Asynchronous vs. synchronous cooperation in innovative design organization

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Abstract. Teamwork collaborative activities involve both asynchronous and synchronous cooperation. In this paper, we describe how these cooperation modes are performed during an innovative design process in the automotive industry. Asynchronous cooperation is performed through exchanges on a portal, while synchronous cooperation occurs in face-to-face meetings. We compare the cooperation modes, regarding the team's tasks. It is highlighted that synchronous cooperation marked out the project course, and is expanded through asynchronous cooperation. But some tasks are preferably performed on asynchronous mode, such as those involved in project steering. Asynchronous cooperation better supports conveyance communication processes (sharing out information), rather than convergence communication processes (shared meaning of design). In contrast, synchronous cooperation offers efficient push and pull of information, making use of both conveyance and convergence.

Keywords: Asynchronous communication, synchronous communication, collaborative design, innovative design, virtual team cooperation

1 Introduction

Since the 1990's, technological innovation has been a key factor in ensuring company competitiveness. Nowadays, most of innovation processes are conducted by "global companies" which bring together, during a project, geographically distributed actors: the manager, internal or external specialists, and the persons in charge of monitoring technological advances and handling corporate knowledge. These actors come from a variety of professional fields and their individual involvement in the innovation process can vary considerably. Their activity mainly consists of "collecting, analyzing and providing all the information, knowledge and know-how necessary to reach the decision to innovate" [1]. These distributed teams experience new forms of coordination and cooperation, such as remote or face-to-face work, in a synchronous or asynchronous mode [2], [3], [4], [5], [6], [7].

The aim of this paper is to investigate how these cooperation modes (synchronous versus asynchronous) are performed in such an innovative design process, and to assess their specific properties, regarding the tasks to be accomplished by the team.

We report the case of a global team in the automotive industry, made up of 20 members, belonging to 5 firms. The aim of this "global" team was to develop a number of mobility services in a vehicle, such as navigational assistance, route planning aids, cultural events booking, etc.

2 Cooperation in Innovative Design Processes through Web-Based Collaborative Platforms

The interdependency between "cooperation" and "innovation" seems obvious, but few studies have been carried out in this field. In the design sciences, innovation is more often linked to "creativity" [8], from the standpoint of the problem solving process [9], [10], [11], [12]. Another line of research investigates technological supports for innovation, developing tools for idea generation or creativity support [13], [14], [15], [16]. In both cases, cooperation processes are not at the core of the studies, and if dealt with at all, it is only from the standpoint of coordination [17].

Innovative design is more than team creativity. It is characterized by long-term distributed activities [18], during which group decision making must be performed by multidisciplinary teams [19], [2]. In an innovative design process, cooperation is performed not only face-to-face (during technical working group meetings or steering committees), but also in a distant and asynchronous way through Web-based collaborative environments. These environments (e.g. a number of CSCW tools perform this role: structured content management tools, forums, notification tools, calendars, charts, etc) must support the articulation of work [20] by enabling the actors of the innovation process to manage the operative and temporal synchronization required by the interdependencies of the tasks [21].

But in many cases, task interdependencies require more than an operative articulation of the work involved. Partners have to perform co-design activities [21] during which they must reach a cognitive synchronization about the problem. This is a question of monitoring the problem-solving process itself [3] in a context of strong cognitive constraints. These cooperative activities require communication channels and functions [22] through which the actors can negotiate, argue, debate and compare their viewpoints about technical documents, deliverables or product specifications. In such cases, remote cooperation through Web-based platforms is usually considered to be too poor, and partners have to meet in face-to-face meetings [23].

3 Utility and Complementarity of Asynchronous vs. Synchronous Cooperation

A large number of studies on communication through groupware have been carried out in the field of the CSCW. But few of them focus on the comparison between synchronous cooperation and asynchronous cooperation, although it was stressed that remote work is not an efficient way to interact on difficult problems [24]. "A

groupware can only manage distribution of information but *regular face to face meetings are mandatory.*" ([23], p. 6).

Asynchronous cooperation has been much investigated through a number of studies undertaken about open source software communities. In these studies, synchronous cooperation is usually not tackled since open source software teams have few possibilities of face-to-face meetings [25]. Moreover, these virtual teams cope more with software development improvements rather than with innovative design [26]. In business and management, a number of studies have been carried out on virtual teams, providing numerous theoretical frames. But, according to Schiller and Mandviwalla [5], the theoretical foundations of current IS research on virtual teams have not yet been established.

Other studies conducted in various sectors, such as e-commerce, e-government, e-health and e-learning, examine how face-to-face interactions are affected when coming into online communication [27]. But these interactions differ much from those which occur in innovative design situations, from two standpoints. First, they follow foreseeable cooperation patterns, contrary to design situations. Second, they are more peer-communication (advice, assistance, etc.), whereas design teams involve many more stakeholders.

Détienne, Boujut and Hohmann [28] conducted a study on collaborative design tasks in remote synchronous mode. Four students met in 4 successive remote meetings to design a child bike trailer. They highlighted that the team progressively built up new communicative strategies, in order to meet the specific constraints of this remote and synchronous communication mode. This adaptation over time was also stressed in asynchronous interactions by Newlands, Anderson and Mullin [29]. Regarding the innovative design meetings that we investigate, these studies have two limitations: the designers are not professionals but students, and the short time design sessions do not account for the specificity of long-time professional collaboration.

The complementarity between asynchronous and synchronous cooperation could be characterized according to the degree of *assertiveness* and *cooperativeness*, such as described by [17]. The authors point out that team efficiency depends on how assertiveness and cooperativeness are performed during the group interactions. In [30], the two modes of cooperation are characterized according to two fundamental processes: information conveyance and shared meaning convergence.

Synchronous and asynchronous cooperation can be compared from other standpoints, such as those summarized below:
☐ their efficiency, according to the teams' behaviour [31], [29], [32], [33];
☐ the management of the virtual teams [34], [35], [6];
☐ the co-elaboration of shared knowledge [36], [37], [32].

Some of the research issues which will be investigated in the paper are: Which dimensions determine the use of one mode of cooperation rather than another in innovative design? How do the actors of distributed and virtual teams interact? What are the activities, which are always conducted in a synchronous and face-to-face cooperation mode? Why are they not performed through the Web-based collaborative environment? Is it due to the current limitations of the tool or is it because of the constraints of the cognitive activity themselves? Conversely, what are the activities which seem to be performed both in face-to-face cooperation and in remote mode?

4   Field Study

The issues investigated in this study are based on the collection of the open exchanges obtained over a six-month phase extracted from the design cycle. This phase was the most collaborative one throughout the two years of the project. During this phase, the collaboration was either synchronous (with face-to-face meetings) or asynchronous (through a portal workspace). The face-to-face meetings took place about once a month. 6 to 12 participants attended these meetings, depending on the subjects dealt with. Each meeting followed a specific agenda. In the course of the project, the members had free access to the extranet portal. Some of the functionalities which they could access to were e-mail, web forum, advice exchanges, etc. More information about the system can be found in [1].

5   Methodology

We recorded all the exchanges which were produced either during six face-to-face meetings, each lasting from 2 to 7 hours and gathering 18 actors took all together. These meetings provide us with 22 hours of discussions. Data published by 17 partners on the portal workspace were also recorded, representing 150 messages.

Figure 1 shows some simplified examples among 1353 synchronous *collaborative contributions* of the 22 hours of meetings, and 150 *collaborative contributions* of the asynchronous publications.
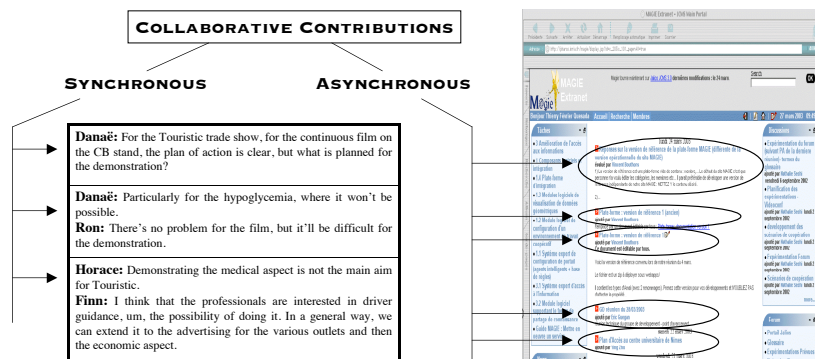

Fig. 1. Simplified examples of collaborative contributions, according to the cooperation mode

All these exchanges were coded into *collaborative contributions*. A *collaborative contribution* is a topic unit, similar to Clark's "joint actions" [38] or Olson's units [36]. A *collaborative contribution* has 5 main attributes:

It is initiated by an actor who follows it through;

It is centered on one topic (and only one);

It can contain more than one speaker or author (here, from 1 to 9);

It has a beginning and an end;

It is part of a COLLABORATIVE ACTIVITY (CA) (see below)

All these *collaborative contributions* are included into larger units, which are called COLLABORATIVE ACTIVITIES (CA). A "CA" describes, at a macro-level, different tasks which are performed by the project team to complete the innovative process. A "CA" is close to Clark's "joint activities" [38]. The identification and the description of the CAs was done during a first step of our study [39]:

☐ TAKING STOCK OF PROGRESS: this "CA" aims at ensuring that the commitments are respected in terms of deadlines, resources, production or requirements (e.g. producing a deliverable, a software package, etc.);

☐ STEERING THE PROJECT: this "CA" aims at organizing the directions in which the group wishes and/or is able to follow (e.g. identifying and choosing the trade shows and conferences at which the project could be presented);

☐ EXAMINING A SUBJECT: this "CA" aims at debating a topic related to the project is examined by a group of actors (e.g. the choice of presentation for a trade show);

☐ PRESENTING A PROPOSITION: in this "CA", a partner presents a proposition to the other partners (e.g. comparing the functionalities offered by the Webpads on the market);

☐ BRAINSTORMING: this "CA" is a creativity session (e.g. the projected use of a Webpad).

6   Results

6.1   Does one Cooperation Mode Exclude the Other?

In Figure 2, we present an overview of the whole design cycle (26 weeks duration). On this figure, both cooperation modes are represented on a temporal axis, according to the number of the *collaborative contributions*.
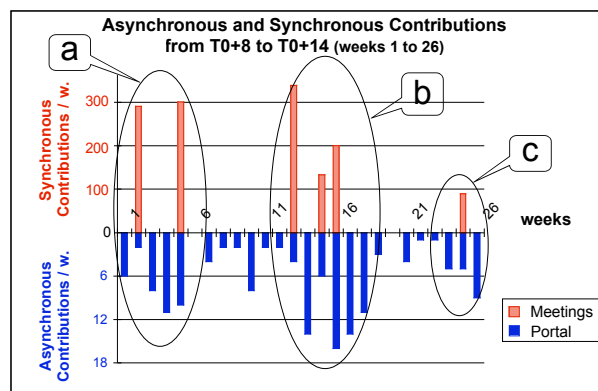

Fig. 2. Combination of *collaborative contributions* in both modes over the 26 weeks design period

The *synchronous cooperation* occurs in face-to-face meetings which are distributed over the design cycle into 3 main periods (surrounded as *a, b, c* on the figure). A first

period of intensive exchanges occurs at the beginning of the process (see "a" meetings on the figure). It corresponds to the initial orientations and the creativity phase. A second period occurs in a middle period ("b" meetings) during which concepts are developed and refined. The last one ("c" meeting) at the end of the design cycle corresponds to the effective realization of the artifact.

As figured above, the *asynchronous* cooperation performed during these 26 weeks project duration is strongly correlated to *synchronous* cooperation. During the 3 intensive collaborative work periods, *asynchronous contributions* represent 81% (121/150) of the whole asynchronous contributions, whereas these three periods represent only 54% of the project duration (14 weeks /26 weeks). During these 3 periods, 8.64 contributions per week were published, whereas only 2.42 contributions per week were published in the inter-periods. In other words, this means that asynchronous cooperation is 3.5 times higher when bound to synchronous cooperation.

Moreover, even if the meetings frequency decreases, the asynchronous mode does not replace the synchronous mode (see for instance between week 6 – week 11). The analysis of the *asynchronous contributions* content shows that these contributions aim at bringing information to prepare the meetings or to supplement them afterwards.

Thus, the choice of one cooperation mode does not exclude to use the other one. We consider that the asynchronous mode prepares, sustains and extends the synchronous meetings.

6.2 Does the Cooperation Mode Modify Addressing Behaviour?

In this section, we examine whether the cooperation mode implies a specific addressing behaviour. Here, we only consider the explicit addressing, which consists of starting a *collaborative contribution* either for all stakeholders, or for a few of them, or just for one of them. These addressing categories are figured in Table 1:
1. *All*: towards all;
2. *Restricted*: towards some of the participants (in the synchronous cooperation) or a list of addressees (in the asynchronous cooperation).
3. *Personal*: towards one individual.

Table 1. Addressing of the *collaborative contributions,* according to the cooperation mode

	Collaborative contributions	Cooperation Mode			
	% (frequency)	Asynchronous		Synchronous	
Addressing	All/Everybody	92.5	(139)	71	(958)
	Restricted	3	(4)	6	(81)
	Personal	4.5	(7)	23	(314)
	(χ2 significance, $p<0.00001$)	100%	(150)	100%	(1353)

The results show a predominant addressing behaviour towards *All* stakeholders, either in asynchronous or synchronous mode. This is an unexpected result which has to be further interpreted. As a matter of fact, we would have expected to have much more *personal* and *restricted* addressing, as emphasized in previous studies [37].

Some reasons can explain the low score of *Personal addressing*. The first one is that the conceptual phase of an innovative design process encourages each participant to take part as much as possible in every discussion, in order to build up a common knowledge basis. Each participant is fostered to generate ideas related to the topic in question. This situation differs from those described in [37], where the exchanges are structured by bi-directional interactions, on the basis of specific expertise to be questioned and asymmetrical status (project leader vs. expert). Conversely, in our situation, discussions do not only occur between the team leader and certain actors to the exclusion of the others. In our case, the leader initiated only 19% of *Personal addressing*.

The Chi2 test highlights that the cooperation mode implies different ways of addressing behaviours. The interaction between these factors can be summarized as follows: asynchronous cooperation leads to collective addressing, while synchronous cooperation fosters *Personal addressing*. We assume that the score for synchronous/personal which is not so high (23%) could be explained by the fact that, during face-to-face meetings, bi-directional interactions are likely to be performed in an informal way, during coffee or lunch breaks.

The high score of "*All*" addressing in the asynchronous cooperation can be explained by the fact that the participants avoid sending messages through the portal which would not concern all team members. The portal is considered as a tool at the service of the group. Private exchanges are easily supported by traditional media (such as email and telephone).

6.3 Does the Cooperation Mode Lead to Dialogue or Monologue?

Group interactions take various forms, from monologue to multi-party dialogues. Although these two forms of exchanges are tightly dependant, making together a dynamic process, it is worth to distinguish one from another in order to examine the influence of the cooperative mode (synchronous versus asynchronous).

In our case, dialogues gather from 2 to 9 interactants in face-to-face meetings, and from 2 to 5 interactants in remote interactions. The proportion of monologue versus multi-party dialogues depends on various factors. The first one is the type of COLLABORATIVE ACTIVITIES (CAs) in which the team is involved (see section 5). For instance, the "CA" EXAMINING A SUBJECT will lead to multi-party dialogues rather than monologues, while the "CA" PRESENTING A PROPOSITION will rather lead to monologues. Of course, the interlocutor's intention of participating actively also plays a role.

In Table 2, we observe a cross interaction between the cooperation mode and the interaction structure (dialogue vs. monologue). In asynchronous mode, 84.5% of the *collaborative contributions* are monologues: i.e. they do not lead to any answer. In other words, it means the great majority of the contributions published on the portal do not give rise to any reaction. Asynchronous cooperation seems to have only an informative function. This result is in accordance with the literature [23].

30% of monologues are performed in synchronous mode. It is quite surprising that the project team permits having so "many" monologues in face-to-face meetings, while most of these monologues could be published in an asynchronous way. In these

cases, the contributor needs to have direct feedback, which cannot be assured through remote cooperation.

Table 2. Structure of the *collaborative contributions*, according to the cooperation mode

Collaborative contributions % (frequency)	Cooperation Mode			
	Asynchronous		Synchronous	
Monologue	84.5	(103)	30	(403)
Multi-Party Dialogue	15.5	(19)	70	(950)
	100	(122)	100	(1353)

70% of the synchronous *collaborative contributions* are multi-party dialogues. The synchronous mode provides the team with a deliberative space. Participating in a meeting makes it possible to raise questions, i.e. to begin and lead to problem solving.

6.4 Which COLLABORATIVE ACTIVITIES Do Cooperation Modes Favor?

In this section, we examine the effect of the COLLABORATIVE ACTIVITIES (CAs) on the choice of cooperation mode. As described in section 5, there are five different CAs. The results are presented in Table 3.

Table 3. COLLABORATIVE ACTIVITIES, according to the cooperation mode

COLLABORATIVE ACTIVITY (CA)	Cooperation Mode			
	Asynchronous (portal)		Synchronous (meetings)	
TAKING STOCK OF PROGRESS	1.5	(2)	16	(214)
STEERING THE PROJECT	46.5	(70)	17.5	(236)
PRESENTING A PROPOSITION	22.5	(34)	19.5	(266)
EXAMINING A SUBJECT	11.5	(17)	38.5	(520)
BRAINSTORMING	18	(27)	8.5	(117)
Collaborative contributions % (frequency)	100%	(150)	100%	(1353)

In the asynchronous mode, the "CA" STEERING THE PROJECT prevails (46.5%), while EXAMINING A SUBJECT is the most used "CA" in the synchronous mode (38.5%). This can be explained by the fact that STEERING THE PROJECT is partly made up of information transmission. This can easily be done through the portal. Conversely, EXAMINING A SUBJECT triggers open debates, in which all partners' standpoints are requested. For such an activity, the remote mode allows some interactions (11,5%) but is clearly too weak to support all of them.

It is striking that TAKING STOCK OF PROGRESS is only carried out in synchronous cooperation. This "CA" consists in ensuring that the commitments are respected (e.g. producing a deliverable, a software package, etc.). At a first glance, this activity is just a question of acknowledging the work in progress, which could be done in an asynchronous mode. But the low result reported in the table points out that TAKING STOCK OF PROGRESS is more than such a simple task. Analyzing the collaborative

contributions of this CA, we observe that commitments are often re-negotiated in the course of face-to-face interactions, in synchronous cooperation.

Curiously, the "CA" BRAINSTORMING is represented twice more in asynchronous than in synchronous cooperation. This is because the asynchronous BRAINSTORMING is mostly dedicated to transmitting creative ideas collected throughout the innovation trends.

The "CA" PRESENTING A PROPOSITION is the only one to get a similar score in both cooperation modes. However, the content of the collaborative contributions differs, regarding the boundary objects to be dealt with by the partners. In asynchronous cooperation, PRESENTING A PROPOSITION aims at examining final productions (e.g., deliverables, conference PowerPoint, etc.). In synchronous cooperation, the materials used in the "CA" really play the role of boundary objects, launching debates in the project team.

6.5 Which Objectives are the Cooperation Modes Adapted to?

All design projects involve both *management* activities (oriented towards the organizational aspects of the project) and *design* activities (oriented towards artifact development) [36]. In this section, we examine how these objectives are completed through synchronous or asynchronous cooperation.

The results presented in Table 4 highlight that there is no crossing interaction between these factors ($\chi^2 = 0.42$, df $= 1$, p $= 0.51$, not significant).

Table 4. Task-oriented objectives, according to the cooperation mode

	Collaborative contributions	Cooperation Mode			
	% (frequency)	Asynchronous		Synchronous	
Task-oriented	Organizational Management	57.5	(86)	55	(738)
Objective	Artifact Development	42.5	(64)	45	(615)

An interesting result is the lower score of the artifact development, compared with the organizational management tasks. This emphasize that innovative design is not only restricted to the development of an artifact. Innovation is not only a matter of creativity. Organizational management also matters. This had been pointed out by various previous studies, which shows that the part of the task-oriented objectives in a project varies significantly.

6.6 Which Cooperation Mode for which COLLABORATIVE ACTIVITIES, according to the Task-oriented Objective ?

The COLLABORATIVE ACTIVITIES (CAs), which were described in § 6.4 can be classified according to the Task-oriented Objectives examined in the previous section. This means that all CAs is oriented either towards an organizational management task or towards an artifact development task. In this section, we analyze how a cooperation

mode is dependant from these factors. The results reported in Table 5 show outstanding differences.

Table 5. *Organizational Management* and *Artifact Development* in CAs according to the mode

	Cooperation MODE		COLLABORATIVE ACTIVITY (CA)	Cooperation MODE		
	Asynchronous	Synchronous		Asynchronous	Synchronous	
Organizational Management	100 *(2)*	97.5 *(209)*	TAKING STOCK OF PROGRESS	0 *(0)*	2.5 *(5)*	Artifact Development
	71.5 *(50)*	97 *(229)*	STEERING THE PROJECT	29.5 *(20)*	3 *(7)*	
	62 *(21)*	42.5 *(113)*	PRESENTING A PROPOSITION	38 *(13)*	57.5 *(153)*	
	70.5 *(12)*	33 *(172)*	EXAMINING A SUBJECT	29.5 *(5)*	67 *(348)*	
	3.5 *(1)*	13 *(15)*	BRAINSTORMING	96.5 *(26)*	87 *(102)*	
	(86)	*(738)*	**% *(Frequency of Contribution)***	*(64)*	*(615)*	

No specific cooperation mode is preferred for those Cas, which are specifically dedicated to one and only objective. This is the case for TAKING STOCK OF PROGRESS and STEERING THE PROJECT, which are almost exclusively carried out for organizational management objectives, regardless of the cooperation mode. BRAINSTORMING is exclusively focused on the artifact, regardless of the cooperation mode.

The case is different for the CAs EXAMINING A SUBJECT and PRESENTING A PROPOSITION which are not dedicated to one or another task-objective. For these CAs, synchronous mode of cooperation is preferred when developing the artifact (EXAMINING A SUBJECT = 67% and PRESENTING A PROPOSITION = 57.5%). But, if the team objective is to manage the project, these two CAs are preferably done through an asynchronous cooperation (70.5%, 62%). Further investigation needs to be done in order to test the cross interaction on a statistical basis.

7   Conclusion

As a conclusion, we can say that synchronous and asynchronous cooperation do not appear as symmetrical channels. Synchronous cooperation marked out the project course, and is expanded through asynchronous cooperation.

Although asynchronous cooperation is subordinated to face-to-face meetings, this mode must not be considered as a weaker cooperation mode. Some tasks are preferably performed on asynchronous mode, such as those involved in project steering. But these tasks are not the most demanding in cooperation, since they mostly consist in transmitting information. It thus appears that asynchronous cooperation better supports conveyance communication processes (sharing out information), rather than convergence communication processes (shared meaning of design). In contrast, synchronous cooperation offers efficient push and pull of information, making use of both conveyance and convergence.

The asynchronous cooperation is satisfactory neither for the collaborative contributions whose initiators expect returns, nor for interactions between two team members. In the first, case face-to-face meetings satisfy this need. In the second case,

e-mail and the telephone are used. A project process requires many exchanges through well-documented interactions. Asynchronous and synchronous modes are useful channels for different interactions, in both assertiveness and cooperativeness.

This first step of our study must be complemented with further analysis of the synchronous collaborative contributions, in order to model the establishment of the common ground of knowledge. The functionalities of a "cooperative" portal for use in innovative design must be considered in this light.

8   References

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