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AND TYPE OF COMMUNICATION ON
PERFORMANCE IN VIRTUAL TEAMS

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SUSAN G. COHEN

Center for Effective Organizations
Marshall School of Business
University of Southern California

RAMON RICO

Universidad Autónoma de Madrid

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Ramón Rico*

and

Susan G. Cohen**

* Universidad Autónoma de Madrid (Spain)

** University of Southern California (USA)

Address: Departamento de Psicología Social y Metodología

Universidad Autónoma de Madrid

Ctra. Colmenar Km.15

28049 Madrid

Spain

Tel: 34 913 978 584

Fax: 34 913 975 215

E-mail: ramon.rico@uam.es

EFFECTS OF TASK INTERDEPENDENCE AND TYPE OF COMMUNICATION ON PERFORMANCE IN VIRTUAL TEAMS

This laboratory study proposes a model of virtual team performance based on the fit between the characteristics of the task and the type of communication media used by members of the team. Using a 2 x 2 factorial design of 240 participants randomly assigned to 80 three-person teams, we investigate the effects of within-group task interdependence and the degree of communications synchrony on performance in virtual teams (VT). Teams worked virtually (not meeting face-to-face) performing a merit rating task. The analyses revealed an interaction effect between task interdependence and synchrony of communication. We found high values of VT performance both: a) under conditions of "low task interdependence" and "asynchrony of communication" and b) under conditions of "high task interdependence" and "synchrony of the communication". The results show that superior VT performance is contingent on the match between the nature of the task and the choice of communications modality. This work complements past research that has focused mainly on virtual teams using asynchronous technologies or comparing them with face to face teams.

Work is changing. Indeed, one might say it is evolving away from what we called the post-industrial era to today's knowledge-based society. The effects of these changes are being felt at different levels. People's relationship with work is gradually changing from the need to use tools to a need to respond to the unexpected. Firms are faced with demanding competitive challenges due to their immersion in global markets, the increasing complexity of the environments in which they operate, and the pace of organizational change (Mohrman, Galbraith & Lawler, 1998; Cascio, 2000; Duarte & Tennant, 2001; Cohen & Gibson, 2003).

The accelerating development of new information technologies may be a cause or consequence, and at the very least accompanies these organizational changes. The use of new information technologies generate opportunities and promising solutions to the need for flexibility in organizations.

In this context, virtual teams have become a source of competitive advantage, due to the spread and growing importance of teams in modern society (Cohen & Bailey, 1997) and their key role in the design of our organizations (Mohrman, Cohen & Mohrman, 1994).

Virtual teams are above all teams or working groups. However, they interact via electronic communications systems. The members of these teams do not tend to meet in the conventional sense; they are scattered (Bell & Kozlowski, 2002) and membership itself is changeable, adapting to the shifting requirements of the tasks and projects undertaken (Townsend, De Marie & Hendrickson, 1996).

The increasing popularity of virtual teams highlights two related issues. First, the use of these work units in organizations is far ahead of research on the subject, and second, as suggested by Montoya-Weiss, Massey & Song (2001) we may enrich our

knowledge of how virtual teams (VTs) work using what we already know about non-virtual teams. However, we need to remain aware of the opportunities and limitations that virtuality imposes on working teams.

Numerous scholars have contributed to the growing research on the effectiveness of VTS. Key findings include: a) how team building process are improved by the structuration of activities with a goal-setting structure (Huang, Wei, Watson & Tan, 2003) or temporal coordination mechanisms (Montoya-Weiss, et al., 2001); b) How virtual teams are requiring a kind of "distal" leadership (Bell & Kozlowski, 2002) that requires from managers delegation and facilitation skills; and c) how the type of task that the team is carrying out influences virtual team performance (Straus & McGrath, 1994; Hollingshead & McGrath, 1995). Many of them point out, however that we need to discover more about the interaction between communications technologies and the kind of task carried out by a team (Bell & Kozloswski, 2002; Mazniewski & Chudoba, 2000; Mazniewski & Atanassiou, 2003; Montoya-Weiss, et al., 2001).

Pairing up the study of these concepts might seem a mere fancy were it not for the consistent relationship between the type of task and the processes used and results obtained by teams (Goodman, 1986; McGrath, 1984; Guzzo and Shea, 1992; Levine and Moreland, 1990, Cohen & Bailey, 1997) and the necessary use of communications technologies for virtual teams to interact at all. These technologies indeed permit the dispersion of teams in space and time, while remaining a key element of their processes (Bell & Kozlowski, 2002; Olson & Olson, 2003).

In this paper, we report on an experiment to test how the fit between the characteristics of the task, in particular task interdependence, and communication synchrony influences VT performance.

Task interdependence

Teamwork involves interaction with other team members, with whom the individual maintains a given level of interdependence. Work must, therefore, be interactive to complete a set of tasks (Stewart & Barrick, 2000) and share information, knowledge or materials in order to achieve the desired outcomes (Susman, 1976; Cummings, 1978). Interdependence in the task thus implies the degree to which team members will interact and depend upon each other to attain their goals (Campion, Medsker & Higgs, 1993).

Studies of task interdependence go back a long way. To follow the proposals of Wageman (1995) and Stewart & Barrick (2000), we may identify two main approaches. The first treats task interdependence as the product of technological requirements (Thompson, 1967; Van de Ven, Delbecq & Koenig, 1976). The second conceptualizes interdependence as the outcome of perceived member needs to cooperate with each other (Shea & Guzzo, 1989; Van der Vegt, Emans & Van der Vliert, 1998).

We agree with Wageman (1995) that task interdependence is a structural characteristic and at the same time, that the same task may be carried out with differing levels of interdependence. In this light, our approach in this paper concentrates on the extent to which instructions and the context of task performance are capable of affecting the degree of interdependence between the members of a team as they work.

Type of communication technology in virtual teams.

If interdependence is the "glue" that holds conventional teams together, communication technologies serve as the bond linking the members of virtual teams. They allow team members to communicate and share data and information despite

disparities in location and time-zone. In this way, they become the key channel for interaction in virtual teams (Bell & Kozlowski, 2002).

E-mail, web-based repositories of shared knowledge, group calendars, newsgroups, instant messaging, chat, electronic whiteboards and videoconferencing tools are just some of the plethora of technological options and alternatives available to channel communication between organizational formations of this kind.

Communication technologies are defined by the three dimensions of space, time and the level of support they provide to the group activity (Warkentin, Sayeed & Hightower, 1997). Considering only the first two, however, these alternatives may be classified in terms of the synchrony of communication, which is the degree to which communication technologies allow teams to work together in the same space and time (Montoya-Weiss, et al., 2001).

The attention given to this asynchrony-synchrony continuum has been somewhat uneven. In the first place, this is partly because of the widespread stereotype of virtual teams as structures that allow work to take place continuously around the globe (Lipnack & Stamps, 2001). Second, most research has been aimed at measuring the effects of electronic communication has compared face-to-face teams without communication technology with those using asynchronous forms of computer-mediated communication (Bell & Kozlowski, 2002; Maznievski & Chudoba, 2000). Thus, a number of variables have been identified to take into account the limitations electronic communications impose on virtual teams (McGrath & Hollingshead, 1994) and measure how these may impact on performance (Warkentin, Sayeed & Hightower, 1997).

Face-to-face communication is an orderly process in which verbal and non-verbal cues offer feedback, facilitate turn taking and transmit subtle shades of meaning.

Asynchronous communication, however, presents numerous difficulties, erasing many of the cues that permit regular intercourse and feedback: interruptions are frequent, pauses are long and information overload may arise (McGrath, 1991; Ocker et al, 1995).

A number of studies show that communication is less efficient in virtual than in face-to-face teams (McGrath & Hollinshead, 1994; Straus, 1996). They reveal how difficult it may be for team members to remain aware of each other's presence (Olson & Olson, 2003) and highlight the obstacles to the development and upkeep of trust relationships (Jarvenpaa, Knoll & Leidner, 1998; Rocco et al. 2000). In short, electronic communication poses a number of problems due to the difficulty of eliciting social cues and constructing the kind of relational ties that smooth interaction (McGrath, 1990; Warkentin et. al 1997; Maznievski and Chudoba, 2000).

Therefore, it follows that face-to-face teams would outperform virtual teams, and by extension, that VTS using synchronous as opposed to asynchronous communication technologies would also be more effective. A recent review (Maznievski & Chudoba, 2000), however, reveals some disagreement in this regard. While the results of some studies support the hypothesis, others reflect better performance in virtual than in face-to-face teams, and a final group appears to suggest that there is no difference between the two types of teams.

Joint effects of task interdependence and type of communication technology on virtual team performance.

One straightforward way to resolve the confusion arising from such contradictory empirical evidence relating technological influence on virtual teams and their performance is to consider the role played by the type of task undertaken by the team (O´Connor, Gruenfeld, & McGrath, 1993; Hollingshead, McGrath, & O´Connor,

1993; Hollingshead & McGrath, 1995). A recent review (Hollingshead & McGrath, 1995) uses the typology proposed by McGrath (1984) to classify the possible tasks that a group may undertake into four classes: generate, choose, negotiate and execute. This work shows that virtual teams using asynchronous communication perform better than face-to-face teams in generation tasks (e.g. idea generation). In the case of intellective or negotiation tasks, however, face-to-face, and therefore synchronous, teams perform better than VTS using asynchronous communication.

Furthermore, it has been noted that the effects of communication technologies on teams may be largely a consequence of the manner in which the task is structured in response to the constraints of a given technology (Watson, DeSanctis & Poole, 1988; Holllingshead & McGrath, 1995). This consideration unequivocally points to interdependence as a structural feature of relations between the team members (Van der Vegt, et al., 1998). In this light, we may ask what are the roles played by task interdependence and the type of communication technologies used in the final performance of virtual teams?

In a recent study, Maznievski & Chudoba (2000) found that tasks requiring greater interdependence in the most effective teams were commonly associated with a higher frequency of communication between team members, a higher level and complexity of decision-making processes, and richer communication channels. Also, Turoff et al. (1993) reported that the amount of interaction the communication technologies must support relates to the amount of interdependence required by a task.

As we have already mentioned, the technology used imposes a certain structure on the task in terms of the required level of interdependence, but it is no less true that the same task may be performed at different levels of interdependence (Wageman,

1995). This fact may provide further facets for the understanding of longitudinal studies (Hollenhorst, et al. 1993) which suggest that the differences comparing virtual teams using asynchronous technologies with face-to-face teams tend to decline over time. A plausible explanation for this finding is that the team adjusts the level of interdependence in the task to the possibilities for interaction permitted by the technology.

Based on the above, we investigated to what extent performance in a VT may depend on the individual team member's degree of synchrony in the communication technology used. Hence, we hypothesize that:

H1: For low task interdependent teams, synchrony in the communication technology is negatively related to team performance.

H2: For high task interdependent teams, synchrony in the communication technology is positively related to team performance.

METHOD

Participants

Two hundred forty participants were randomly assigned to 80 three-person teams. We recruited subjects from Human Resource Management masters degree courses and final-year Psychology students in Spain. These participants were considered ideal because the tool used to support the work of the virtual teams, Edustance ®, was at the final stage of testing and not yet available in the market.

Task Setting

The task used replicates Saavedra, Earley & Van Dyne's (1993) adaptation of the merit rating task originally proposed by Marcic (1989). The items were written up in

Spanish, maintaining the structure originally proposed. In this study, the task was managed electronically through the Edustance ® website environment. As in the original study performed by Saavedra, et al. (1993) each description had a correct and unique numerical solution, based on the weights assigned to the different phrases that describe different workers by two independent experts (Kappa= .92).

Design

The true experiment was a 2 (task interdependence: low and high) X 2 (communication technology synchrony: asynchrony and synchrony) factorial design. As in the work of Saavedra et al. (1993), the time allotted for the task was insufficient to complete all of the descriptions offered to the participants under the different conditions.

Procedure

The procedure followed the rules established by Saavedra et al. (1993), with appropriate adjustment of our variables and their application to a virtual teams work environment. The participants were placed in groups of 12 or 24 and each session included all of the experimental conditions with one or two teams per condition depending on the number of participants present.

On arrival, the participants were seated in a room with individual work stations from which they were able to access the intranet hosting the Edustance ® tool. When the participants opened the session in the system with the usernames and passwords assigned by the researchers, they entered a work area containing the necessary resources to carry out the task. As shown in figure 1, the resources of the team consisted of different links. The first four allowed the team to access: 1) the instructions adjusted to the relevant experimental condition; 2) practice employee descriptions; 3) the 42

employee descriptions for the definitive task; and 4) the tables of weightings to rate the employees and calculate merit increases. Finally, a link was provided to open the forum or chatroom depending on the experimental condition assigned.

------ Insert Figure 1 about here ------

When the participants had entered the work environment, the experimenters asked them to access the instructions, which were read out loud with the participants. These instructions were translated and adapted to Spanish from Saavedra et al. (1993, pg 65-66) "For many employees, their annual pay raise is the most important feedback that they receive from their organization. In the following group exercise you will rate employees …… calculate a total weighted score for the employee. Determine a recommended merit increase using the guidelines of the form." The experimenters performed an example together with the participants in order to demonstrate how to determine the rating, how to weight it, how to calculate the total weighted score and how to recommend a merit increase. The existence of a single correct solution for each employee that would be used to determine the team's performance was stressed.

The participants were requested to perform the task individually for five minutes in order to be sure that the task was well understood. We asked for questions and then we enacted the experimental manipulations. For this purpose, the participants were asked to exit the online work environment and were distributed in three different rooms. They were given a new password and username providing direct access to the experimental conditions.

The instructions for participants working under the condition of low interdependence explained that they were working as a team, but that each member should work individually to complete each stage to determine the salary increase for the

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employees. In the high interdependence situation, the participants were also told that they should work as a team, but in this case each team was free to decide how to distribute responsibilities for the performance of the task. In the asynchronous communication technology conditions, the participants were provided with a web-based work environment consisting of a kind of bulletin board system. The system permits team members to communicate by "posting" messages in a hierarchical way, providing a clear structure for the messages. In the synchronous communication technology conditions, participants were provided with a chat application. This application allows team members to establish real time communication. At the same time, it provided information on the team members connected and indicated which member was online at any given moment.

After accessing the new work area, the participants were asked to open a link providing three practice examples. They were given 10 minutes to complete this task. Following Saavedra et al. (1993) we chose to use a practice team trial in addition to the individual one as an opportunity for the group as a whole to rehearse their task. At the end of this period, a further five minutes were allotted to give feedback to the participants on their efforts and resolve any questions that arise. The participants were then asked to open all of the necessary windows to carry out the task and to access the link containing the descriptions of employees. The experimenters reinforced the manipulations and started the 30-minute period for the task. Microsoft Word Pad documents with rating sheets were collected on a diskette given to a team member, designated by his/her own team, to record the results. While rating documents were scored, participants completed a questionnaire that included manipulation checks. Finally the experimenters debriefed the teams and thanked them for taking part.

Measures

In order to check the experimental manipulation, we prepared a single questionnaire comprising randomly ordered self-report Likert-type items ranging from (1) strongly agree to (5) strongly disagree. Where possible, the items for each scale were averaged out in order to obtain a single measure for each participant.

Task interdependence as perceived by team members was measured following the 5-item scale used by Van der Vegt, Emans, Van de Vliert (2001). "I depend on my colleagues for the completion of my work" is an example of the items used. The coefficient alpha for the five-item scale was .72.

Communication Synchrony was assessed using a single item "Which of the following best characterizes the type of communication you could establish with other team members during task resolution?" where 1= communication between the team members took place with excessive pauses, and 2= communication between the team members took place smoothly at the same time. This item was developed following the definition of synchrony provided by Montoya-Weiss et al. (2001).

Team performance was measured as the total evaluations completed correctly by a team. As we said previously each description had a correct and unique numerical solution, based on the weights assigned to the different phrases that describe different workers by two independent experts.

RESULTS

Manipulation checks

Synchrony manipulation was assessed by a 2 (response category) X 2 (communication conditions) chi-square analysis, which demonstrated that the

manipulation worked, χ^2 (1, 240) = 232.13, p< .00. Only two participants were misclassified.

The task interdependence manipulation was assessed by using the mean scores of each participant on the task interdependence scale. Using the median point of the scale we divided the participants into two groups of high (M= 4.12 SD= .45) and low perceived task interdependence (M= 1.47 SD= .33). A 2 (recoded category) X 2 (task interdependence conditions) chi-square analysis showed that the manipulation worked, χ^2 (1, 240) = 224.5, p< .00. Only four participants were misclassified.

Test of hypothesis

Table 1 provides mean scores, standard deviations and cells for team performance. The results of the ANOVA shows no main effect of task interdependence, F (1, 240) = 2.16, p = .14. On the other hand, a main effect of communication synchrony was found, F (1, 240) = 14.46, p < .001. This was also the case with interaction between the two, F (1, 240) = 183.26, p < .001.

---Insert Table 1 about here---

Thus, the differences found in the performance of the teams did not seem to depend on the degree of interdependence of the team in the performance of the task. On the other hand, higher or lower synchrony in the communication channel available to the team to perform its tasks did indeed play a significant role in team performance. Taken as a whole, the teams that used synchronous communication in the task performed significantly better (M = 13.07, SD = 3,83) than those using asynchronous communication (M = 11.2, SD = 4,23), t (77) = -2.07; p = .041.

Finally, the analysis of interaction revealed that this enhanced or detrimental impact on performance had an inverse and significant effect on the various conditions.

(see fig. 1). The teams using asynchronous communication showed significantly lower

performance when we compare them operating under conditions of low interdependence

(M = 14.9, SD = 2,24) with those in conditions of high interdependence (M = 7.5, SD =

1,70); t (35) = 11.74; p < .00. Conversely, teams using synchronous communication

significantly perform better in a situation of high interdependence (M = 16.05, SD =

2.64) compared with those teams of low interdependence conditions (M = 10.1, SD =

2.12); t (36) = - 7.84; p < .00.

------ Insert Figure 2 about here ------

As a final point, we may note that the difference found in the comparison of those

conditions in which the teams performed best –i.e. low task interdependence and

asynchronous communication (M = 14.9, SD = 2.24) against high task interdependence

and synchronous communication (M = 16.05, SD = 2.64)– was not significant, t (37) = -

1.48; p = .14. The difference between the worst performing teams was, however,

significant. Thus, those teams operating under high task interdependence and

asynchronous communication conditions (M = 7.05, SD = 1.70) perform significantly

worse than those operating in conditions of low task interdependence and synchronous

communication (M = 10.1, SD = 2.12); t (36) = -4.27; p < .00.

DISCUSSION

The empirical evidence obtained from the study reveals how the performance of VTs

depends on the fit between the level of interdependence required by the task undertaken

by a team and the degree of synchrony provided by available communication

technologies. Our findings allow us to maintain our hypotheses regarding the positive

relationship between the performance of VTs and the use of synchronous communication technology in teams carrying out low interdependence tasks.

The finding that task interdependence and communication synchrony interact in their effects on the performance of VTs may provide a coherent pattern integrating the findings of studies that have compared VTs and face-to-face teams performing different types of task using a variety of communications media (Farmer and Hyatt, 1994; Hollingshead et al., 1993; Hollingshead and McGrath, 1995; O' Connor et al., 1993; Ocker et al, 1998; Strauss and McGrath, 1994; Valacich, Dennis and Connolly, 1994).

In the terms of McGrath's task circumplex, the assignment we set for our teams can be defined as intellective. Now, it might be thought in light of earlier research (Hollingshead et al., 1993) that teams using synchronous communication tools would be better at such tasks. However, our results show that the high levels of performance achieved by virtual teams carrying out the same kind of task, in conditions of high interdependence and synchronous communication systems and low interdependence and asynchronous communication systems do not differ significantly.

These results therefore refine the affirmation made by Strauss and McGrath (1994) that the effectiveness of a VT depends to a great extent on the match between the task demands and the communication technology used by the team, because it takes into account the fit between the perception of these structural characteristics by the team members and the capacity of the available communication tools to support the required level of interdependence. This reflection would provide laboratory support for the findings of field studies (Mazniewski and Chudoba, 2000; Ripoelle et al., 2003), where it has been observed that the actual performance of more complex tasks at higher levels of interdependence in different virtual teams is associated with the use of synchronous

communication tools permitting more frequent communication and intricate decision-making processes.

At the same time, the interaction effect found maybe should help us understand why differences in the performance of a given task by different teams using synchronous and asynchronous communication systems tend to decline over time (Hollingshead et al., 1993; O' Connor et al., 1993). Our explanation, in spite we did not take a longitudinal approach in the present study, is that the teams could change their modes of interaction, gearing them more closely the available communication support. For our part, we conditioned the performance of the task at different levels of interdependence via the instructions given. When these levels were supported by the degree of synchrony provided by the communication tools available to the teams, their performance was better.

The results of this study also show that teams using synchronous communications as a whole performed better than those working with asynchronous communication tools. Despite the apparent support this evidence provides for the work of Ocker et al. (1998) and Warketin et al. (1997), among others, the fact that the VTs operating in synchronous conditions and at low levels of interdependence performed worse appears to be more consistent with the conceptual framework of the Media Richness Theory (Straub and Karahana, 1998). It is, in fact, highly likely that the performance shortfall shown by these teams is closely related with the unnecessary "distraction" caused by a medium that is over rich in possibilities for the transmission of communications that are superfluous to effective task performance (Hollingshead et al., 1993).

Some limitations of this study should be noted. In the first place, though every experiment is designed with a view to obtaining evidence of causal relationships, the extrapolation of laboratory findings to real contexts always involves an additional effort. Thus, subsequent research will be needed to confirm our findings in actual working environments. The need for a closer look at the different mediation processes employed by teams in situations where there is a better or worse fit between task characteristics and type of communication (e.g. team strategy, the capacity to handle conflicts appropriately, or the manner in which knowledge is generated and harnessed to achieve team objectives) represents a further limitation. We believe it is necessary to reexamine the robustness of the relationships we have found in light of such intermediating elements.

Taking these limitations into account, the data obtained indeed have implications for practice, theory and research. From a theoretical perspective, we have sought to understand the effects of combinations between the levels of interdependence required by a task undertaken by a virtual team and the communications media used. In this regard, we have tried to highlight the importance of considering perceived interdependence as a basic feature of tasks. Thus, we have activated task interdependence in terms of the perception of team members, thereby providing further support from the laboratory for the opinion voiced by Wageman (1995) that the design of a task will require a given level of interdependence, but that members' perception of task interdependence may vary as they perform their task. Finally, our findings provide further evidence to support the extension of the task-media fit described by Daft and Lengel (1986) to virtual teams. At the same time, it allows us to adapt the task-media fit

more precisely to the taxonomy proposed by McGrath and Hollingshead (1993), enriching the computer systems category with synchronous communication systems.

From a research standpoint, the results of this study open up an avenue for further work to throw light on the interactions found from a longitudinal perspective. This would mean taking the evolution of the team from the commencement to the completion of the task into account, adopting a similar approach to that used by Gersick (1995), or considering the transition rate in the VT in moments of complexity and simplicity arising during the performance of the task in line with the proposals of Ball and Kozlowski (2002) or the findings of Mazniewski and Chudoba (2000). Our findings represent an appeal to the structure of interactions and interdependence within the team and its use of technology, and this calls for further research based on the postulates of the Adaptative Structuration Theory proposed by DeSanctis and Poole (1994).

Finally, from a practical point of view the results of this study make clear that we need to optimize and nurture our investments in communication technologies, which represent the main channel for processes within VTs. We are of course aware of the inevitable restrictions imposed by organizational contexts on the day-to-day work of teams. Such optimization would initially involve adjusting the task / communication technology fit in order to facilitate the choice of appropriate media by virtual team leaders and members. Secondly, it would call for further consideration of the requirements for the design of technological solutions in accordance with task interdependence described by Turoff et al (1993), creating a virtual team working space equipped with tools capable of offering contingent responses to the changing demands of the task and the team members' perception of interdependence.

Viable solutions in this area might include "advisory systems" providing on-line support for the normal flow of the team's work, perhaps through one or more of the following: a) recommendation systems for the type of technology best suited for the phase of the task at which the team finds itself at any given time; b) procedures designed to complement weak points in existing systems, for example by establishing additional task structuration elements in the manner of the explicit temporary coordination proposed by Montoya-Weiss et al. (2001); and c) elements providing a response to the needs awareness of team leaders and members in line with the analysis of Olson and Olson (2003).

If we agree with Bell and Kozlowski (2002) when they say that "virtual teams are here, and they are here to stay" (p.45), then the extension of the research proposed here and the application of findings will be of incalculable value to organizations seeking to harness the full potential of virtual team-working in the pursuit of their objectives.

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TABLE 1

Mean scores, standard deviations for team performance.

Variable	Low Task Interdependence		High Task Interdependence	
	Synchronous Communication Technology	Asynchronous Communication Technology	Synchronous Communication Technology	Asynchronous Communication Technology
Team Performance				
M	10.1	14,9	16,05	7,5
SD	2,12	2,24	2,64	1,7
No. groups/cell	20	20	20	20

FIGURE 1

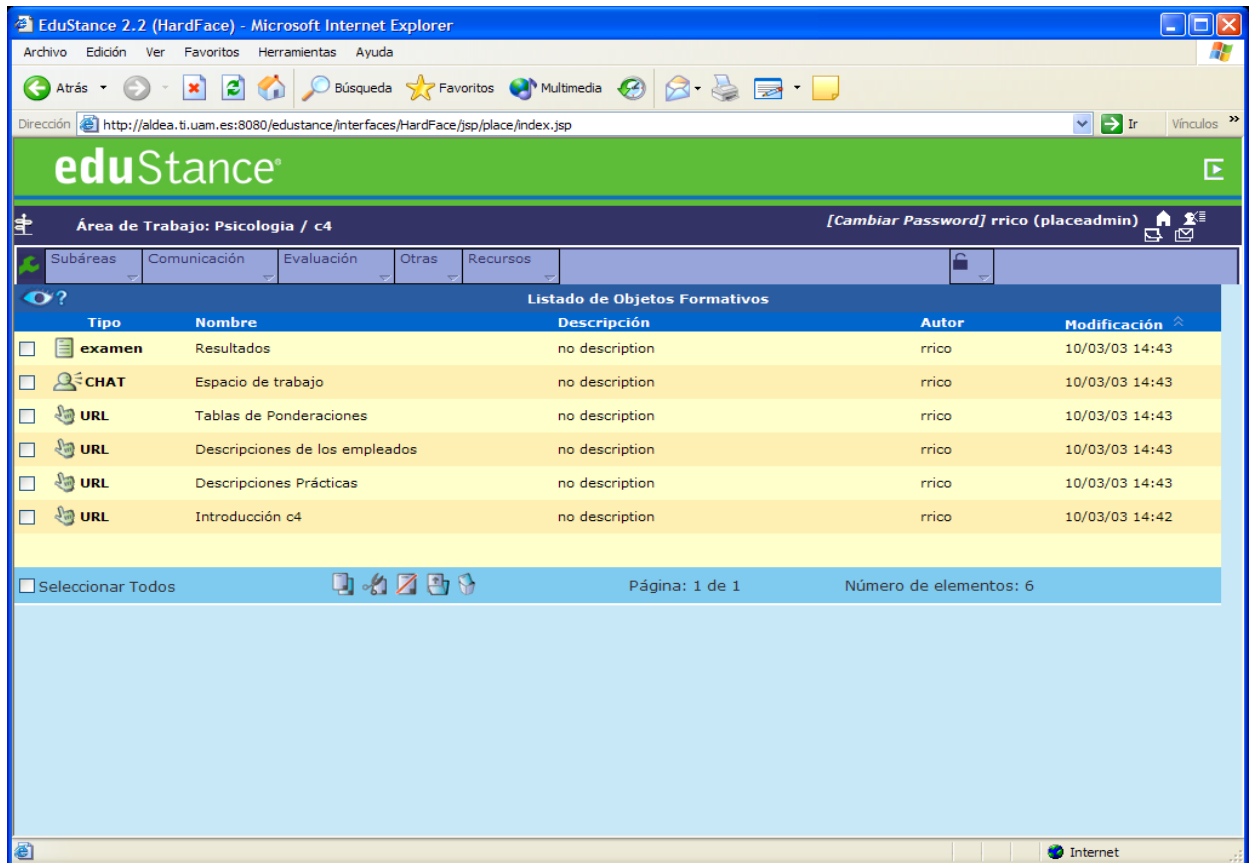EduStance environment for virtual team work

FIGURE 2

Team performance as a function of Synchrony degree of technological communication
and Task Interdependence