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ABSTRACT

This study examined how learners constructed and used shared knowledge in computer-mediated and face-to-face cooperative learning, investigating how to facilitate the construction and use of shared knowledge through dynamic visualization. Forty-eight college students were separated into dyads and assigned to one of four experimental conditions (face-to-face versus computer-mediated cooperation and domain-specific versus domain-unspecific visualization). Students worked on complex cases in which teachers described a plan for an instructional unit and asked for a common evaluation of the plan from a theoretical perspective. Students were given collaborative visualization tools. Dyads in the domain-specific visualization condition received a computer-based graphical mapping tool that included concept cards for case information and cards for theoretical concepts. Learners in the domain-unspecific visualization condition received a computer tool similar to a graphics editor. After pretesting students' domain-specific declarative knowledge and a case task, students collaborated on three cases, then were posttested. Data sources on collaborative knowledge construction came from tape recorded discourses and oral final evaluations. Results indicate that collaborative learning processes were similar among the groups. The processes resulted in comparable resources use, representation, and transfer of shared and unshared knowledge. (Contains 15 references.) (SM)

CONSTRUCTION OF SHARED KNOWLEDGE IN FACE-TO-FACE AND COMPUTER-MEDIATED COOPERATION

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(Paper presented at the symposium "Knowledge construction in face-to-face and computer-mediated environments" at the AERA Annual Meeting in New Orleans, April 2000)

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Background and goals of the study

The psychology of knowledge acquisition has up to this point dealt first and foremost with the individual. Even when analyzing cooperative learning processes, the focus of attention was, how individuals represent their knowledge, how they solve problems, etc. What the learning partners do exactly, how they represent their knowledge and solve problems, has so far played a subordinate role (Jeong & Chi, 1999). We see three lines of development, which are shifting the focus away from the single individual: Firstly, the idea to conceptualize groups as information processors developed in the field of social psychology, (e. g. Hinsz, Tindale, & Vollrath, 1997). Secondly, the discussion on situated cognition (e. g. Salomon, 1993) in the field of cognitive and educational psychology which has shed light on the important role of the social and physical context for cognitive processes. Thirdly, there are technological developments, that contribute to this shifting of the focus: new technologies for computer-mediated communication make possible new forms of cooperative learning. In our study we used a desktop videoconferencing scenario and investigated, if the conditions of such a scenario have (possibly negative) impact on knowledge construction. The focus in this contribution will be on the analysis of the construction of shared knowledge.

Shared Knowledge. In our analysis of cooperative learning we consider three main aspects of shared and unshared knowledge: if two or more learning partners cooperate, they use (1) shared and unshared knowledge resources. It can be investigated, how two or more group members use the knowledge available to them (e.g. from their prior knowledge, from learning material and so on) to collaboratively construct new knowledge in a specific learning environment. From studies in collaborative decision making we know that groups often show a tendency to neglect unshared resources, i. e. knowledge and information which only one or a small proportion of the group members has access to (e.g. Wittenbaum & Stasser, 1992). Instead, those knowledge resources and information are often discussed, of which all members are aware. Only few empirical studies investigated the role of this biased information sampling phenomenon *in the context of learning.*

If group members learn together (2) they can construct shared representations. Here, for example, it can be of interest, to what extent the learning partners construct similar declarative knowledge. The pioneering study of Jeong and Chi (1999) showed that only a relatively small portion of the knowledge which a dyad constructed during collaboration, is actually represented by both of the learners. Moreover, it is not guaranteed, that shared representation will lead to similar knowledge application (Renkl, Gruber, & Mandl, 1997). Therefore, we also consider (3) the transfer of shared knowledge to be an important aspect. Here, a main question is, to what extent former learning partners are similarily able to apply the shared knowledge in new contexts.

Computer-mediated cooperative learning and cooperative learning face-to-face. Sassenberg, Boos, Laabs, and Wahring (1998) showed the phenomenon of biased information sampling (the tendency to neglect unshared knowledge resourses in group decision making, see above) for synchronous computer-mediated cooperation. However, this study also demonstrated that the effect was of comparable size in the computer-mediated scenario and in a face-to-face setting. Therefore, we expected no differences between the videoconferencing condition and the face-to-face setting concerning the use of shared and unshared knowledge resources.

Concerning the construction of shared and unshared knowledge, it is unclear, to what extent the conditions of videoconferencing have an impact (see Fischer & Mandl, in press). Up to this point, no systematic studies on this topic have been conducted. A smaller amount of shared knowledge is possible, for the development of similar positions might be mediated through nonverbal and para-verbal aspects. Although nonverbal and para-verbal signals can be partly transported through audio and video connections, important differences do exist between face-to-face communication and videoconferencing (Fussel & Benimoff, 1995; O'Connaill & Whittaker, 1997). For example, the lack of eye contact and gaze awareness as well as the reduced possibility to make deictic gestures in a video conference could serve as hindering factors. Overlapping turns and unwanted interruptions can often occur under these conditions.

However, most empirical studies on problem solving and decision making showed no differences between videoconferencing and face-to-face conditions concerning the outcome: In spite of partly different process characteristics cooperation partners frequently come to qualitatively similar solutions in the setting of a video conference as compared to face-to-face settings.

Facilitating the construction of shared knowledge through dynamic visualization. In this study, two forms of dynamic visualization were employed. Domain-unspecific visualization: The widespread shared whiteboards (mostly simple graphic editors) should support interaction between remote collaborators by providing them with the possibility to collaboratively visualize graphical elements as well as written notes (Dillenbourg & Traum, 1997). The subject area (e. g. medical diagnosis, botanical classification) as well as the task type (e. g. discussion, decision making, learning) do not play a role in the design of this tools. In the domain-specific visualization, the degrees of freedom of the external representation are constrained by task-relevant structures. For example, so called visual languages are designed to support discourse by providing the collaborators with a set of symbols for task specific categories. To what extent domain-specific visualization as compared to domain-unspecific visualizations support the construction of shared knowledge, has up to this point barely been subject to empirical investigation. We expected that the provision of categories in the domain-specific visualization would promote the construction of shared knowledge, because less coordination effort will be necessary. However, process oriented models like, e.g. the grounding approach (Clark & Brennan, 1991) would argue that co-ordination is part of the construction processes leading to shared knowledge.

Goals of the study and research questions. With this background, the following study will examine (a) how learners construct and use shared knowledge in two different cooperative learning scenarios: computer-mediated cooperative learning and cooperative learning face-to-face. (b) Furthermore, we investigate how the construction and use of shared knowledge can be facilitated through different types of dynamic visualization.

Method

Sample and design. Fourty-eight students of educational psychology volunteered in this study. The participants were separated into dyads such that the partners were only acquainted with each other through their studies. In particular, we took care that partners had not previously worked together in groups. Each dyad was randomly assigned to one of the four experimental conditions in a 2x2 factorial design. We varied (1) the cooperation scenario (face-to-face vs. computer-mediated) and the type of visualization (domain-unspecific vs. domain-specific). Time-on-task was held constant in all four conditions.

Learning environment. Students in both conditions had to work on complex cases in the domain of education. In these cases, teachers describe a plan for an instructional unit and ask the participants for an evaluation of the plan from a theoretical perspective. The students' task was to prepare a common evaluation of the case. While working on a case, students were provided with a collaborative visualization tool to represent their developing solution graphically. After each case, students were asked to give a short oral evaluation of the case from a theoretical perspective.

Type of visualization. Dyads in the *domain-specific visualization* condition were provided with the CoStructure-Tool, a computer-based graphical mapping tool that includes concept cards for case information and cards for theoretical concepts, in which text could be typed in directly. Positive and negative relations can be used to connect cards. Moreover, the screen of the CoStructure-Tool is divided into an empirical and a theoretical plane. Both learners were provided with a keyboard and a mouse and could access the different objects on the screen virtually simultaneously.

Learners in the *domain-unspecific visualization* condition worked on a computer tool which comprises the functionality of a simple graphic editor. The learners could type in and edit text, draw lines, circles and rectangles, change the colors of these items and drag them across the screen.

Procedure. After a pre-test consisting of a domain-specific declarative knowledge test and a case task, students were made familiar with the learning environment, especially with the use of the visualization tools. Next, learners worked together on three cases. During their work on the cases learners were allowed to use a text with a number of relevant theoretical concepts and their descriptions. The collaboration was followed by an individual post test which paralleled the individual pre-test.

Variables and data types. As data source for the variables of collaborative knowledge construction and outcome we used tape recordings of discourses and (oral) final evaluations. These tape recordings were transcribed and analyzed (i.e. segmented and classified). (1) *Use of shared and unshared knowledge resources* : As the indicator for the use of shared resources we determined the number of concepts and case information, which were given in the text and case description. Unshared knowledge was determined as the number of concepts and relations not overtly given in the learning environment (including prior knowledge concepts and inferences made on the basis of the given information). (2) *Representation and transfer of shared and unshared knowledge*: Using a method similar to that used by Jeong and Chi (1999), we measured shared knowledge as the number of concepts which both former dyad members remembered in the knowledge test (for the representation aspect) or applied in the individual transfer case (for the transfer aspect). Unshared knowledge, in contrast, was determined by the number of concepts and relations which only one of the two dyad members applied in the case solution. (3) Strategies of cooperative learning: We conducted exploratory qualitative single case studies (e. g. Roschelle, 1995) using transfer of shared knowledge as the selection criterium. Five dyads with much shared knowledge and five dyads with little or no shared knowledge were included in this analyses. We focused our analyses on two dimensions of the cooperative learning strategy: The *coordination dimension* (e. g. individual vs. collaborative coordination, overt vs. covert coordination) and the *content dimension* (e. g. bottom-up vs. top-down).

Results and discussion

Concerning the *use of knowledge resources* we found a tendency for the computer-mediated dyads to use less shared knowledge resources ($F(1,44) = 2{,}72$; $p = .10$) as compared to dyads in the face-to-face condition (Figure 1). Such a tendency could not be found in regard to unshared knowledge resources ($F(1,44) < 1$; n.s.). The type of visualization had no effect on neither shared ($F(1,44) < 1$; n.s.) nor unshared knowledge resources ($F(1,44) < 1$; n.s.). Collaboration scenario and type of visualization did not interact with regard to neither shared ($F(1,44) < 1$; n.s.) nor unshared knowledge ($F(1,44) < 1$; n.s.).

Concerning the *representation of shared knowledge*, no differences could be found neither with respect to collaboration mode ($F(1,20) < 1$; n.s.), nor to the type of visualization (F

(1,20) < 1; n.s.) nor to the interaction of the two factors (F (1,20) < 1; n.s.). The same is true for the *unshared representation of knowledge* (collaboration mode F (1,20) < 1; n.s; type of visualization F (1,20) = 1,24; Interaction collaboration mode X Type of visualization F (1,20) < 1; n.s.).

Finally, *transfer of shared knowledge* was also not substantially influenced by the factors employed in this study (collaboration mode F (1,20) < 1; n.s; type of visualization F (1,20) = 1,05; n.s. Interaction collaboration mode X Type of visualization F (1,20) < 1; n.s.). The same is true for *unshared knowledge transfer* (collaboration mode F (1,20) < 1; n.s; type of visualization F (1,20) < 1; n.s. Interaction collaboration mode X Type of visualization F (1,20) = 1,18; n.s.).

Taken together these findings suggest (1) that the construction of shared knowledge is neither hampered nor facilitated by the conditions of the synchronous computer-mediated collaboration in a videoconferencing environment as compared to a face-to-face condition; (2) that the domain-specific visualization which proved to be effective in supporting processes of collaborative knowledge construction (Fischer, Bruhn, Gräsel, & Mandl, 1998) is not more effective than the domain-unspecific visualization in facilitating the representation and transfer of *shared knowledge*.

In figure 2 it is salient that only a small proportion of knowledge is actually shared in all of the conditions we employed in our experiment. With the following step of our analysis we therefore tried to rule out, that the shared knowledge we measured was simply caused by similarities in experimental conditions, e.g. learning material. We compared real dyads to nominal dyads (figure 3). Results show that real dyads do not differ from nominal dyads in reference to the representation of shared and unshared knowledge (t(31) < 1; n.s.). However, more shared knowledge is transferred in real dyads as compared to nominal ones (t(31)<; p <.05). These findings could be interpreted such that co-construction within the dyads could only be effective concerning higher order processes in connection with transfer. Real dyads did not differ from nominal dyads concerning the declarative knowledge measured by the knowledge test.

In qualitative single case studies, two strategies of cooperative learning (table 2: adaptive scaffolding and flexible co-construction) could be identified, which are connected with the representation and transfer of shared knowledge. (1) *Flexible co-construction* is a strategy that has been observed in dyads which are homogeneous in regard to prior knowledge. The two learning partners frequently take on different roles concerning the coordination of their common activities. For example, one will do the coordinating for a while but most of the time they will do the coordination task together in negotiating their next steps. On the content level, one learner will assume the responsibility of analyzing the case information for some time and the other will search for adequate theoretical concepts. Afterwards they come together to integrate their individual findings and try to come to a consensus. Sometimes they change their roles after that.

Adaptive scaffolding is a discourse strategy also leading to a high level of shared knowledge. This strategy has been observed in dyads which are heterogeneous in regard to prior knowledge. Here, learning partners take on different roles as well. The more knowledgeable peer takes on the role as a kind of guide and lets the other one do most of the problem solving. He only steps in when he realizes that the other cannot continue on his own. When things have been straightened out, the more knowledgeable peer steps back into the role as a guide. Sometimes a point can be reached, where the guided peer leaves his role and a discussion can take place. Interestingly, it was sometimes the case that the scaffolding was more of an implicit act on the part of the guide (see secret master plan below). It seems necessary that the guided peer makes sure that the guide is explicit in his coordination strategy. In regard to the content strategy, top-down orientation dominates most of the time.

Furthermore, strategies were identified which were closely connected with a small portion of shared knowledge (see table 1). (1) *Secret master plan* is a strategy of cooperative learning which has been observed in dyads which are heterogeneous in regard to prior knowledge. As in the adaptive scaffolding strategy, learning partners take on different roles. The more knowledgeable peer also takes on the role as a kind of guide in this case. However, he is not explicit with the guided peer about the task strategy and thus the latter will not be able to conduct the task on his or her own later on. (2) *Inadequate division of labour* has been observed in dyads which are homogeneous in regard to prior knowledge. Here again, each peer has a different role. However, this role assignment is inadequate for the construction of shared knowledge. For example, a thinker and a painter may come to a high-quality collaborative solution but only one of them (the thinker) will be able to individually apply the knowledge.

Interestingly, no differences between face-to-face and computer-mediated collaboration could be found in regard to these strategies. The same is true for the two types of tool employed in this study. Moreover, the amount of shared knowledge is rather low for both tool types, indicating that the visualization with interactive graphic tools may not be an adequate approach to foster for instance the sharing of the coordination master plan. These complex coordination and content strategies could lead to hypotheses concerning the instructional support of the construction and the use of shared knowledge. For instance, against inadequate role assignment, cooperation scripts proved to be successful instructional means (e.g. O'Donnell, 1999).

Conclusions and outlook

To sum up, whatever differences were assumed between the cooperation modes, the findings of this study hardly show any differences: In videoconferencing, collaborative learning processes were similar (see also Fischer & Mandl, in press) and resulted in resources use, representation and transfer of shared and unshared knowledge which were comparable to a face-to-face setting. The analysis of processes or strategies leading to shared knowledge is in its early beginnings. The strategies described above could serve as tentative hypotheses in a more in-depth analysis and subsequent instructional facilitation of these processes.

In our view, the phenomenon of shared knowledge should be considered more seriously in theoretical approaches to cooperative learning. Theoretical models of cooperative learning should include statements about how shared knowledge arises, and how it can be promoted. It should further allow for the formulation of hypotheses concerning the use and construction of shared knowledge in a specific cooperative learning arrangement. Theoretical approaches as well as empirical studies may consider at least the following three aspects of shared knowledge: (1) The use of shared and unshared knowledge resources, (2) The construction of shared and unshared representations, and (3) shared and unshared transfer. These aspects can also be used to evaluate cooperative learning environments in practice. For example, a seminar over a whole semester will gain much in quality, if participants are going to share more and more knowledge, because the discourse level is likely to increase (Nicolopoulou & Cole, 1993). To support the construction of shared knowledge, the dynamic visualization tools we employed in this study seem not to be adequate means. It is up to further studies to analyze and describe conditions and tools which effectively enhance learners' capabilities to construct shared knowledge.

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Table 1:

Strategies correlating with high and low proportions of shared knowledge (examples).

Strategies for sharing knowledge		
Flexible co-construction	coordination is part of the negotiation process	top-down
Adaptive scaffolding	Fading coordination by the more knowledgeable partner	top-down
Strategies for not sharing knowledge	**Coordination strategy**	**Content strategy**
Secret master plan	one partner co-ordinates; cognitive and metacognitive processes covert	bottom-up or top-down
Inadequate division of labour	one partner co-ordinates most of the time, cognitive and metacognitive processes covert	mostly top-down
Vertical flight	sequential monologues; no coordination concerning the task	top-down or ignorance of case data

Figure 1.

The use of shared and unshared knowledge resources of the dyads in the four experimental conditions.

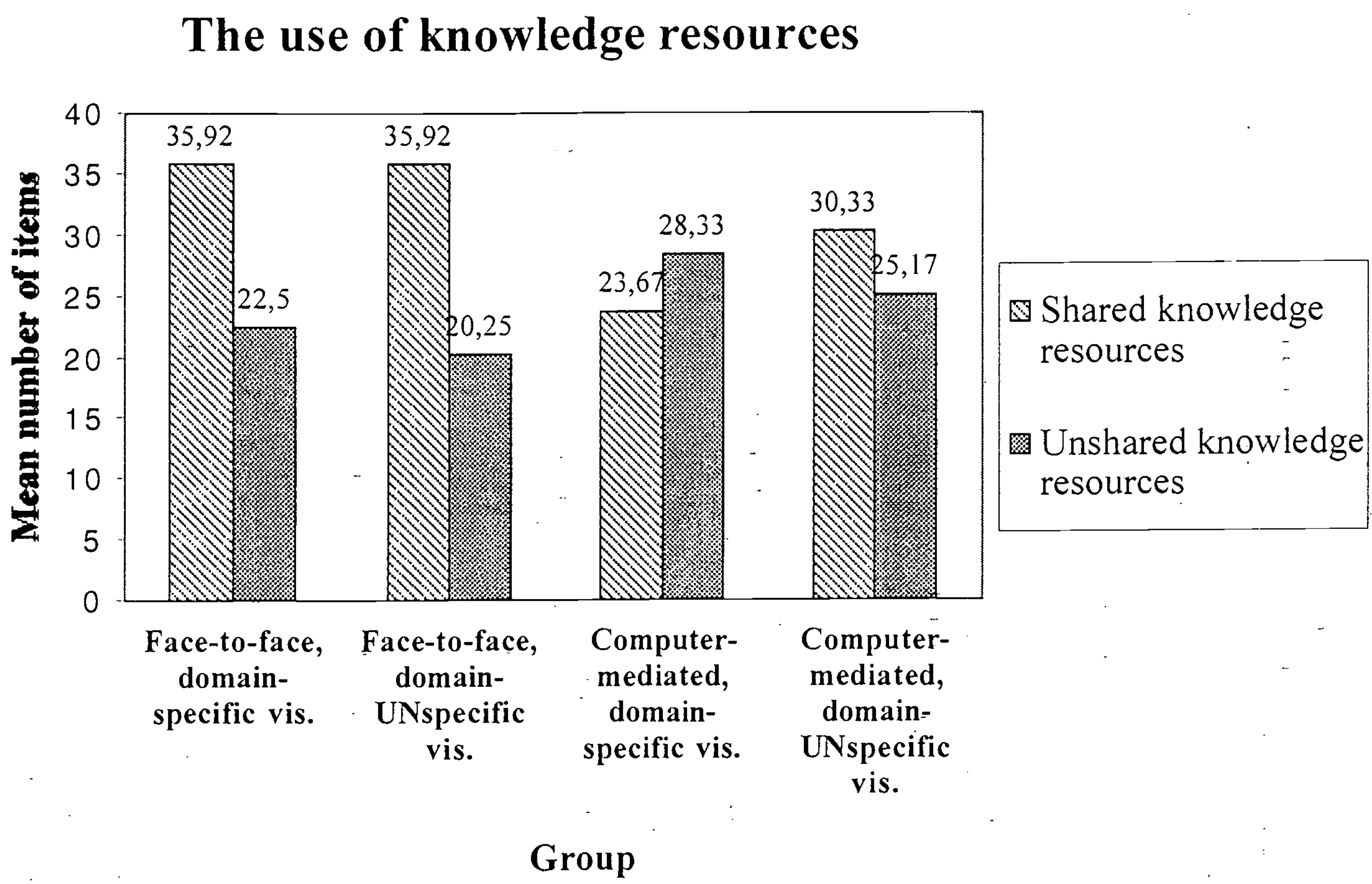

Figure 2.

The representation of shared and unshared knowledge in the four experimental conditions.

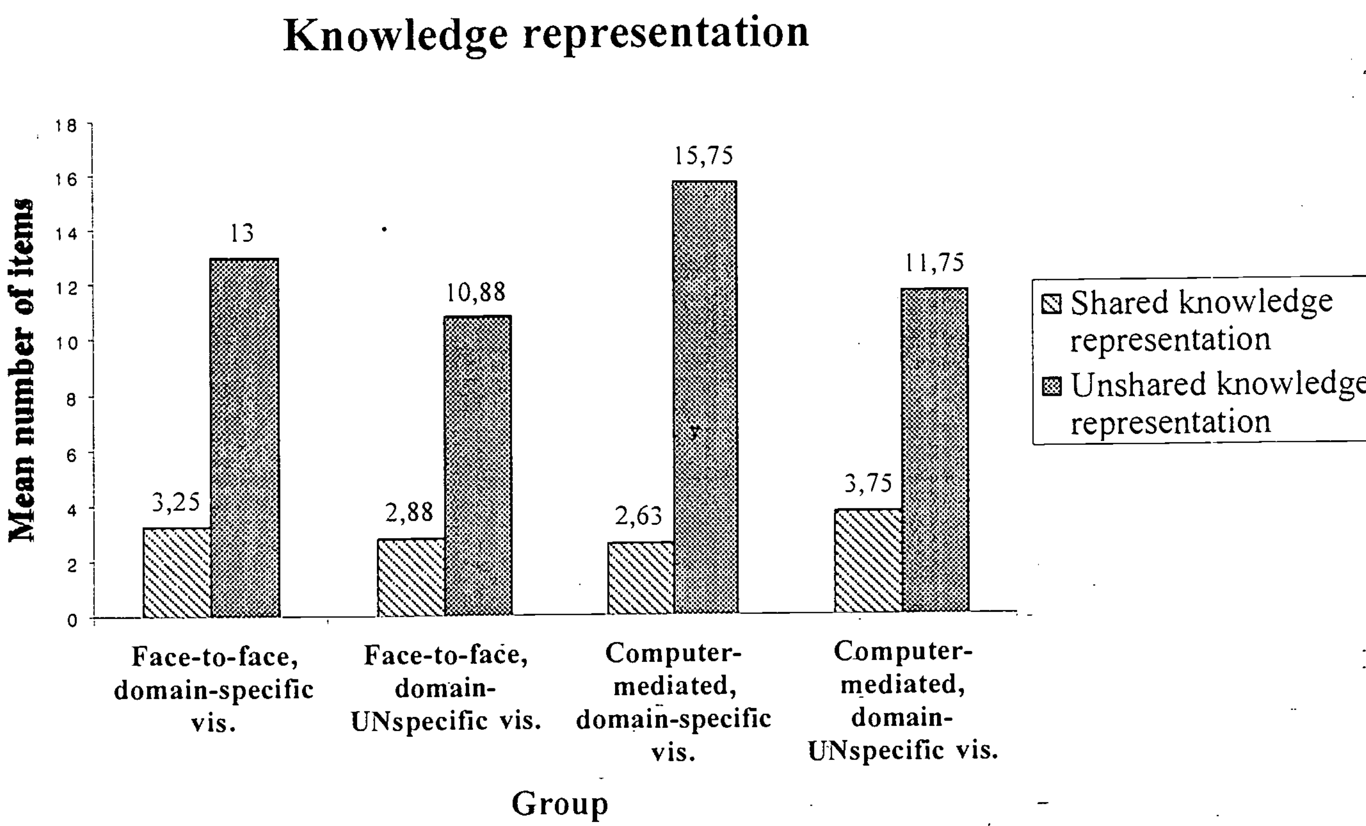

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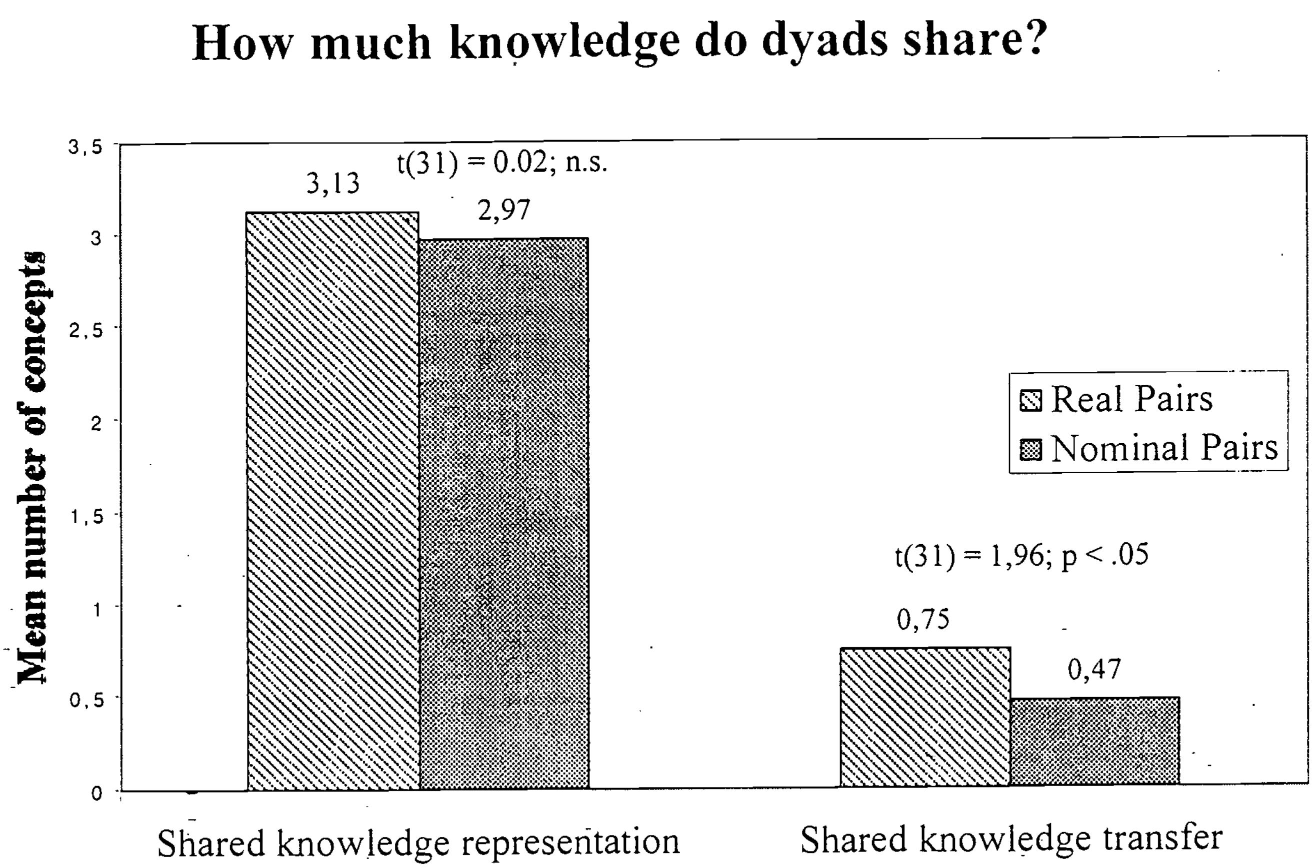
Figure 3.

Shared knowledge representation and transfer in real vs. nominal pairs.



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