schemas (VanLehn, 1996). Superficial processing and an illusion of understanding may be counteracted by promoting the elaboration and reflection of the example, especially by eliciting self-explanations (Renkl, Stark, Gruber & Mandl, 1998). Self-explanation activities can be promoted by various instructional measures, for example the provision of supportive instructional explanations (Renkl, 2002).

How do these results on individual learning with worked-out examples transfer to our scenario? First and foremost, our assumptions are supported by a small strand of research that has shown that observational learning can be of special value in the context of dialog and discourse. Stenning and colleagues (1999) have provided empirical evidence that the observation of example dialogs can support the acquisition of dialog competence. Along the same lines, a study by Cox, McKendree, Tobin, Lee, and Mayes (1999) analyzed the effect of reading the content of a tutor-student dialog with positive results on subsequent dialog. Furthermore, in industrial settings, a behavior modeling approach (Goldstein & Sorcher, 1974) based on observational learning (Bandura, 1977) has been shown to be an effective training method for the acquisition of complex behavioral skills (Latham & Saari, 1979, Meyer & Raich, 1983). Analogous to the role of elaboration support in processing worked-out examples, Decker (1984) has shown the importance of "learning points" – instructional explanations accompanying the model's behavior to support deep processing – in behavior modeling training.

Combining these different strands of research, we expect that observing the worked-out example of a well-structured computer-mediated collaboration and reflecting on the solution steps and on the behavior of the collaborating partners constitutes a promising method to learn relevant aspects of a good collaboration.

Learning From Scripted Collaborative Problem Solving

A second instructional approach relates to a well-researched measure to support collaboration: cooperation scripts. The main idea behind the usual application of cooperation scripts is to enforce a fruitfully structured interaction by giving precise instructions on how to interact and thus improve the joint problem-solving and knowledge acquisition. There is sufficient evidence that cooperation scripts can be effective measures for supporting face-to-face collaboration (O'Donnell & Dansereau, 1992; for an overview see O'Donnell, 1999), as well as collaboration in computer-mediated settings (Hron, Hesse, Reinhard & Picard, 1997; Reiserer, Ertl & Mandl, 2002). Reiserer et al. (2002) have particularly extended the application of cooperation scripts to supporting collaboration in desktop-videoconferencing settings.

And yet, cooperation scripts have mostly been implemented as short-term "online" interventions directed towards immediate effects on the outcome of a single collaboration. But what are the long-term effects of cooperation scripts? Would it be possible to script collaboration over many sessions? Following the motivation theory of Deci and Ryan (1985), which identifies self-determination as a major constituent of motivation, cooperation scripts may cause motivational problems, because they often regulate the interaction in too strict a manner. Negative motivational responses of participants are to be expected, particularly in the long term and with adult collaborators (Hron et al., 1997; Bruhn, 2000).

Another critical point may be that being guided by a script does not encourage reflection on the "whys" of the scripting. A failure to develop an understanding of the importance of the specific steps for a good collaboration may prevent deeper learning from occurring with regard to the desired collaborative skills. Moreover, not understanding the "whys" of the phases the script prescribes may increase the negative motivational responses to the script.

From an instructional point of view, the central question is whether the effects of cooperation scripts extend beyond the experimental session in which they were provided, by promoting the capabilities to collaborate and the understanding of collaboration. In short: can people *learn* to collaborate by following a script?

Collaborative Problem Solving Without Instructional Guidance (Unscripted Collaboration)

Another possibility is to involve people in collaborating on a task similar to the ones they will be confronted with later. In the present scenario, this might mean that collaborating partners could gain experience on at least three different levels: experience in performing the steps necessary to solve tasks of this type (problem-solving); experience in jointly working with the specific partner (collaborative problem-solving); and experience in communicating and working with the desktop-videoconference system (computer-mediated collaborative problem-solving). Such collaborative problem-solving without any additional help can be regarded as the most natural but also most restricted form of situated learning. The question is whether relevant learning processes would actually occur in such a situation. Would people pay attention to the critical collaborative processes? Would they reflect upon their interactions and draw appropriate conclusions from these considerations? On the one hand, research on learning by solving problems (DeCorte, 1996; Evensen & Hmelo, 2000) as well as considerations on the potential of learning by doing (Schank, Berman & Macpherson, 1999) hold that this might be possible. On the other hand, however, cognitive load theory (Sweller & Cooper, 1985; Sweller, VanMerriënboer, Paas, 1998) strongly suggests that the demands of problem-solving in such a complex situation might cause cognitive overload and lead to failure of both the problem-solving and the learning process. It can be expected that the present situation will be particularly likely to cause such overload, because the demands of solving the problem at hand are aggravated by the difficulties of working collaboratively and in an interdisciplinary constellation, and by the challenges of computer-mediated interaction.

Learning From a Collaboration Example, a Cooperation Script, and from Unscripted Collaboration: Hypotheses

The central idea of our instructional approach is illustrated in Figure 2. Participants in the conditions with instructional guidance (model and script condition) should

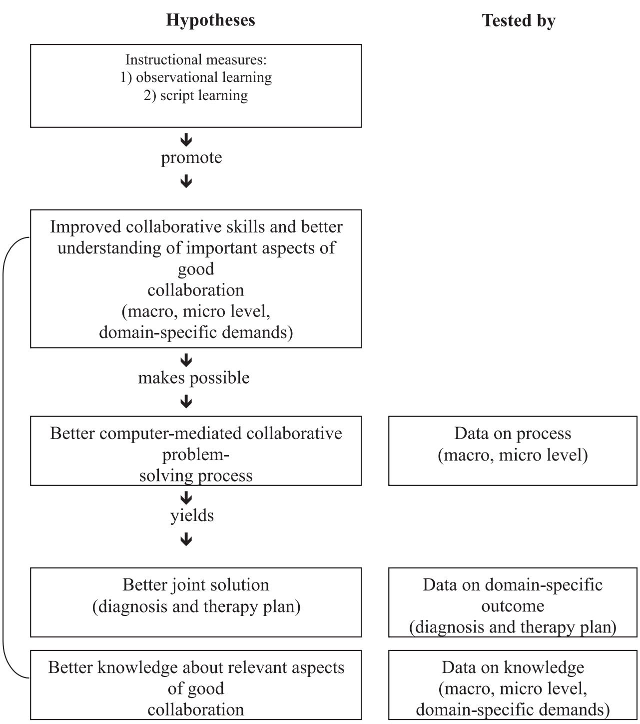

FIGURE 2 Instructional hypotheses and data.

acquire skills on all three levels (micro, macro, domain-specific demands) during the learning phase. These skills should result in better collaborative problem-solving processes and thereby yield better joint solutions. An improved explicit knowledge about meta-aspects of collaboration and about the solution of the task should be a further consequence.

Main hypothesis. We expect to find the following results with regard to performance in a second collaboration following the instructional phase: learning from observing a worked-out collaboration example and learning from scripted collaboration should both show better results than learning from unscripted collaboration and a condition with no opportunity for learning at all. A slight advantage is expected for learning from observing a worked-out collaboration example. This main hypothesis is based on the following assumptions for the individual conditions:

Assumption 1. Providing a worked-out example of well-structured collaborative problem-solving promotes the acquisition of collaborative problem-solving skills. This type of observational learning from a collaboration example should be even move advantageous if elaboration activities are supported by instructional means – for example, explicit stimulation of self-explanatory activities and instructional prompts to direct the observer's attention to relevant aspects of the collaboration example.

Assumption 2. Scripted collaborative problem-solving during a learning phase (= learning from a cooperation script) is expected to lead to collaborative problem-solving skills, which become manifest in the process and outcome of subsequent collaborative work. It must be taken into account, however, that negative motivational responses to the script could lead to learning problems and that being guided through the collaboration by a script does not promote reflection on the various phases. Therefore, a slight disadvantage of the script condition would be expected compared to the model condition.

Assumption 3. Unscripted collaborative problem-solving is not expected to be a very successful measure for promoting collaborative problem-solving skills, because the combination of a new, complex problem, collaboration, and interaction in a new computer-mediated setting is expected to cause cognitive overload.

Experimental statement. To test the effects of the instructional approaches, the experimental design should provide clearly separated phases for learning and for applying the acquired knowledge.

METHOD

An experiment was conducted comparing the three conditions outlined above and a control condition (see Table 1): (a) observational learning from a worked-out example of computer-mediated collaboration (model condition), (b) learning from scripted computer-mediated collaborative problem-solving (script condition), (c) learning from unscripted computer-mediated collaborative problem-solving (unscripted condition), and (d) control condition without a learning phase.

The experimental paradigm set up comprised two phases: a learning phase and a subsequent application phase. During the learning phase, the experimental variation was implemented. The goal of the learning phase was the acquisition of knowledge about elements relevant for a good and potentially successful collaboration. Effects of the experimental variation were then expected to become evident in the application phase, which was the same in all conditions. Aspects of the collaborative problem-solving process during the application phase as well as its outcome – the joint solution – were investigated as dependent variables. Further, explicit knowledge about elements of a good and potentially successful collaboration was assessed in a posttest.

Table 2 shows the interplay of elements of good collaborative problem-solving, their implementation by instructional measures, and their assessment. The table gives an overview of all three levels, the "macro" level of coordinating the collaborative process, the "micro" level of the communication, and the level of domain-specific demands for the joint task solution. The previously identified aspects of good collaboration were implemented in the instructional material of both worked-out collaboration example and script. Although the scenes of the worked-out collaboration example modeled the aspects of good collaboration targeted by the instruction, the script gave participants step-by-step instructions to act correspondingly. The table further shows the dimensions of the assessment. De-

TABLE 1
Experimental Paradigm and Design

Model Condition	*Script Condition*	*Unscripted Condition*	*Control Condition*
Experimental learning phase (case 1)			
Observational learning from a worked-out example of computer-mediated collaboration	Learning from scripted computer-mediated collaborative problem solving	Learning from unscripted computer-mediated collaborative problem solving	No learning phase
Application phase (case 2) In all four conditions: computer-mediated collaborative problem solving			

TABLE 2
Outline of the Elements of Good Collaboration, Their Implementation by Instructional Measures, and Their Assessment

Theory Elements	*Implementation*	*Assessment*
Macro level: Coordination	Promotion of coordinative skills	• Logfiles of activity patterns • Dialogs: Analysis of coordinative categories • Posttest Subscale A
Micro level: Communication	Promotion of communicative skills	• Dialogs: Analysis of communicative categories • Posttest Subscale A
Domain-specific problem solution	Promotion of domain-specific skills	• Quality of the joint solution • Posttest Subscale B

tails on the instruction provided in the experimental conditions as well as details on the process analyses will be provided below.

Collaborative Task

In accordance with the scenario described at the outset, the collaborative task comprised the interdisciplinary solution of psychiatric cases with combined psychological and physical pathology. Dyads of advanced medical and psychology students were asked to jointly diagnose the patients described in the cases and to develop a suitable therapy plan making use of their complementary expertise.

Task material. Two cases were utilized in the experiment. They were constructed by researchers in the field of clinical psychology in collaboration with psychotherapists and psychiatrists and were designed specifically to meet the requirements of this study. In both cases a psychological disorder coincided with some physical illness:

- Case 1: panic disorder and cardiac dysrhythmia
- Case 2: depression and multiple sclerosis

To make the correct diagnosis and map out an adequate therapy plan, medical as well as psychological aspects had to be considered. Therefore, both cases made it necessary to take advantage of the complementary domain knowledge represented in each dyad. Both case descriptions included information about current physical and psychological symptoms, the present living situation as well as details on the personal and medical history. Current medical treatments (e.g. medication) were indicated. It should be emphasized that the contents of the two cases were completely independent from each other. With regard to content knowledge, no transfer was possible from case 1 to case 2.

In addition to the case description, participants were provided with text material about task-specific psychological and medical aspects of diagnosis and treatment. Medical students received different text materials than students of psychology. For example, although medical students were given information on psychopharmacological treatments, psychology students received texts about psychotherapeutic treatments. In this way, the complementarity of domain knowledge, which would be expected to characterize expert physicians and psychologists, was experimentally increased in our participants, who could be seen as having an intermediate level of natural expertise (Boshuizen & Schmidt, 1992).

Participants

Thirty-six advanced students of psychology and 36 advanced students of medical science volunteered to participate in the study. The students were paid for their participation. Thirty-six dyads, each comprising a medical student and a student of psychology, were set up and assigned to one of the four conditions, resulting in a total of 9 dyads in each condition. Prior to the actual study, a questionnaire was sent to students who had indicated an interest in participating, asking for information about: (a) domain knowledge, (b) technical skills, and (c) experience with working collaboratively.

- The level of the students' prior *domain knowledge* was assessed by asking which courses they had attended. Because we were aware of the contents of the courses, we were able assess their level of relevant domain knowledge at least indirectly.
- To estimate the participants' *technical skills* relevant for working with the desktop videoconference, we asked them to answer a number of specific multiple-choice questions designed to ascertain the extent to which they used (a) the World Wide Web for information retrieval, (b) the Internet for communication via E-mail, chat, or newsgroups, and (c) applications like MS Word, Excel, PowerPoint, and other programs.
- With regard to their *prior experience with collaboration,* participants were asked to rate themselves on a five-point scale ranging from "very much" to "hardly any." Next, they were required to specify their collaborative experiences by choosing from a list of alternatives including *where* the experience had taken place (in school, at the workplace, in a sports team) and *what* the collaboration had been about, for example, solving a problem together, peer learning, reaching a joint goal.

For all three areas, a minimum requirement was set and students who did not meet this requirement were excluded from participation. The remaining students were grouped into three levels of proficiency. Dyads were formed comprising people from the same level. The dyads were then randomly assigned to the four conditions, although it was ensured that each condition included an equal number of participants from each level.

Setting

The two partners stayed in separate rooms for the entire experimental session. Their only collaboration was computer-mediated. The computer-mediated scenario consisted of a desktop-videoconferencing environment (VCON, ViGO professional) including audio and video connection, personal text editors and a shared text editor (WordPad shared with MS NetMeeting). As can be seen in the screenshot displayed in Figure 3, each of the two participants of a dyad was able to see the video picture of the remote partner on their individual computer screen. A continuous audio channel provided the possibility to talk to the remote partner. In addition, the shared text editor allowed the two participants to view and also edit

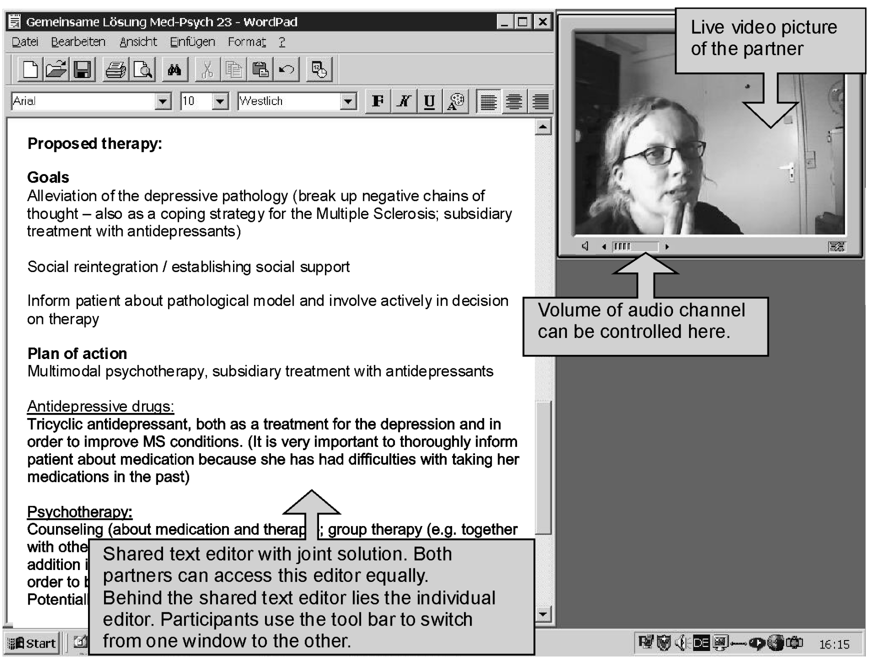

FIGURE 3 Screenshot of desktop videoconference setting.

text jointly. The individual text editors enabled each partner to take notes and write individual text. The scenario supported synchronous verbal communication and joint activities (e.g. editing of the joint solution) as well as individual work phases.

Learning Phase: Experimental Conditions

The contents that were to be conveyed in the instructional conditions during the learning phase – relevant aspects of a good collaboration on the macro and micro levels and in terms of the domain-specific demands for a good task solution – are summarized in Table 3. These contents were part of the exemplary collaboration that was introduced above (see represented in Figure 1). Table 3 demonstrates the characteristics of a good collaboration discussed in the theoretical part of the paper, and was used as the basis to design the model and to formulate the script.

TABLE 3
Overview of Instructional Contents

Macro level
1. Time management (global and local)
2. Coordination of work
   a. Division of labor: Content
   b. Division of labor: Roles
   c. Technical coordination
3. Consideration of distribution of knowledge and material (complementary expertise)

Micro level
1. Function of content-related utterances
   a. Asking the partner about a new content (elicitation)
   b. Explaining new content to the partner (explication)
   c. Giving feedback (agreement, disagreement, further inquiry/clarification)
2. Turn-taking
   a. Simultaneous talk (interruption)
   b. Explicit handover

Domain-specific demands
1. Diagnosis
   a. List of symptoms from case description and relation to International Classification of Diseases criteria
   b. Decision for specific diagnosis (based on (a))
2. Therapy
   a. Goals of therapy
   b. Therapeutic measures, psychotherapy (→ psychology)
   c. Therapeutic measures, pharmacological treatments (→ medicine)
   d. Order of the measures
   e. Treatment: Outpatient or inpatient
   f. Prognosis (expected difficulties, possible relapse, or failure of the therapy)
   g. Additional therapeutic measures indicated (physiotherapy, rehabilitation)
   h. Assumed duration of the therapy
   i. Areas of responsibility of medical doctor and psychologist

The following paragraphs describe in more detail what happened during the learning phase in each of the four conditions:

Observational learning from a worked-out collaboration example (model condition). This experimental condition (henceforth called *model condition*) was realized in the following way: during the learning phase of the experiment, participants listened to recorded scenes of the collaborative problem-solving between a psychology student and a medical student on the first psychiatric case (case 1). The scenes were presented via audio recordings. In addition, animated slide clips allowed participants to observe the development of the joint solution in the text editors of the model collaborators.

Worked-out examples usually consist of a formulation of the problem, a description of the solution steps, and the solution itself. Accordingly, the recorded scenes allowed the observing participants to follow the solution steps for the case problem at hand. In addition, the joint solutions for the diagnosis and the therapy plan presented as part of the model collaboration provided the participants with a model solution.

The model collaboration was delivered as a multimedia presentation on the computer screen. A screenshot from the presentation is shown in Figure 4. The model setting closely resembled the desktop videoconference setting in which participants later collaborated: the text editors were located on the left-hand side of the screen (the screenshot depicts the joint text editor with the joint model solution); on the right-hand side of the screen, images symbolically representing the two model collaborators were positioned where the video picture of the partner could be seen in the later collaboration. During the presentation of the model collaboration, the two partners of each dyad were sitting separated from each other in the same rooms in which they later collaborated via the desktop videoconference.

To facilitate elaboration and learning from the worked-out collaboration example, the model presentation was accompanied by short instructional explanations displayed on the screen before and after each scene (see box in the middle of the screen). An example is provided in the screenshot. Further, self-explanation activities were prompted in the course of the model presentation. For example, after being presented with the model solution for the diagnosis, participants were asked to discuss the important features of the solution with their partner via the desktop videoconference. Both the instructional explanations as well as the self-explanation activities were expected to support a deeper processing of the worked-out collaboration example and, in consequence, foster greater learning.

Learning from scripted collaborative problem-solving (script condition). During the learning phase, dyads in the scripted collaboration condition (henceforth called *script condition*) were provided with a detailed script prescribing specific phases for their interaction. The script was structurally equivalent to the worked-out collaboration example, meaning that participants in this condition

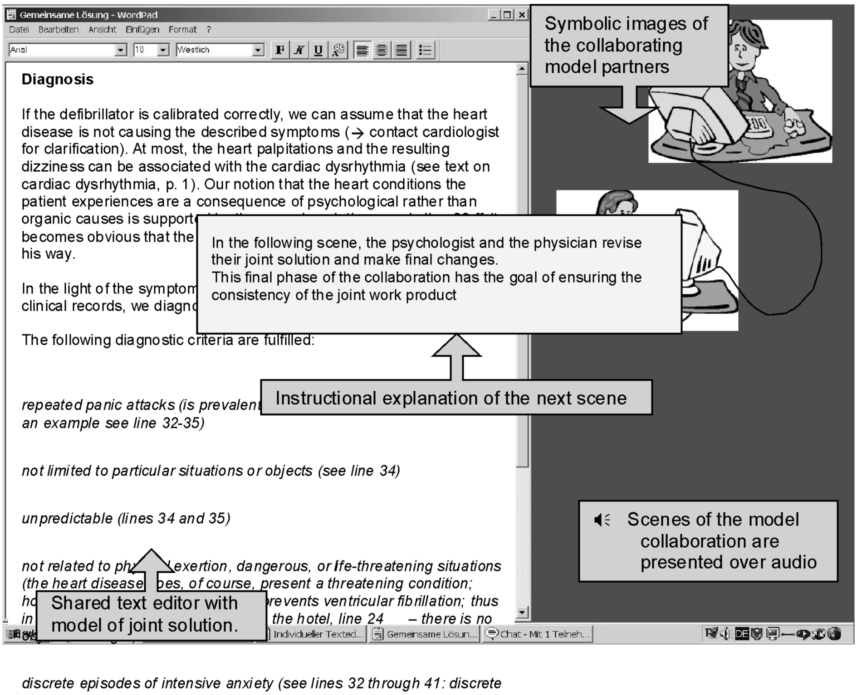

FIGURE 4 Screenshot from model presentation.

actively engaged in the same collaborative phases that were presented to the participants in the model scenes. For example, although participants in the model condition listened to the model collaborators clarifying questions about the case, the participants in the script condition were asked to do this with their partner. Instructions in the script were given in the following way:

> Please use the following 7 minutes to ask your partner any questions you might have about the case. Make use of each other's knowledge to clarify information given to you about the patient in the case description before turning to the diagnosis.

Participants received the script instructions on paper.

Learning from unscripted collaborative problem-solving (unscripted condition). This experimental condition (henceforth called *unscripted condition*) was set up to control for learning effects of collaborative problem-solving without instructional guidance. Dyads collaborated freely during both the learning and the application phase.

Control condition. A control condition restricted to collaboration in the application phase was set up. These dyads had no opportunity to gain experience in collaborating on the task during a learning phase.

The two instructional conditions, model and script, were compared to the control condition and the unscripted condition to assess the effects of systematic instructional intervention. Next, the effects of model and script were contrasted to test the possible superiority of being instructed by a worked-out collaboration example. Finally, the performance under the control condition was compared to that under the unscripted condition to identify learning effects that might have resulted without systematic instruction.

Application Phase

The activity during the application phase was the same in all four conditions: computer-mediated collaborative problem-solving. Dyads collaborated via the desktop-videoconference system to formulate the diagnosis and to work out a therapy plan for the patient introduced in the second case. No further instruction or help was given in any of the conditions.

Procedure

The experiment was administered separately for each dyad. Overall, the experimental session took nearly 6 hr, with a 24 hr break between the first (learning) phase and the second (application) phase. The first phase consisted of an introduction, technical instructions, and exercises (30 min), an overview of the material for case 1 (20 min), and an experimental learning phase (2 hr). The second phase included an overview of the material for case 2 (20 min), an application phase (2 hr), and a posttest (30 min).

After the initial introduction, 30 min were allotted for a thorough introduction to the desktop videoconference system. Collaborative exercises with the system (not content-related) ensured that all participants had mastered the functions of the system needed for the collaborative activity.

During the learning phase, the experimental variation was implemented. Dyads in the model condition observed a worked-out collaboration example, dyads in the script condition solved the first case following a script prescribing specific work phases for their collaboration, and dyads assigned to the unscripted condition collaborated freely on solving case 1. Dyads assigned to the control condition were not involved in the experimental learning phase.

During the application phase, the collaborative task was the same in all conditions: to develop a joint solution for case 2. Finally, an individual posttest was administered. The test included questions about central aspects of a good collaboration and about important elements of a therapy plan.

Dependent Variables

The collaborative process during the application phase, its outcome, the joint solution, as well as the performance on an individual knowledge posttest were analyzed as dependent variables. To gain information about the collaborative process during the application phase, two kinds of analyses were performed. The first analysis was based on activity patterns extracted from logfiles taken during the application phase. Second, an in-depth analysis of parts of the dialogs of all 36 dyads was performed at the macro level, as well as for a sample of 8 dyads at the micro level.

Collaborative process: Logfile analyses. On the basis of logfiles taken during the application phase, the activity patterns of all 36 dyads were analyzed. Minute by minute it was noted whether the partners talked with each other, whether they used the personal or shared text editors, and whether text segments were exchanged. For a statistical analysis, individual and joint phases of work were identified from the activity patterns of all 36 dyads. The total amount of individual and joint work (in minutes) was added up for each dyad.

The instructional guidance provided by the model and the script condition followed the exemplary collaboration pattern depicted in Figure 1. The phases of individual and joint work each added up to about half of the total amount of time (amount of individual work: 57 min; amount of joint work: 63 min).

As we have pointed out, allowing enough time for individual work is of central importance in the case of complementary expertise of the collaborating partners. However, recent studies have provided evidence that individual work is often neglected in computer-mediated collaboration of the type analyzed in the present study (Hermann et al., 2001). Hence, the *amount of individual work* was of central interest in the present study. Of particular relevance for the study's rationale was the deviation of the collaboration during the application phase from the exemplary collaboration. If participants were able to learn from the model and the script, this should become evident through smaller deviations. The match between exemplary collaboration and empirical collaboration patterns was analyzed by comparing the empirical data with the overall amount of individual work in the exemplary collaboration. This was achieved by computing the *absolute differences between empirical data and exemplary collaboration for the amount of individual work*.

Collaborative process: Analysis of dialogs at the macro and micro level. A second approach to the collaborative process was taken by analyzing parts of all the dialogs with regard to coordinative (macro) aspects and communicative (micro) aspects. As was shown in Table 2, the criteria for these analyses were derived from the characteristics of good collaboration discussed in the introduction and implemented in the instructional material. The analyses were conducted to elucidate the collaborative process and the coordinative strategies used by participants in greater depth than could be achieved by the logfile analysis. Due to the great time expenditure of these analyses, they were performed only for the diagnosis part of the dialogs. The diagnosis part was chosen here because the quality and correctness of the diagnosis was vital, and therefore representative, for the entire collaboration.

For the *analysis of the macro aspects*, criteria were developed allowing the assessment of relevant elements of the collaboration from the dialog (see Table 3: macro level). An example for each category is given in Table 4. They were extracted from transcribed dialogs.

Time management (1) was assessed both globally (e.g., whether partners mapped a plan for their general proceeding and arranged a timetable) and locally (e.g., whenever the partners referred to time and monitored the state of their work, and rearranged their timetable if necessary). Second, special attention was paid to the assessment of *coordination of work (2)*. Coordination encompassed here the division of labor with regard to both content and person: whose role (*2b, division of labor: roles*) was to do what (*2a, division of labor: content*). Further, talk about the *technical coordination* of work, for example when X asked Y to go ahead and copy her individual notes on the diagnosis in the shared text editor, was assessed in a separate category (2c). Finally, explicit reference to the situation of complementary expertise in the dyad was assessed (*3, consideration of distribution of knowledge and material*). Similar to the logfile analysis, the macro-level dialog analysis was performed minute-by-minute. It was possible to classify each minute in terms of its utterances on every category. The analysis of the macro level was run on the video recordings of all 36 dyads.

The system of criteria that was developed for the *analysis of dialogs at the micro level* (see Table 3: micro level) assessed the communicative *function of utterances (1)*: when the collaborators asked *questions* (1a); when *explanations* were formulated (1b); and when partners gave each other *feedback* in the sense of showing agreement, disagreement, or demanding further explanation (1c). In addition, the *turn-taking* behavior during the collaboration was assessed (2). It was noted when the partners *talked simultaneously*, thereby interrupting each other (2a), and when they *explicitly handed over a turn* (2b). As the micro level required a fine-grained analysis at the turn level it had to be performed on transcribed dialog. Because the transcription of dialogs and the analysis itself were very time consuming, they could only be carried out for a restricted sample of 8 dyads (a successful and a less successful dyad from each condition). Illustrative examples are given in Table 4 for all categories except turn-taking.

TABLE 4
Examples for Macro and Micro Level Criteria for the Assessment of Collaborative Process From the Dialog Data

Macro level
1. Time management (global and local)
   Psych: How should we divide our time?
   Med: Hmm …
   Psych: Should I write it down somehow—roughly—so that we have an overview.
   Med: Should we—wait a second—we have time till 8.30
2. Coordination of work
   a. Division of labor: Content
   b. Division of labor: Roles
      Med: Okay, now we do our individual—I write something on the Multiple Sclerosis [MS], whatever fits there, and you write about the depression, what do you think?
2. Coordination of work
   c. Technical coordination
      Psych: Could you open your, your window "joint solution," please?
      Med: Uh huh (clicks on window with joint text editor), yes. Mmm.
3. Consideration of distribution of knowledge and material (complementary expertise)
   Med: Do you also have something on the medication?
   Psych: No, no, no, that's your area. I have, I only have the psychological therapies here.

Micro level
1. Function of content-related utterances
   a. Asking the partner about a new content (elicitation)
      Psych: Do you know whether both could be caused organically? This depressive, um, disorder—well, and perhaps also the side effects that the pharmaceuticals have?
1. Function of content-related utterances
   b. Explaining new content to the partner (explication)
      Med: Okay, so Multiple Sclerosis—that is a disease of the … the nerves are wrapped with some layer and this is called Myelin. This way the nerves transmit well. And this Myelin layer is destructed in the case of MS. And this is a chronic process, it is pro-, progre-, progressive; so the Myelin layer—well, it wears down more and more, over years.
1. Function of content-related utterances
   c. Giving feedback: further inquiry/clarification + disagreement
      Med: You were talking about psychotic, right?
      Psych: Noo, the G 3 is about the organic disorder.
1. Function of content-related utterances
   c. Giving feedback: further inquiry/clarification + agreement
      Psych: Did you understand what I just said?
      Med: Uh huh. You said, that you think that in addition to the depression—in addition to the depression and the Multiple Sclerosis there is also a psychotic component.
      Psych:Exactly!

Outcome. To analyze the quality of the joint solution of the second case, a system of quantitative criteria was developed by experts in the area of psychotherapy. Two experts, a clinical psychologist and a psychiatrist with a medical background, jointly developed a prototypical solution for the second case. This solution was then reviewed and extended by more experts until an exhaustive solution had been reached. Criteria of this final solution were derived to assess the particular solutions of the participants. The elaboration of the diagnosis (justification of the diagnosis from case material) and the quality of the planned therapy were analyzed.

To justify a particular *diagnosis*, the ICD (International Classification of Diseases, Chapter V [F]: Mental and Behavioural Disorders; World Health Organisation, 1993) provides diagnostic criteria – basically a list of symptoms that a patient has to fulfill. Participants were expected to extract symptoms in support of their diagnosis from the case description and relate them to the diagnostic criteria listed in the ICD. For example, they may have cited the patient's strong feeling of hopelessness as one symptom relevant for the diagnosis "Moderate Depressive Episode". In all, there were 15 symptoms that could be extracted from the case description and related to the diagnostic criteria of the ICD.

A good *therapy plan* required goals of the therapy to be specified, therapeutic measures to be planned, and potential problems to be discussed. The therapeutic measures were expected to include both psychological and medical treatments. For the therapy score, the number of goals specified correctly, the number of appropriate therapeutic measures listed, and the number of relevant potential problems discussed were added together.

Posttest. Although both the measures regarding the collaborative process and the measures regarding its outcome, the joint solution, assessed collaborative skills, the posttest adds a different dimension to the assessment in that it required explicit verbalization of knowledge about what constitutes a good collaboration and task solution. As argued earlier, we assumed that instructional support measures would improve people's collaborative skills *and* increase their knowledge about aspects characteristic for a good collaboration and requirements of a good task solution. Such effects were expected to be revealed by the individual posttest.

The posttest on individual learning effects contained two subscales: Subscale A, *metaknowledge about central aspects of a good collaboration*; and Subscale B, *knowledge about important elements of a good therapy plan*. Subscale A refers to literature-based assumptions on general (micro and macro) characteristics of a good collaboration in the given type of scenario. Participants were asked to describe important aspects that needed to be taken into account when collaborating in the present scenario. They were expected to name aspects such as the importance of continuously ensuring mutual understanding, using the partner as a resource for clarification, explicit coordination, and division of work. A maximum of 7 points could be achieved on this scale. Subscale B relates to a facet of the domain-specific demands: the planning of the therapy. Participants were asked to describe what needed to be included in a thorough therapy plan. They were expected to name elements such as the necessity to specify the goals of a therapy before thinking about concrete measures, the importance of considering both psychotherapy and pharmacological treatments, or the importance of discussing expected difficulties, like possible resistance of the patient, relapse, or failure of the therapy. On this scale, a maximum of 9 points could be achieved (see Table 3, domain-specific level, therapy).

Experimental Hypotheses

It was hypothesized that participants in the instructional conditions (model and script condition) would acquire knowledge of relevant characteristics of good collaboration and corresponding collaborative skills during the learning phase. These skills were then expected to be revealed in the collaborative process during the application phase, in its outcome, the joint solution, as well as in the individual posttest (see Figure 2). Consequently, participants in the instructional conditions (model and script) were expected to outperform their control counterparts on all dependent variables: a better match of the amount of individual work with the exemplary collaboration, better coordination and communication as assessed from the dialogs, a better elaborated diagnosis and a better therapy plan, better knowledge about central aspects of a good collaboration, and better knowledge about important elements of a therapy plan. A slight advantage was expected for the model condition compared to the script condition. Further, we expected that the unscripted condition would not outperform the control condition.

RESULTS

Comparing the four conditions, the results of univariate analyses of variance for each of the dependent variables are presented in a separate table below. All tests were based on a Type I error probability of .05. Eta-square effect-size estimates are provided for statistically significant effects. In accordance with our hypotheses, three a priori defined contrasts were computed for each dependent variable in the case of a significant overall effect. First, the two instructional conditions were contrasted with the unscripted and the control condition (contrast 1). Second, the performance in the model condition was compared to the performance in the script condition (contrast 2), and finally, the unscripted condition and the control condition were compared (contrast 3).

Because all the dependent measures on the quality of the joint solution and the posttest comprised a content analysis of freely formulated text, the reliability of the scoring procedure was safeguarded by having a second, independent judge score parts of the material. The correlation between the two raters exceeded .85 for all scales.

Collaborative Process: Logfile Analyses

From logfiles taken during the application phase, a diagram depicting the pattern of activities over time was made for each dyad. In Figure 5, one illustrative example for each of the four conditions is presented. The first diagram was taken from the model condition, the second from the script condition, and the third and fourth from the unscripted and the control condition, respectively. The activity pattern of the dyad from the model condition shows clear-cut phases alternating between individual and joint work and a substantial amount of individual work. The pattern resembles many of the phases of the exemplary collaboration outlined in Figure 1, for example: a short initial (coordinative) dialog; then an individual phase: re-reading case description and writing first draft (of the diagnosis) in the personal text editor; another collaborative phase at the end: discussing and revising the text in the joint editor. The dyad in the script condition also shows a well-structured pattern, although particularly towards the end of the work, phases become less distinct. Also, the amount of individual work of the script dyad is lower than that of the model dyad. Compared to the exemplary collaboration (Figure 1), too much time is spent on reading the material. In the activity pattern of the dyad from the unscripted condition, marked phases of individual or joint work cannot be easily identified and instead blend into a blurred pattern. In addition, the amount of individual work is low in this condition. The possibility to prepare text for the joint solution individually by writing in the personal editor was hardly used. For the control condition it was particularly difficult to select a prototypical example, because these dyads without learning phase differed substantially in the way in which they worked on case 2. The fourth diagram depicts the collaboration of a dyad with a minimum of individual work and extensive phases of dialog. In this dyad we see hardly any writing in the personal text editors.

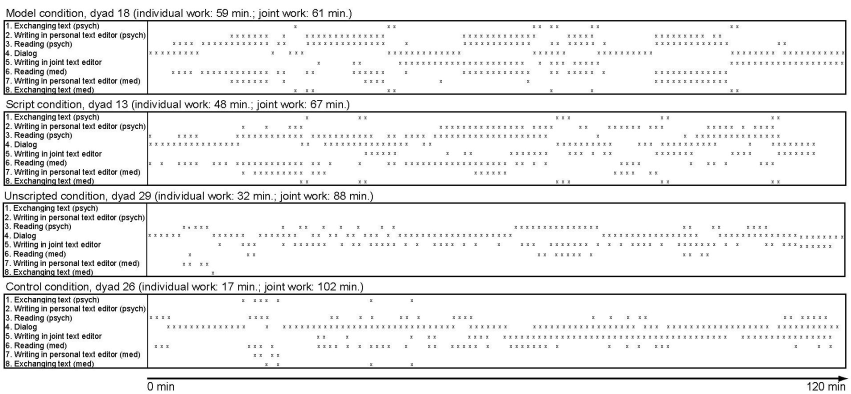

FIGURE 5 Activity patterns: one example from each condition.

To analyze the differences between the conditions statistically, individual and joint phases of work were identified from the activity patterns of all 36 dyads. The total amount of individual and joint work (in minutes) was added up for each dyad. As noted above, of particular interest for this study was the amount of individual work and specifically its deviation from the exemplary collaboration. This was assessed by computing the absolute differences between the empirical and the exemplary amount of individual work time for each dyad.

A comparison of the four conditions (see Table 5) for this variable based on the data of all dyads revealed statistically significant differences in the overall test of a univariate analysis of variance and in a comparison of the instructional conditions (model and script condition) with the conditions without instruction (unscripted and control condition). In accordance with our hypotheses, the deviations between exemplary prescribed amount of time and amount of time found empirically on individual (and joint) work were significantly lower in the conditions with instruction compared to the dyads that did not receive any instruction for collaborative problem-solving. There was a slight, but not statistically significant, advantage for the dyads in the model condition compared to the script condition and practically no difference between the unscripted and the control condition without any learning.

To gain a better understanding of this result, we analyzed the variable "absolute differences between empirical data and exemplary collaboration for the amount of individual work" more closely. We found that these differences were higher in the conditions without instruction for two reasons:

1. The average amount of individual work of the dyads was lower in all conditions than the time spent on individual work in the exemplary collaboration (57 min). The difference was modest for the model condition, with an average amount of individual time of $M = 53.00$ min, but substantial for the other conditions, with

TABLE 5
Results on the Absolute Differences Between Empirical Data and Exemplary Collaboration for the Amount of Individual Work

Variable	*Model Condition*	*Script Condition*	*Unscripted Condition*	*Control Condition*	*F*	*p*	η^2
M[a]	9.11	13.33	23.67	26.56	3.42	.03	.24
SD	8.12	11.35	14.20	18.08			
Contrast 1	1	1	–1	–1	9.60	<.01	.23
Contrast 2	1	–1	0	0	0.44	.51	
Contrast 3	0	0	1	–1	0.21	.65	

Note. $n = 9$ dyads in each condition.
[a]Mean scores on the absolute differences between empirical data and exemplary collaboration for the amount of individual work (in minutes). The higher the score, the greater the absolute difference.

$M = 44.56$ min for the script condition, $M = 39.11$ min for the unscripted condition, and $M = 40.67$ min for the control condition.

2. Although the dyads in the model condition and also to some degree those in the script condition did not vary too much with regard to the amount of individual time ($SD = 11.89$ model condition, $SD = 12.43$ script condition), the unscripted and the control condition showed a great deal of variance with regard to this aspect ($SD = 21.72$ unscripted condition, $SD = 28.64$ control condition). These differences are statistically significant (Levene's test of homogeneity of variance $p < .01$).

Collaborative Process: Dialog Analyses

Results on the macro level: Time management and coordination of work. The comparison of macro categories (see Table 6) revealed significant differences among the four conditions only for the coordination of the content-related division of labor. This overall significance is mainly due to the small amount of time in which the dyads of the unscripted condition spoke about the division of

TABLE 6
Results on the Analysis of the Dialogs on the (Macro Level)[a]

Variable	*Model Condition*	*Script Condition*	*Unscripted Condition*	*Control Condition*	*F*	*p*	η^2
Time management							
M	3.67	4.00	1.11	2.44	2.54	.07	
SD	4.39	1.50	1.36	1.01			
Coordination							
Division of labor: Content							
M	12.89	13.56	8.00	15.33	3.90	.02	.27
SD	4.81	4.56	2.55	6.36			
Contrast 1	1	1	–1	–1	0.96	.34	
Contrast 2	1	–1	0	0	0.09	.77	
Contrast 3	0	0	1	–1	10.65	<.01	.25
Division of labor: Roles							
M	18.78	16.22	10.33	19.22	2.73	.06	
SD	9.92	7.17	3.77	7.50			
Technical coordination							
M	8.00	7.44	5.78	7.78	0.53	.67	
SD	4.00	4.10	3.73	4.71			
Consideration of distribution of knowledge/material							
M	13.67	10.67	8.89	14.44	2.17	.11	
SD	5.41	5.72	2.57	6.54			

Note. $n = 9$ dyads in each condition.

[a]Mean scores on the macro categories. The scores indicate the minutes of dialog in which utterances on a category were detected.

labor. It is interesting to note that this is a consistent pattern in the results for all macro categories: the unscripted condition shows less activity than the other conditions. We will come back to this result in the discussion section.

Results on the micro level: Function of utterances and turn-taking. Due to the small sample size (two dyads from each condition), a statistical comparison of the four experimental conditions was not possible. Descriptively comparing the dyads from the different conditions, the only notable result was that collaborations in the control conditions were characterized by poorer turn-taking (more interruptions, less explicit handovers). We will come back to this point in the discussion.

Quality of the Joint Solution

With regard to the joint diagnosis, the overall test of differences between the four conditions yielded a statistically significant result (see Table 7). Dyads in the model condition on average produced a significantly better elaborated and justified diagnosis than dyads in the script condition. There was no difference between the unscripted and the control condition. The overall test also showed a significant result for the therapy plan (see Table 7). Dyads in both instructional conditions (model and script) produced a better therapy plan than dyads in the unscripted and the control condition. However, this time, dyads in the script condition were slightly better than in the model condition. There was no difference between the unscripted and the control condition.

TABLE 7
Results on the Quality of the Joint Solution

Variable	*Model Condition*	*Script Condition*	*Unscripted Condition*	*Control Condition*	*F*	*p*	η^2
Diagnosis[a]							
M	8.89	4.39	6.50	6.28	5.06	<.01	0.32
SD	1.64	3.43	2.35	2.08			
Contrast 1	1	1	–1	–1	0.09	.76	
Contrast 2	1	–1	0	0	15.04	<.01	0.32
Contrast 3	0	0	1	–1	0.04	.85	
Therapy[b]							
M	14.44	18.67	12.61	11.67	3.50	.03	0.25
SD	4.30	6.97	4.57	3.34			
Contrast 1	1	1	–1	–1	7.09	.01	0.18
Contrast 2	1	–1	0	0	3.24	.08	
Contrast 3	0	0	1	–1	0.16	.69	

Note. $n = 9$ dyads in each condition.
[a]Mean scores on the elaboration of the diagnosis. The higher the score, the better the elaboration.
[b]Mean scores on quality of the therapy plan. The higher the score, the better the quality.

The importance of individual work for successful collaboration, which was discussed in connection with the collaborative process, is corroborated by the following result: the sample of dyads was divided into two subsamples according to the overall quality of their joint solution (diagnosis and therapy) by means of a median split, resulting in successful (M = 25.47, SD = 4.69) versus less successful (M = 16.25, SD = 3.45) dyads. Similarly, the sample was divided into dyads with "low" and "high" amounts of individual work by means of a median split (M_{low} = 27.83, SD = 11.86; M_{high} = 60.83, SD=9.55). An analysis of frequencies ($\chi^2[1, N = 36] = 11.11$, p = .001) revealed that successful dyads were mostly to be found in the quadrant with the higher amount of individual work, whereas unsuccessful dyads were predominantly situated in the quadrant with the lower amount of individual work (see Table 8).

Posttest

The posttest results (see Table 9) revealed that participants in both instructional conditions significantly outperformed their control counterparts on the two subscales: Subscale A, knowledge about central aspects of a good collaboration; and Subscale B, knowledge about important elements of a therapy plan. On both subscales, participants in the unscripted condition performed slightly better than participants in the control condition.

DISCUSSION

Summarizing the results on the *logfile analyses* of the collaborative process during the application phase, both instructional conditions – and especially the model condition – resulted in a well-balanced proportion of individual and joint work. In comparison, dyads in the unscripted problem-solving and the control condition on average showed insufficient parallel individual work, and a great

TABLE 8
Frequencies of Dyads for Quality of the Joint Solution by Amount of Individual Work

		Dyads: Quality of the Joint Solution	
		Less Successful	*Successful*
Dyads: Amount of individual work	*Low*	14	4
	High	4	14

Note. Cells show frequencies of dyads for quality of the joint solution (variable divided by median split) by amount of individual work (variable divided by median split).

TABLE 9
Results on the Two Subscales of the Posttest

Variable	*Model Condition*	*Script Condition*	*Unscripted Condition*	*Control Condition*	*F*	*p*	η^2
Subscale A[a]							
M	3.14	3.06	2.33	1.67	7.04	<.01	.24
SD	1.11	0.89	1.33	1.04			
Contrast 1	1	1	–1	–1	17.79	<.01	.21
Contrast 2	1	–1	0	0	0.05	.82	
Contrast 3	0	0	1	–1	3.28	.07	
Subscale B[b]							
M	4.06	4.11	2.31	1.94	14.57	<.01	.39
SD	1.45	1.31	1.16	1.11			
Contrast 1	1	1	–1	–1	42.97	<.01	.39
Contrast 2	1	–1	0	0	0.02	.90	
Contrast 3	0	0	1	–1	0.73	.40	

Note. $n = 18$ participants in each condition.
[a]Mean scores on knowledge about central aspects of a good collaboration. The higher the score, the better. [b]Mean scores on knowledge about important elements of a therapy plan. The higher the score, the better.

deal of variance with regard to this aspect. In other words, dyads in the control condition differed considerably in the way in which they collaborated. This phenomenon is widely known from the literature on collaborative problem-solving and learning: without support, people differ greatly in the way in which they collaborate (for examples, see Johnson & Johnson, 1992; McGrath, 1984; Salomon & Globerson, 1989).

In comparing the results of the *dialog analyses* on the *macro level* for the four conditions, we notably found that the number of utterances within these categories was consistently very low under the unscripted condition. In explaining this outcome, two assumptions should be considered:

1. More coordinative dialog is needed when collaborating for the first time.
2. More coordinative dialog is needed for a good time management and a good coordination of work.

A consequence of the first assumption is that dyads in the control condition, collaborating on case 2 for the first time, should need more coordinative dialog compared to the three other conditions. The second assumption means that dyads in the instructional conditions (model and script) should show more coordinative dialog than the two other conditions. Taking both assumptions together, only the dyads in the unscripted condition should be characterized by a small number of coordinative utterances, which was in fact the case.

It is important to keep in mind that the scores for the macro-level analysis presented here were gained through a time-sampling procedure: each minute of dialog was classified for the occurrence of the macro categories. In other words, what we assessed was the quantity, or intensity, of coordinative activity. In further analyses it would be desirable to not only add up the amount of time of different aspects of coordinative dialog, but also to assess the quality of the dialog with regard to these aspects.

The result of the dialog analysis of 8 dyads at the *micro level* was not very meaningful. We should question whether the communicative features that were assessed can be influenced by a relatively short experimental intervention, as they may concern long-established individual differences in everyday communication.

The results reported for the *quality of the joint solution* can be summarized by stating that dyads in the model condition yielded very good results on the diagnosis and good results on therapy planning. The script condition yielded heterogeneous results, below average for the diagnosis but outstanding for the therapy plan. There were no differences between the unscripted collaboration and the control condition without learning. The somewhat poorer performance of dyads of the model condition on the therapy planning may partly be explained by the observation that dyads in this condition collaborated with much enthusiasm and thus sometimes had problems with the time constraints for the task. In contrast, dyads in the script condition initially had motivational problems coming to terms with their collaboration in the application phase. These motivational problems cannot be confirmed by quantitative data as motivation was not assessed formally in this study. However, examples of the participants' frustration with the script they had been required to follow during the learning phase can be found in the transcripts of their collaboration in the application phase. To illustrate this with an example from the dialog of dyad 4: during their initial time planning, the medical student states "I see, well, I guess I'll just write and then,… I mean we don't have to proceed as rigidly as the first time"; the psychology student reacts with affirmative nodding.

The *posttest* results are interesting as they add a different dimension to the results. Although both the measures on the collaborative process and on its outcome, the joint solution, assessed collaborative skills, the posttest required explicit verbalization of knowledge about both general and domain-specific aspects of the collaboration. The clear superiority of the instructional conditions on both subscales of the posttest implies that participants in the instructional conditions were able to profit from the instruction they received during the learning phase not only for their subsequent collaboration (as evident in the results on the process and outcome variables) but also with regard to the explicit knowledge they had acquired about important aspects of a good collaboration.

What do the results reveal in terms of the effectiveness of our instructional support measures? We had formulated the hypothesis that participants in the instructional conditions should outperform their unscripted and control counterparts in the application phase by having acquired relevant skills on collaborative problem-solving during the learning phase. The results indeed provide some supportive evidence that observational learning from a worked-out collaboration example as well as scripted collaborative problem-solving during the learning phase had beneficial learning effects, which became manifest in the subsequent collaborative process, its outcome, and the posttest. Further, we were interested in finding out whether an advantage could be detected for the model condition compared to the script condition. However, apart from one subscale on the quality of the joint solution (diagnosis), the two instructional conditions were not found to differ substantially. Overall, the script condition did better than expected. With regard to a comparison of the unscripted and the control condition, we had hypothesized that the condition with unscripted collaborative problem-solving during the learning phase would not outperform the control condition substantially in the application phase. Although dyads in the unscripted condition were in most cases slightly better than dyads in the control condition, the two conditions did not differ substantially. It can be concluded that learning by unguided collaborative problem-solving on a task is much less effective than systematic intervention and almost as bad as having no opportunity for learning at all.

GENERAL DISCUSSION

Desktop-videoconferencing settings are gaining in importance for remote collaborative problem-solving and learning (Finn, 1997; Whittaker, 1995). The reasons for this development are manifold. Desktop-videoconferencing settings enable distributed partners to collaborate. The audio and video connection enables an immediate interactive contact. Shared applications like text documents and visualization tools help to focus the collaborative process and make it possible to reflect on its outcomes (Dillenbourg & Traum, 1999; Whittaker et al., 1993). Furthermore, they allow the integration of individual contributions of the partners into a joint work product. In this way, complex tasks, which often require complementary knowledge of experts from different content areas, can be mastered with greater ease.

However, remote collaboration is not without challenges. For one, solving a complex task collaboratively, specifically the step-by-step solution of the task and its coordination, is a challenge in itself. In addition, computer-mediated communication of remote partners imposes specific challenges. The transmission of information has to be carried out in a much more explicit way. Collaborating partners often fail to complete their joint task or require too much time and effort. To guarantee efficiency, the collaboration has to be supported.

We have investigated methods to provide this support by taking an instructional approach. In the experiment presented, (a) observational learning from a worked-out example of a well-structured collaboration and (b) learning from scripted collaboration were investigated as potential measures to promote the competence for interdisciplinary collaboration in a desktop-videoconference setting. An experimental paradigm was employed that investigated the learning effects of these instructional treatments in a subsequent collaboration. In sum, both methods showed positive effects on process and outcome of the collaboration during the application phase. The learning effects of the scripted collaboration condition were better than expected; however, possible motivational costs of the script may still need to be addressed. The results lead us to draw the following conclusions:

We have seen that observational learning from worked-out collaboration examples can be a promising way to promote collaborative skills. If such an example is well conceived, it can function as a model for the people observing the collaboration, especially if they are supported in reflecting on what they see and hear (Renkl, 2002). To optimize observational learning from a worked-out collaboration example, we suggest including short phases of active collaborative problem-solving. Bearing in mind findings from the literature on individual learning with worked-out examples (Stark, 1999; Stark, Gruber, Renkl & Mandl, 2000), we assume that a well-balanced mixture of observing solution steps and active problem-solving would yield the best results.

It has been shown in this study that cooperation scripts represent not only a valuable means of supporting ongoing collaboration but that scripted collaboration can also trigger learning and thus promote collaborative skills. Partners who work jointly on a problem-solving task following a cooperation script can acquire collaborative skills that also improve the collaboration in subsequent tasks. This result leads us to the conclusion that cooperation scripts should be considered more closely in future research as a promising *instructional* measure. As research on cognitive apprenticeship (e.g. Collins et al., 1989) has shown, complex cognitive skills can be acquired if performance is scaffolded externally in the beginning and the support is later faded out. It is our assumption that cooperation scripts can be designed to provide such scaffolding for collaboration. Referring to the cognitive apprenticeship method called “procedural facilitation of writing” (Scardamalia & Bereiter, 1985; Scardamalia, Bereiter & Steinbach, 1984), the cooperation script may be regarded as a “procedural facilitation of collaborating”. However, scripting collaborative problem-solving with the objective of fostering the acquisition of collaborative skills brings with it much higher demands than merely optimizing the problem-solving outcome. The various elements of the script have to be reflected on and elaborated by the collaborating partners to fully understand their usefulness and to promote their internalization and thus their acquisition as a standard of subsequent collaborative work. This presupposes acceptance rather than reactance towards the script in the first place. Hence, the motivational problems experienced by participants in the script condition of our experiment urge us to take the considerations and preliminary results on negative motivational effects of scripts (Bruhn, 2000; Hron et al., 1997; Kollar, 2001) very seriously.

The poor results of unscripted collaborative problem-solving on a subsequent task indicate that unguided learning by doing is not very effective for computer-mediated collaborative problem-solving. The reason for this might be that the task is so demanding (the work on the psychiatric case itself, the collaboration, and the technical setting) that the cognitive overload impairs the solution process and learning.

Finally, it should be conceded that some dyads in the control conditions working without the experiences of a learning phase collaborated quite efficiently and with good success. However, the majority of the dyads only succeeded with instruction.

What are the limitations of the present study and what agenda do they set for further research? With our instructional support methods, we are aiming to improve relevant collaborative competences of the partners and thus potentially improve collaboration in the long run. However, in the present study, the effects of the instructional measures were tested in only one application case. Therefore, long-term effects of the model and script instruction have not yet been tested. It would be desirable to have data on a greater number of delayed application cases to support the assumption that the instructional measures (model and script) have the potential to improve collaborations with long-lasting effects. One possibility to gain such data might be to investigate the learning effects of our instructional measures as part of a curriculum element. Running such a field study would allow data to be gained over an extended period of time and for several application cases.

Further, it would be desirable to replicate the present study with true domain experts – in other words psychologists and physicians who have already practiced their profession for several years. In the present study, the complementarity of domain knowledge, which would be expected to characterize expert physicians and psychologists when collaborating in the real world, was experimentally increased by distributing relevant domain information. In terms of information available for the problem-solving, this improved the comparability of the experimental setting to the real world. However, the intermediate participants of our experiment would be expected to differ from natural experts also with regard the way their knowledge is organized and applied to a given case (Boshuizen & Schmidt, 1992). This difference could not be mimicked by providing domain-related information; it requires long-lasting practical experience.

The scenario investigated in the present study can be seen to be of high practical relevance. On a general note: in many domains, the enormous and rapid growth of domain knowledge, in combination with an ever increasing specialization of this knowledge, has led to a growing need for collaboration between experts from different fields of expertise. As a result of this development, the investigation of collaboration between spatially distributed experts, as well as the promotion of such collaboration, have moved into the focus of research activities. More specifically, the collaboration of psychologists and medical doctors (or of doctors with different specializations) on complicated cases is a daily challenge. And yet, both parties seem to be insufficiently prepared to meet this challenge: they seem to lack collaborative skills, meaning that these collaborations are often experienced as frustrating and unsuccessful (Tönnies, Breuer-Schneider & Schwieger, 1992). We believe that it is worthwhile to investigate ways of helping them to collaborate better. Results from this research may then be used to develop elements for the medical and the psychological curricula. The acquisition of competences in computer-mediated interdisciplinary collaboration might be a benefit worth achieving for students in both domains in addition to content-related knowledge.

ACKNOWLEDGMENTS

This research was supported by the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation) with a project grant awarded to Hans Spada and Franz Caspar (contract Sp 251/16–1 and 16–2).

We thank Franz Caspar and Katrin Schornstein for their work on the clinical aspects of the project. Many thanks also go to our student research assistants Dejana Diziol, Jana Groß Ophoff, Nina Klitzke, Anne Meier, Friederike Renner, and Stefanie Sosa y Fink for their help with many practical aspects of the project such as data collection and scoring.

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