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Towards an integration of the *learning perspective* and the *communication perspective* in computer-supported instructional communication

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Abstract

Research on *computer-supported instructional communication* (CSIC) refers to the study of interactions between instructors, learners, and system components in computer-based learning environments. At least two strands of research can be identified that are crucial for the understanding of CSIC: From the learning perspective, rooted in cognitive and educational psychology, CSIC is analysed with regard to its potential for promoting specific cognitive processes, and thus ultimately for improving learning. From the *communication perspective*, rooted in social psychology and communication science, CSIC is analysed with regard to conditions that affect its effectiveness and efficiency. CSIC researchers face the challenge of integrating the two traditionally separate research strands and their distinct methodological frameworks. In turn, new methods and findings emerging from integrative application of research methods lead to new conceptual challenges regarding the causal mechanisms mediating between the inter-individual and the intra-individual level in CSIC. We provide examples of CSIC research that demonstrates successful methodological integration, and introduce open conceptual challenges.

Keywords:

computer-supported instructional communication; instructional design; computer-mediated collaboration scripts; virtual learning environments; research methods

Research on *computer-supported instructional communication* (CSIC) refers to the study of interactions between instructors, learners, and system components in computer-based learning environments (Rummel, & Krämer, 2010). Like research on instructional communication in general (Mottet, Richmond, & McCroskey, 2006), CSIC aims at identifying factors that contribute to successful communication and effective learning. It includes not only individual but also collaborative learning settings. In so far, it has some overlap with the neighboring field of computer-supported collaborative learning (CSCL; Stahl, Koschmann, & Suthers, 2006). The focus of CSIC, however, is on the systematic exploration of factors that determine the effectiveness of instructional messages designed by teachers and tutors, such as instructional explanations, task instructions, or prompts, with respect to fostering individual learning. The literature on discourse processes in education (Graesser, Gernsbacher, & Goldman, 2003) forms the basis of the argument to view such messages as *communication*, as their comprehension is seen as a transactive process between the author and the learner rather than a bottom-up extraction of meaning by the learner (cf. Graesser et al., 2003, p. 5). CSIC encompasses also non-verbal aspects of instructional communication, such as the effects that social cues or non-verbal behaviours displayed by pedagogical agents in virtual learning environments have on the processing of instructional messages (e.g. Bente & Krämer, 2010). On another level, many (though not all) CSIC arrangements include the collaboration between students on a shared learning task. In this case, CSIC is concerned with factors that contribute to peer-to-peer communication processes that will foster individual learning, such as knowledge exchange and knowledge co-construction in the context of collaborative problem-solving, argumentation, and discussion (e.g. Rummel, Mullins, & Spada, 2012).

As the term implies, CSIC focusses on instructional communication in computer-supported learning environments. The benefit of computer-mediated learning does not only lie with the fact that distances in time and space can be overcome (e.g. in virtual courses). In addition, computer-supported technologies can serve as powerful research tools and provide new possibilities for designing instructional communication: for example, log file analyses provide an automatic assessment of students' behavior patterns, and the employment of avatars or pedagogical agents allows for a systematic control of factors potentially affecting the results of (verbal and non-verbal) instructional communication (Krämer & Bente, 2010).

At least two strands of research can be identified that are crucial for the understanding of CSIC. Cognitive processes on the part of the learner may be focused, as has traditionally been done within cognitively oriented educational psychology. From this perspective on CSIC, which we will refer to as the *learning perspective,* instructional communication is analyzed with regard to its potential for promoting specific cognitive processes, and thus ultimately for improving learning. The impact of variations of the instructional communication (e.g., a teacher, tutor, or pedagogical agent offering explanations, prompting cognitive and metacognitive activities, or providing examples) is assessed by looking at learning outcomes, but more importantly, by relating the learning outcomes to particular aspects of the learning process (e.g., self-explanations, elaborations of the learning content, errors, help seeking behavior). On the other hand, communication research and social psychology provide information on basic conditions that render instructional communication effective and satisfying. We will refer to this perspective as the *communication perspective*. For example, the effects of the degree of sociality, e.g. in terms of the availability of nonverbal communication, are a major research area within computer-mediated communication (Bente, Rüggenberg, Krämer, & Eschenburg, 2008). Also, the effects of instructional communication on the exchange and processing of information in groups has been researched extensively by social psychologists (Brodbeck, Kerschreiter, Mojzisch, & Schulz-Hardt, 2007; Ziegler, Diehl, & Zijlstra, 2000).

Currently, CSIC researchers face the challenge of integrating the two traditionally separate research strands of cognitively oriented educational psychology (*learning perspective*) on the one hand, and communication research and social psychology (*communication perspective*) on the other. There are different avenues for such integrative research. In this paper, we give examples of *cumulative integration*, in which methods and concepts from both perspectives are employed in a side-by-side fashion, *synthetic integration*, in which new research methods are developed that bridge between the two perspectives, and *transformative integration* resulting in new technologies that open up new research fields. We also show how the new methods and findings emerging from integrative application of research methods lead to new conceptual challenges. The methodological and theoretical discussions that gave rise to this paper were part of an interdisciplinary network of CSIC researchers who all aim at integrating methods for supporting and assessing learning with methods for supporting and assessing communication in CSIC. The research examples were selected from the work of different research teams within the network, with the aim of illustrating the different avenues for methodological integration.

In the remainder of this paper, we first provide an overview of the two perspectives (the *learning perspective* and the *communication perspective*), and on the typical methods they employ. Then, we introduce a framework for classifying integrative research approaches, and describe three examples of integrative CSIC research that is illustrative of the framework`s categories. We end with a discussion of the conceptual challenges arising from the new methods and findings of research that aims at integrating the *learning perspective* and the *communication perspective*.

1. The learning perspective and the communication perspective in CSIC

The difference between the two perspectives on CSIC can best be shown by comparing and contrasting the typical methods they employ. We will use the term *method* to refer to any operationalization of a CSIC construct. Thus, a method always includes a conceptual component (WHAT), specifying a certain concept as relevant for observation and/or manipulation (such as the pooling of information), plus a procedural component (HOW), specifying certain procedures the researcher must follow (such as procedures for measuring the amount of information pooled). For each perspective, we will discuss typical *intervention methods* (specifying the operationalization of typical independent variables), typical *process measures* (specifying the operationalization of relevant mediating processes), and typical *outcome measures* (specifying the operationalization of relevant dependent variables). The examples have been selected for their typicality of a specific research tradition; they are not meant to represent an exhaustive list.

1.1 Learning perspective methods

Taking a *learning perspective* on CSIC, a prototypical computer-supported learning setting presents instructional communication designed by an instructor with the aim of fostering cognitive processes conducive to learning in the learner, or a group of learners. Opportunities for providing instructional communication in novel ways afforded by computer technology, such as multimedia or hypermedia environments, are explored with respect to their potential for supporting individual information processing and, eventually, learning.

Interventions typically aim at fostering deep understanding of learning materials, with the computer being used as an aid for delivering materials and instructions. Examples include computer-based training interventions that aim at improving learning strategies (Berthold, Faulhaber, Guevara, & Renkl, 2010), or multimedia environments that combine the presentation of instructional explanations with prompts designed to elicit further processing of material (Berthold & Renkl, 2010). Another important aim is to implement adaptive support for learning, for example embedded within intelligent tutoring technology (Rummel et al., 2012).

Typical *process measures* include indicators of individual performance during a learning phase, such as error rates (Mullins, Rummel, & Spada, 2011), as well as measures indicating deep vs. shallow processing of learning materials, such as different types of self-explanations (Berthold, Röder, Knörzer, Kessler, & Renkl, 2011). Often, coding and rating schemes are used to analyze recorded CSIC sessions and log-files post-hoc, in order to classify a wide range of learning-related activities (Wittwer, Nückles, & Renkl, 2010). These may be complemented by online measurements such as eye-movement data (Schwonke, Berthold, & Renkl, 2009), think-aloud protocols (Ericsson, 2003), or measures of cognitive load (Eysink, de Jong, Berthold, Kolloffel, Opfermann, & Wouters, 2009).

Typical *methods for measuring CSIC outcomes* focus on knowledge of different type and quality that an individual learner has acquired (De Jong & Ferguson-Hessler, 1996). Procedural knowledge refers to actions or manipulations that are valid within a domain, and is typically assessed as problem-solving performance (e.g., multiplying fractions to calculate the joint probability of a series of events; Berthold & Renkl, 2009). Conceptual knowledge refers to knowledge about facts, concepts, and principles that apply within a domain and is typically assessed by asking learners for explanations or justifications of a concept or principle (e.g., asking why the fractions have to be multiplied rather that added; Berthold & Renkl, 2009). Robust learning is said to have taken place if knowledge is retained over extended periods of time (long-term retention or reproduction) and if students are able to transfer the acquired knowledge to new situations, i.e. to show heightened performance in a transfer test (VanLehn et al., 2007). Robust knowledge often also accelerates future learning; for instance instruction that increases fluency in one skill may enable learners to concentrate their attention on other, novel aspects in future learning situations, leading to faster learning of the new materials (VanLehn & the PSLC, 2006).

1.2 Communication perspective methods

Taking a *communication perspective* on CSIC, the main unit of analysis is typically not the individual, but rather a whole social or socio-technical system, such as a group of collaborating learners, a tutor-tutee or teacher–learner dyad, or the communication patterns within a virtual classroom. Properties of CSIC are explored with respect to their effects on the communication processes within these systems. Typical *interventions* aim to create conditions of efficient communication. Social cues in the environment of an individual learner may be manipulated and their effects on learner`s behaviours observed, such as learners` emotional reactions to a pedagogical agent and their processing of its instructional messages (Bailenson, Beall, Loomis, Blascovich, & Turk, 2005; Domagk, 2010). A typical method from social and organizational psychology is the structuring of group interactions with the aim of promoting discussions that will result in effective problem-solving. Computer-supported learning environments are particularly well-suited for structuring group processes because it allows to guide learners through a sequence of tasks that are aligned with suitable tools for communication and for work (Piontkowski, Keil, & Hartmann, 2007). The coordination of communication can be enhanced by feeding back information on important, but not easily observable intra- and inter-individual processes. These are assessed, aggregated, and often also visualized by CSIC systems (Buder & Bodemer, 2008).

Methods for measuring CSIC processes include keeping track of the ways in which specific pieces of information are exchanged and integrated during group discussions (Buder & Bodemer, 2008), identifying participation rates (Bachour, Kaplan, & Dillenbourg, 2010), mapping communication structures (Nurmela, Lehtinen, & Palonen, 1999), measuring communication efficiency and perspective-taking (Jucks, Becker, & Bromme, 2008; Jucks & Bromme, 2011), or assessing individual`s evaluation of a communication processes (Domagk, 2010). Many CSIC environments further allow for assessing implicit measures of social behavior that would be difficult to gather in the physical world, such as gaze and movement behavior (McCall, Blascovich, Young, & Persky, 2009).

Methods for measuring CSIC outcomes from a communication perspective include judging the quality of communication outcomes, such as the number and quality of generated ideas (Ziegler et al., 2000) or the quality, completeness, and correctness of answers or explanations (e.g. in the form of wikis or databases; Cress, Barquero, Schwan, & Hesse, 2007). Furthermore, researchers are interested in shared cognitions that emerge at the group level as an effect of CSIC, such as the differentiation of a transactive memory system (Michinov & Michinov, 2009).

2. Examples of integrative research

Interdisciplinary research fields such as CSIC are driven by the integration of methods and concepts from the collaborating research traditions. Integrative research endeavours can be classified along a continuum ranging from segregated research practices over the application of multiple methods in a side-by-side fashion to a transformation of existing concepts and methods into new theoretical frameworks and research programs (Huutoniemi, Klein, Bruun, & Hukkinen, 2010). In our presentation of integrative CSIC research, we focus on three types of integrative endeavours that combine and / or transform research traditions with respect to methodological frameworks and tools (methodological interdisciplinarity, Huutoniemi et al., 2010): *cumulative*, *synthetic*, and *transformative* integration. While there is a continuum of “integrativeness” from cumulative to transformative methods, all three approaches aim at integrating *learning perspective methods* with *communication perspective methods* and are important in shaping current CSIC research.

Cumulative integration combines methods and concepts from multiple perspectives and applies them side-by-side (cf. the notion of multidisciplinarity; Huutoniemi et al., 2010). An example for a CSIC method that represents a cumulative integration of the learning and the communication perspective can be found in computer-mediated collaboration scripts (see Example 1). Research employing computer mediated collaboration scripts as a kind of CSIC typically combine intervention methods, as well as process and outcome measures, from each of the two traditionally separate perspectives. In contrast, *synthetic integration* approaches generate new methods altogether. Our second example (Example 2) is an approach towards studying learning on the group level in CSIC, crossing a classical social psychological paradigm for studying information exchange in groups (communication perspective) with an analysis of knowledge construction through the drawing of inferences (learning perspective). Our last example (Example 3) illustrates how new technologies enable new research methods that transcend the traditional boundaries between the *learning perspective* and the c*ommunication perspective* and create a novel research field altogether (*transformative integration*). Specifically, we introduce the fledgling research field of virtual learning environments, in which methods from learning and social psychology are integrated with concepts and tools also from additional disciplines such as human-computer interaction and computer science.

2.1 Example 1: Computer-mediated collaboration scripts

Many CSIC arrangements include the collaboration between students on a shared learning task. CSIC then has the goal to facilitate knowledge exchange and knowledge construction in the context of collaborative problem-solving, argumentation, and discussion. An integrative CSIC intervention method towards achieving these goals consists in the design of computer-mediated *collaboration scripts* that structure students` individual and collaborative interaction with the learning environment, as well as with one another (Dillenbourg & Jermann, 2007; Diziol & Rummel, 2010). Research on the effective design of collaboration scripts combines the aim to experimentally test the effectiveness of specific design features with a focus on collaborative learning, placing it at the intersection of CSIC and CSCL.

Computer-mediated collaboration scripts structure learners' interaction with one another and with the learning environment by sequencing specific phases of collaborative and individual work, and by prescribing activities or roles for each phase (Kollar, Fischer, & Hesse, 2006). Collaboration scripts target cognitive and meta-cognitive, as well as social and meta-social levels of collaborative learning (Diziol & Rummel, 2010). Thereby, they bridge between the *learning perspective* and the *communication perspective* on CSIC. This integration concerns intervention methods, as well as process and outcome measures. Because methods and measures taken from the two traditionally separate perspectives are typically employed alongside one another, collaboration scripts can be seen as an instance of *cumulative methodological integration*.

With regard to intervention methods, collaboration scripts employ instructional prompts and instructional explanations aimed at promoting individual cognitive processes conducive to learning (e.g. self-explanations, studying worked-out examples), alongside methods aimed at supporting effective communication (e.g. structuring discussions; scaffolding communication by providing sentence openers). Process measures range from measures of individual cognitive processing of materials (e.g. time-on-task; eye-tracking measures) to measures of communication effectiveness and efficiency (e.g. information exchange; communication structures). Outcome measures include tests of individual learning gains (e.g. performance gains from pre- to post-test) as well as group products as they are typically studied within social psychology as indicators of effective group communication (e.g. the quality of group solutions and decisions). Researchers differ in what aspects of a script they emphasize (e.g. deep individual learning vs. efficient collaborative problem-solving). However, since the general aim is to promote social interactions that are conducive to individual learning, all designers of computer-mediated collaboration scripts are to at least some degree faced with the challenge of orchestrating methods that address both learning and communications, and thus, find a way of integrating the two traditionally separate perspectives.

An illustrative example of a computer-mediated collaboration script is given in a recent study by Rummel et al. (2012). The learning domain in this study was linear equation solving. Rummel et al. extended the Cognitive Tutor Algebra (CTA), a computer-based tutoring system for high school mathematics, to a collaborative setting. On the macro level, they distributed expertise for the collaborative task between two learning partners, thus ensuring resource interdependence. This creation of interdependence aimed at motivating students to participate in an exchange of information and at ensuring a fruitful problem-solving process (*communication perspective*). On the other hand, during the individual studying phase, students were supported by prompts, hints, and feedback from the CTA that had been designed to ensure deep processing of materials and foster learning (*learning perspective*). During the joint problem solving phase, the student dyads were further supported on a micro level. One script component consisted of instructions for engaging in effective collaborative problem solving and efficient communication. For instance, when exchanging their individual solutions, students were instructed to alternate between the roles of explainer and listener. While this first set of prompts was directed at the interacting dyad and can be seen as mainly aiming at an increase of communication efficiency (*communication perspective*), additional prompts, given at both the dyad and the individual level, targeted deep, elaborative processing of the learning materials (*learning perspective*). For example, the student in the role of explainer was prompted to give explanations on a high level of elaboration, and the student in the role of listener was prompted to listen attentively and ask for further explanations. Further, when the dyad made an error that was identified by the CTA, an error message popped up prompting for reflection and consultation of helpful resources. The process measures that the authors employed, too, combined typical *learning perspective* methods (e.g. ratings of the depth of elaboration on hints and error messages from the CTA) with typical *communication perspective* methods (e.g. an in-depth narrative analysis of problem-solving steps in dyads` dialogs at a particularly difficult step in the solution process). Outcome measures reflected the effectiveness of both joint and individual problem-solving.

On a conceptual level, the design of computer-based collaboration scripts raises important questions concerning the interplay between individual cognitive processes conducive to learning, and inter-individual communication processes conducive to group information processing and problem-solving. Comprehensive theoretical models that make explicit the cognitive, attentional, and/or motivational processes mediating between the inter-individual and the intra-individual level are still sparse. From the view of cognitive psychology, a recent attempt towards providing a conceptual framework has been made by Chi (2009). In her framework, individual *learning* as a result of *communication* between learners, or of "interacting with a peer in joint dialogues" (p. 82) is referred to as *interactive knowledge construction*. Chi suggests that such interaction is conducive to individual learning via cognitive processes that create new knowledge structures and in doing so "incorporate a partner`s contributions" (p. 77). The knowledge creation processes themselves are conceptualized as being the same as in individual, constructive learning: for example, new knowledge is created by drawing inferences, organizing new information, connecting information to prior knowledge, restructuring existing knowledge, or repairing faulty knowledge. But what determines when, and how, learners take up other`s contributions? How do aspects of *communication* such as media constraints or the presence of social cues influence how individuals take up others` contributions? And how can we use CSIC for facilitating these processes? Our next example shows one possible approach towards answering some of these questions.

2.2 Example 2: Studying the interplay between intra-individual and inter-individual information processing in the drawing of collaborative inferences

The research introduced in this example bridges the *learning perspective* and the *communication perspective* by studying the interplay between intra-individual and inter-individual information processing in a collaborative problem-solving setting (Deiglmayr & Spada, 2010, 2011). Other than in the example of collaboration scripts above, the focus of this research was not on individual learning, but on identifying and supporting dialog patterns leading to the generation of novel information and, eventually, a good problem solution. To this purpose, the authors took a research paradigm traditionally utilized to study group-level decision making (communication perspective), but adapted the method so that it enabled them to study in detail the creation of new knowledge from inferences, a cognitive activity typically considered as the basis of individual learning (*learning perspective*). The resulting research paradigm can be considered an example of a *synthetic methodological integration.*

The starting point for this research was the analysis of collaborative problem solving on the basis of distributed information, an instructional scenario found in many collaborative learning settings (Dillenbourg & Jermann, 2007; Rummel & Spada, 2005). In social psychology, such situations are studied under a paradigm that views groups as information-processing systems, modelling inter-individual processes in analogy to intra-individual cognition (Hinsz, Tindale, & Vollrath, 1997). A frequently applied research method in this paradigm is the so-called “hidden profile”. A hidden profile is a decision making task in which the group’s potential advantage over its individual members is maximal (Brodbeck et al., 2007). Setting up a hidden profile involves a careful and controlled distribution of critical information items among group members prior to discussion in order to establish a known distribution of information in the group. Each information item is either *shared* (i.e., known to all group members) or *unshared* (i.e., initially known to only one group member). To succeed in a hidden-profile task, group members must focus their discussion on unshared information. However, the typical finding is that unshared information items have a much lower chance of being pooled during discussion than shared items, resulting in suboptimal group decisions (Brodbeck et al., 2007).

Deiglmayr and Spada (2010, 2011) took the hidden profile paradigm as a starting point for investigating interactive knowledge construction on the basis of distributed information. In a computer-conferencing setting, student dyads solved a murder-mystery problem that required them to exchange and interpret evidence in order to identify the true murderer from among four suspects. However, in contrast to the decision-making tasks traditionally studied with the hidden profile paradigm, the focus of the study was not on the pooling of information, but on the creation of new information (i. e. interactive knowledge construction sensu Chi, 2009). In particular, to succeed in the murder mystery task, students needed to integrate initially unshared information by drawing inferences that generated new insights into the murder mystery. For example, one student might know that suspect Wolfgang's fingerprints were found on the gun with which the murder was conducted, while her partner might know that Wolfgang owned the gun and had shown it around to his guests in the afternoon. Together, the students could then infer that Wolfgang the fingerprints need not indicate that Wolfgang was the murderer. Pre-discussion information distribution was as carefully controlled as in a classical hidden profile. Thus, the researcher knew exactly what information items were shared vs. unshared between collaborators. Information exchange and inference drawing were assessed via a content analysis of discussion transcripts.

The main focus of analysis was on so-called collaborative inferences. Collaborative inferences integrate unshared information that is initially distributed between learners. Thus, they have the potential to generate genuinely new knowledge at the group level. In a first experiment (Deiglmayr & Spada, 2010), the authors found that collaborative inferences were rarely drawn spontaneously by the students. A model-based analysis of specific inference patterns in students' discourse revealed that the most important difficulties lay on the intra-individual level: To draw collaborative inferences, students need not only pay attention to new information they learn from their partner, but also need to retrieve complementary pieces of information from memory. As this retrieval process is prone to disruption during an ongoing discussion, many opportunities for drawing a collaborative inference are lost. In a following experiment, Deiglmayr and Spada (2011) devised a training intervention with an adaptive inference tutoring tool that addressed the specific difficulties found in this earlier work. For example, the tutoring tool trained students to react immediately to new information from their partner and to take some time to reflect on it. The training proved very effective in increasing the rate of collaborative inference drawing, and thus collaborative knowledge construction, during both training and unsupported transfer.

Conceptually, the analysis of collaborative inferences exemplifies a possible way of illuminating the interplay between inter-individual communication, as traditionally researched by social psychology and communications science, and individual learning, as traditionally studied by cognitive and educational psychology. However, the analysis also raises new conceptual issues: For example, does it make at all sense to speak of "collaborative" inferences, when the act of drawing an inference is conceptualized as a strictly individual cognitive act? How can we capture, conceptually and empirically, the mutual influences, mediated by communication, between two (or more) individuals` cognitive processes? We will not attempt to answer these questions here, but will return to them in the discussion.

2.3 Example 3: Manipulating the social context with virtual learning environments

As the third and last example, we introduce a relatively novel field within CSIC which exemplifies how new technologies enable new research methods that transcend the traditional boundaries between the *learning perspective* and the c*ommunication perspective* (*transformative integration*). This novel field is the study of virtual learning environments (Blascovich & Beall, 2010). Other than the first two examples, which have introduced research at the intersection of CSIC and (cognitively oriented) CSCL, CSIC processes in virtual learning environments range from, for example, the interaction of an individual leaner with a pedagogical agent to the mutual influence of multiple learners in a large virtual classroom. Virtual learning environments allow researchers to examine the interplay between communication, social cognition, and learning. The presence of nonverbal communication and social cues, in particular, can be manipulated in virtual learning environments in ways that would be difficult or impossible in more natural learning environments. This enables new methods for studying how -- often subtle -- variations in social aspects of CSIC influence individual learning activities and outcomes. Specifically, the presence or absence of instructors or co-learners, their nonverbal and verbal behavior, and their social identities can all be varied independently to identify the critical components of a given educational interaction. In doing so, methods from educational and social psychology are integrated with concepts and tools from disciplines such as human-computer interaction and computer science.

Virtual learning environments have demonstrated that one way in which CSIC can influence learning is by manipulating the social cues present in the environment. Virtual humans provide an obvious source for these cues. Avatars (virtual humans controlled by humans) and agents (virtual humans controlled by computers) can contribute both verbally and nonverbally to interactions in virtual worlds and, in doing so, can convey information or simply provide a social environment that is conducive to learning. Work by Moreno and colleagues (Moreno, Mayer, Spires, & Lester, 2001) illustrates the potential contribution of instructional messages delivered by interactive agents to learning. Participants completed a computer-based lesson in which explanations were either provided by text on the screen or by the speech of a pedagogical agent. It was shown that the speaking agent produced better transfer learning and elicited more positive affective responses from participants. In a study on virtual co-learners (Lee et al., 2007), beginner-level English speakers completed a lesson in English idioms. Completing the task with a socially supportive co-learner agent resulted in better recall of the material. These facilitative effects suggest that the explicit feedback of computer agents, even when that feedback is strictly social, offers a powerful tool to be explored within CSIC.

Research with agents and avatars further showed that individual learning is influenced by nonverbal aspects of CSIC (Krämer & Bente, 2010; Schönbrodt, & Asendorpf, 2011). For example, a recent body of research on transformed social interactions (TSIs) within virtual environments demonstrates several ways in which simple changes to nonverbal dynamics affect both learning and social outcomes. In one study, pairs of participants listened to a persuasive passage delivered by an avatar (Bailenson et al., 2005). In an attempt to tap into the inherent power of direct eye contact, the gaze behavior of the avatar was manipulated between conditions such that in one condition the avatar's gaze was directed at each participant for 100% of the time (a manipulation that would be impossible in the physical world). This manipulation of the speaker's gaze had significant effects on persuasion and memory for the speech in this task. Along similar lines, McCall and colleagues (McCall, Bailenson, Blascovich, Miyanohara, & Beall, 2009) attempted to leverage the power of the social orienting reflex, the automatic tendency to orient where others are oriented, by manipulating the orienting behaviors of co-learner agents within a virtual lecture. Despite the fact that participants were unaware of the manipulation, they had greater recall from the lecture when their co-learner agents spent more time oriented toward the lecturer.

As this selection of studies illustrates, virtual environments allow researchers to use basic social processes to influence CSIC. Current research, however, is only beginning to tap into the advantages of these technologies. Future work can, for example, continue to explore the potential of social virtual environments by manipulating and measuring social dynamics (e.g., eye gaze, signals of support, etc.; Bailenson et al., 2008). The findings that have already resulted from this new field show multiple links between, on the one hand, factors such as social presence, nonverbal aspects of instructional communication, or interpersonal trust that are traditionally studied from the communication perspective, and, on the other hand, factors such as individual attention and information processing that are traditionally studied from the learning perspective. However, as with the mutual influence of communication and learning in computer-mediated collaboration scripts (Example 1), the causal mechanisms behind these links remain still to be explored.

3. Discussion

Our aim in this paper has been to introduce the emerging field of CSIC. CSIC aims at identifying factors in the design of computer-mediated instructional messages that contribute to successful communication and effective learning in computer-based learning environments. Two strands of research are being integrated within current CSIC research: From the *learning perspective*, rooted in cognitive and educational psychology, CSIC has adopted methods for analysing the potential of learning environments and instructional messages for promoting specific cognitive processes, and thus ultimately for improving learning. From the *communication perspective,* rooted in social psychology and communication science, CSIC has adopted methods for analysing the conditions that affect the effectiveness and efficiency of communication in computer-mediated settings. We have introduced new methods and findings enabled by the integrative application of research methods from the two perspective:

the design of computer-mediated collaboration scripts that address factors enabling efficient communication as well as factors enabling effective learning, the study of collaborative inferences that crosses a social psychological research paradigm for studying efficient information exchange in groups with the analysis of knowledge creation from the drawing of inferences, and, finally, virtual learning environments as a novel technology that has given rise to CSIC research on the effects of social cues and nonverbal behaviours on the cognitive processing of instructional messages. The new research methods and designs introduced in all three examples have in common that they raise challenging conceptual questions concerning the causal mechanisms mediating between the inter-individual and the intra-individual level in CSIC.

For example, in order to design effective computer-mediated collaboration scripts, it would be valuable to know what constitutes an optimal sequencing of individual and collaborative learning phases, when to provide instructional explanations and learning materials, and how to distribute tasks and/or resources among learners, given a particular learning goal. To answer questions such as these, however, not only more empirical research is needed, but also a theoretical link between individual cognitive processes and inter-individual communication and information processing that eventually enable "interactive" learning (Chi, 2009). Basically the same issue is raised by research on the effects of social cues in virtual learning environments. Findings from this line of research make it clear that the analysis of interaction in CSIC cannot be limited to the verbal exchange of information, but that social cues and non-verbal behavior (or the absence thereof) play an important role in shaping communication, learning, and presumably also the processes mediating between the two levels. Detailed process analysis of the interplay of individual cognition and inter-individual (verbal and non-verbal) communication, such as the analysis of collaborative inference in our Example 2, represent first steps towards deriving a more complete theoretical framework. However, these issues also touch deeper conceptual questions that are much debated in the literature on distributed cognition (Hutchins, 1995; Salomon, 1993): For example, how should “knowledge”, or even “information” be conceptualized at the group level (cf. Nickerson, 1993), and how would this conceptualization differ in different CSIC context, such as collaborative learning, tutor-tutee-interaction, or learner-system interactions? Should we conceptualize cognitive processes not as individual properties, but as phenomena emerging from an on-going interaction between peers or between teacher and learner (Järvelä, Volet, & Järvenoja, 2010; Stahl, 2006)? If so, how can we define them in operational terms and measure them appropriately? Is there a way of determining intra- and inter-individual factors contributing towards cognitive processes, possibly in terms of explained variance? We do not attempt to provide an answer to these far-reaching questions in this paper. However, they are at the core of current CSIC research and theory-building.

In a similar vein, the complexity of CSIC data sets often calls for advanced statistical techniques that require more explicit models of assumed interdependencies and thus, comprehensive conceptual models of relevant factors in CSIC and their interrelations. To elaborate, CSIC data are complex because they often combine measures of communication processes, learning processes, group-level or system-level outcomes, and individual learning outcomes. Such complex data sets pose challenges for statistical data analysis. Data obtained from interacting learners, or from sets of learners interacting with a number of tutors or agents, typically violate the independence assumption of common statistical analysis methods such as ANOVA and multiple regression, because individuals become more similar through their shared learning experience. From a statistical viewpoint, such interdependence needs to be explicitly modelled, for example, in the context of structural equation modelling (Paus, Werner, & Jucks, 2012) or in multi-level analyses (Cress, 2008). These advanced statistical techniques require a clear conceptual and operational distinction between different levels in a nested data-set, along with explicit assumptions about the expected interrelationships between process variables, outcome variables, and mediators. Therefore, in the future of CSIC research, the use of advanced statistical analysis techniques and theory-building are likely to go hand in hand.

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