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A Review of How Space Affords Socio-Cognitive Processes during Collaboration

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ABSTRACT

This paper reviews the literature about social and cognitive functions of spatial features used when collaborating in both physical and virtual settings. Those concepts come from various fields like social, cognitive as well as environmental psychology or CSCW (Computer Supported Collaborative Work). We briefly summarize the social and cognitive affordances of spatial features like distance, proxemics, co-presence, visibility or activity in the context of physical and virtual space. This review aims at grounding in an explicit framework the way human beings use space to support social interactions. This review can be used as a starting point to design efficient applications that take spatial context into account.

Keywords: *HCI, CSCW, collaboration, spatial features, space affordances.*

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1. Introduction

Cognitive research traditions have strongly concentrated on personal uses of space, namely as a basis for abstract thought (Gattis, 2001 for instance) studying the use of space on memory (Yates, 1969) and peculiar aspects of problem solving (Kirsh and Maglio, 1994; Kirsh, 1995). While many studies concern the relationship between space and individual cognition, we are instead concerned by social interactions.

The aim of this document is to present an overview of the literature concerning the socio-cognitive roles of space in both physical settings and virtual worlds, when available. Even though it deals with cognitive and environmental psychology, attention will also be drawn on other disciplines: geography, urban planning, social sciences and so forth. The topic of space and its social/cognitive functions is indeed very transversal and covered by different disciplines.

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Our focus here is to address the role of spatiality in collective situations. By collective, we refer to situations that involve two or more persons interacting together. There is a wide range of task that can be carried out by those partners from informative discussion to collaboration and joint activity. Our point is not to depict the functions of space in each of those situations but instead to provide the reader with an exhaustive view of how human beings rely on spatiality when interacting together.

Since the literature on space is vast and multidisciplinary (from cognitive psychology to Human-Computer Interaction, from architecture to computer sciences/virtual world research), this paper reports on the significant concepts dealt by those various disciplines. However, the functions of space presented here rely above all on social, environmental and cognitive psychology experiments.

Concerning the topic of how space is used by groups, three methods are used: ethnographic studies, experimental studies and prototypes design/test. The two first methodologies are often employed for studies that take place in both physical and virtual settings. The prototype design/test method is rather used for experiments in virtual and mixed realities. Tasks studied in those studies are both real ones (in social and environmental psychology) and artificial ones (in cognitive psychology mostly)

At this point, it is important to digress and provide a brief explanation of what we refer to while addressing the concept of virtual space. A wide range of computer environments could be considered as “virtual space”: mud/moo, chat, 3D environment, groupware, virtual worlds, video-games, teleconference systems and so forth. Generally speaking, a virtual space is a multi-user information space where users have a representation of their partners as well as themselves (Dieberger, 1999). This shared environment is hence populated by people and constitutes a context for collaborative activities such as learning, working or playing. The representation of environment ranges from text-based interfaces to the most complex 3D graphical output. The key issue is not the representation in itself but the fact that there is a spatial metaphor in which participants carry out a joint task. Of course, there are important differences between all these settings. Compared to face-to-face interactions, mediated communications through a virtual space is conveyed by different representations. Space could indeed be explicitly represented (like in text-based metaphor like in mud/moo) or implicitly (3D virtual worlds). The spatial representation could also be a limited portion of the real space as it happens in teleconferencing.

When dealing with the concept of space in collective situations, one should consider three dimensions as presented in figure 1: *persons, space/place and artifacts*, and a

corollary feature, which is *activity*. From the relation between each of those components, affordances of space emerge among the group. This decompositional framework allows to present in the following sections the functions of spaces that emerges from those relations. Each section describes the uses of space fostered by all the abovementioned dimensions. We also would like to show that specific functions of space are present in both settings whereas others are not available in one particular context.

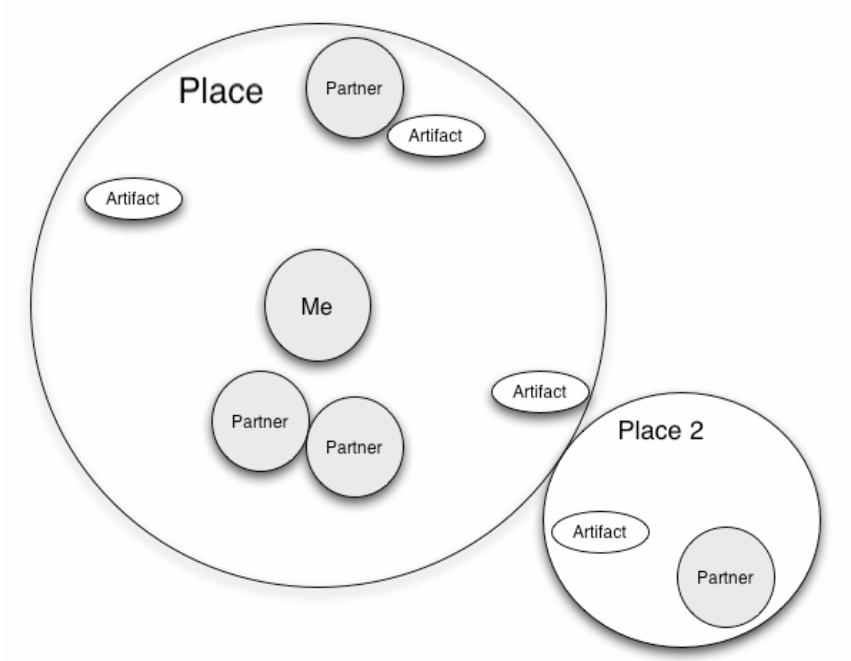

Fig. 1: in this example, groups of people are performing joint activities in the same workspace. The artifacts are objects used to carry over the task

2. Relation1: Person/Person

When considering the person-to-person relationships in a spatial environment, the most important feature that must be taken into account is distance and its corollorary: proximity. This section describes those two important features.

On the one hand, distance between individuals is meaningful in terms of social interactions. Proxemics is the term coined by Edward Hall (1966) to describe the social use of space in the physical world, and personal space in particular. Personal space is the area with invisible boundaries surrounding an individual's body. This area function as a comfort zone during interpersonal communication. It disappears in peculiar environments (elevator, crowd). As a matter of fact, Hall proposes four main distances represented in table 1 that are employed in American interactions. Moreover, each distance has a particular meaning, in terms of the kind of interaction allowed. Hall

argues that those meanings depend on the culture. Hall also shows how distance constrains the types of interaction that are likely to occur, by communicating to participants as well as observers the nature of the relationships between the interactants and their activity. Distance measures indicate an important facet of face-to-face communication. Allen (1977) demonstrated that the probability of two people communicating in an organization is a decreasing hyperbolic function of the distance separating them (past the first 30 meters of physical desk separation, it is rapidly decreasing).

Category	**Approximate distance**	**Kind of interaction**
Intimate distance	up to 0.5 meters	Comforting, threatening
Personal distance	0.5 to 1.25 meters	Conversation between friends
Social distance	1.25 to 3.5 meters	Impersonal business dealings
Public distance	More than 3.5 meters	Addressing a crowd

Table 1. four types of distance (Hall, 1957).

Other studies focused on the relationships between proxemics and social rituals. For instance, Hall (1957) points out that the distance between a boss and an employee when talking is higher than the distance between two employees. In the context of the military hierarchy, Dean et al. (1975) also reach the same conclusion: high-ranking individuals in a hierarchy use more space than those who have the same or a lower ranking. Distance between people is hence a marker that both express the kind of interaction that occurs and reveals the social relationships between the interactants.

Several academics (Jeffrey and Mark, 1998; Krikorian et al. 2000) show that the notion of personal space also exists in virtual environments (like 3-Dimensional worlds: Active World or Online Traveler). They found that personal space seems to influences behaviors within a virtual world. A certain social distance is kept and spatial invasions produced anxiety-arousing behavior (like verbal responses, discomfort and overt signs of stress) with attempts to re-establish a preferred physical distance similar to physical world observations. The authors suggest that the participants "*are developing perceptions of virtual environments that mirror perceptions of real environments*". This leads to a transfer of social norms such as personal space from the real world to virtual space. Physical proxemics is translated into social interactions into virtual environments. Becker and Mark (1998) reached the same conclusion: in virtual world as well as in moo, they found that social distance exists and social positioning is expressed by the positioning of the avatars. People maintain an appropriate social

distance in virtual world: this social convention is transferred from the physical space. There is thus identification to some extent of the physical body with the graphical representation.

Smith et al. (2000) analyzed graphical chat logfiles and found that spatial management occurred in a very similar manner than in the physical space, considering proximity and orientation. For instance, participants maintained personal space (like in Jeffrey's experiment) and seemed to stand near and look toward those with whom they spoke. The graphical component of such virtual environment is important since people clustered together when interacting as they would do in face-to-face interactions. In addition, Grayson and Coventry, (1998) showed that *"proxemic information is preserved in video conferencing and produces effects similar to those of face-to-face interactions but less pronounced".* They explained this phenomenon by explaining that the video conveys only visual proxemic information compared to the multimodal information available in face-to-face interaction.

One the other hand, the concept of proximity is also fundamental (Kraut et al., 2002). It refers to the low distance between the participants of a team. According to Kiesler and Cummings (2002), "*close proximity between people is associated with numerous emotional, cognitive and behavioral changes that affect the work process for the better*". Kraut and his colleagues propose a decompositional framework to identify the mechanisms by which proximity makes collaboration easier. The first effect of proximity is when initiating conversations: it is easier in physical settings than in mediated communication. Furthermore, proximity increases frequency of communication (people communicate most with those who are physically close) as well as the likelihood of chance encounter. Proximity also facilitates transitions from encounters to communication. In this respect, Kendon and Ferber (1973) focused on how partners makes the transition from seeing each others to engaging conversation: they often wait until the other is free, catch the other's gaze to signal intent to interact and then walk to an adequate distance, according to the social norms described in table 1. Finally, community membership and repeated encounters allowed by close proximity foster informal conversations, which are the cornerstone of collaboration. The underlying cognitive mechanism here is grounding: the way people build and update the amount of information (understanding, presuppositions, beliefs, knowledge, assumptions…) shared by team-mates involved in a collaborative task. The disadvantage of physical proximity is that people must attend to the same thing at the same time unlike media space where participants could attend to different things. As a

matter of fact, the interaction must be synchronous and it privileges people who are nearby. Additionally, the opportunistic and spontaneous communication that is supported is not always welcomed by the participants because of task interruption or loss of privacy. Using other media to initiate communication is however possible, namely with buddy lists (who is available in the chat room). Spontaneous communication is less frequent in this situation. Chance encounters as well as informal conversations are also supported in virtual communities on the web and on mobile phones (Gross, 2002).

The second effect of proximity is that conducting conversations in collocated settings is way easier. Indeed, physical proximity allows the use of different paralinguistic and non-verbal signs: precise timing of cues (verbal backchannel for instance), coordination of turn-taking or the repair of misunderstanding. Nevertheless, there is disadvantage of physical proximity: the face-to-face interaction is costly from a cognitive point of view for both speaker and listener. They have to monitor what is being said as well as the feedback, which is given. Concerning the use of other media to conduct conversations, Clark and Brennan (1991) pointed out different grounding costs: emitting the message (more difficult to type in a chat than to talk in a phone), changing speakers, repairing misunderstanding and so forth. Beside, people try to ground their interactions according to the least collaborative effort: they adopt strategies in grounding considering the costs due to the media with as little combined effort as possible.

Finally, the last effect of close proximity in work settings is that it helps maintaining task and group awareness. According to Dourish and Belloti (1992), "*awareness is an understanding of the activities of others, which provides a context for your own activity*". When participants are collocated, it is easier for them to gather and update information about the task performed by the others and the global setting of the group activities. When people work in the physical domain, their collaboration is afforded by relatively unconscious use of the inherent properties of space, body presence, movement, sensory mechanisms etc. However, this information (conveyed by physical proximity) is necessary for internal communication but not sufficient. Supporting awareness in virtual environment is very challenging (Gutwin and Greenberg, in press) since:

- The interaction between the participants and the virtual workspace generates less information than in a physical one.

- The input and the output of a computer provide much less information than the action in the physical world.
- Groupware systems do not really provide users with the limited awareness information available.

A related situation of proximity is hence co-presence: when the participants of a team are collocated, their proximity is maximal. Presence is the psychological sense of "being there" in the environment, physical or virtual (Lombard and Dilton, 1997). Co-presence is thus the psychological sense of “being together” in such an environment. It can be defined as a form of human co-location where the participants can see each other. Zhao (2001) claims that it is the condition for having interactions between two people. He has defined a taxonomy of co-presence based on the different media used by the participants (see table 2). Co-presence is the cornerstone of collaboration since it is the subjective experience of being together with other participants. Face-to-face communication generates the most intense sense of co-presence. Talking in a chat, on the other hand generate a low sense of co-presence. As a consequence, creating a strong sense of co-presence is the challenging issue that virtual multi-user environments designers need to address. Co-presence also provide audibility: being in the same room, close to other persons allow people to perceive sound in the environment: overhearing others’ conversations, someone picking up an artifact, others’ verbal shadowing, the running commentary that people commonly produce alongside their actions, spoken to no one in particular. Gaver (1991) also pointed out the importance of ambient audio in the workplace.

Where is the other located ? How is the other present ?	**The other is located in physical proximity**	**The other is located in electronic proximity**
The other is present in person	Corporeal co-presence (*face-to-face*)	Corporeal tele-co-presence (*face-to-device*)
The other is present via simulation (AI)	Virtual co-presence (*physical simulation, instrumental robots, communicative robots*)	Virtual Tele-co-presence (*digital simulation, instrumental agents, communicative agents*)

Table 2. a taxonomy of human co-presence in a dyadic situation (from Zhao, 2001).

Furthermore, distance between people has great influence on friendship formation, persuasion and perceived expertise (Latané, 1981). According to Latané, the time spent interacting, paying attention and trying to persuade partners among a group decline with distance. Social influence appears to be heavily determined by distance. Latané et al. (1995) found that the degree to which people influence each other seems to decrease as the distance separating their homes increases. Moon (1998, 1999) also revealed that the perceived physical distance has a negative impact on persuasion in computer-mediated communication Bradner and Mark (2002) examined how geographic distance affects social behavior when people use computer-mediated communication. They focused on three behaviors, which are cooperation, persuasion and deception. The results of their experimental study shows that people are more likely to deceive, be less persuaded by and initially cooperate less with someone they believe to be distant. Even though participants initially cooperate less with remote partners, their willingness to cooperate increases quickly with computer-mediated interaction.

Before moving on to the next section, one should also mention another function of proximity, which is the possibility to for collocated people engaged in conversation to look at one another. Mutual gaze plays a powerful role in face-to-face conversation: regulating the conversation flow, monitoring if the addressee has understood what the contributor meant, communicating facially evident emotion, communicating the nature of the interpersonal relationship, communicating the status, preventing distraction and information overload, signaling interest and attention and coordinating turn-taking during the interaction (Kendon, 1967; Clark & Schaeffer, 1989; Argyle & Cook, 1976). Mutual gaze, like nodding are two means of acknowledgement to the addressee. In virtual space like MOO or 3D environment, gaze is a function rarely supported, apart from teleconference. In the context of those video-mediated social interactions, there is a strong lack of opportunity to connect via eye gaze. It is however possible though difficult to gaze into each other's eye during a video-based conference (Cohen, 1982; Okada, 1994). Literature about the video-based teleconferencing indicates that this drawback leads to less satisfying and less productive conversations. Systems that provide video channel with eye contact also encourage participants to "overuse" the visual channel, which may be counterproductive (Anderson et al., 1997). Research has been conducted in order to track a computer user's eye gaze, for instance to use this information for referential communication. We will address this question in the next section when considering referential communication.

3. Relation 2: person/artifact

Another topic the literature about spatiality addresses is the relationships between people and artifacts located in the vicinity of the participants of a social interaction. Indeed, when a speaker talk about an object to his hearer, they are involved in a collaborative process termed referential communication (Krauss and Weinheimer. 1964; Clark and Wilkes-Gibbs, 1986). In constructing the referring expression, the speaker tries to get the hearer to identify the object that he has in mind. Establishing a referential identity is a crux issue in order to build a mutual belief that the addressee(s) have correctly identified a referent. In this respect, spatial features like proximity, salience and permanence are often used in order to select reference objects and frames (Tversky and Lee, 1998). Those reference objects and frames serve to schematize the location of figures.

"In perceiving a scene, figures are not just discerned and identified, they are also located. Figures are not located in an absolute way, but rather relative to other reference figures and/or a frame of reference. (...) Reference objects and reference frames serve to schematize the locations of figures. (...) How are reference objects and frames selected? Proximity, salience, and permanence are influential factors" (Tversky and Lee, 1998: 163)

Those authors showed how two people work together in the creation of agreed references: referring is a collaborative process between speaker and hearer. Tversky also found that referenced frames often used are: natural borders, axes, side of a room, side of a piece of paper, horizontal and vertical lines (real or virtual). Language, by providing a framework to describe space and by selecting features of a scene schematizes space and allows people to ground the discussion. However, language is not the only part of this grounding process. As a matter of fact, the practice of pointing, looking, touching or gesturing to indicate a nearby object mentioned in conversation is also used on a regular basis. This process is called deictic reference. Space is then used so as to facilitate communication. Since we all know that the world is physically structured in the same way for everybody, this spatial knowledge can thus be used for mutual spatial orientation.

It is to be noted that each individual views the environment from a different visual angle (Piaget and Inhelder, 1956). That is why speakers have to take the point of view of their addressee in order to understand the reference. This process is termed perspective-taking or mutual modelling: the ability of one person to empathize with the situation of another .The spatial arrangements of artifacts and participants differs upon

angle of view. One can discriminate different ways to describe spatial locations (Schober, 1993): egocentrically (with reference to oneself like "in front of me"), from the addressee's perspective (like "in front of you"); or from a mutual or "neutral" perspective ("between us"). Findings reveal that people find messages from egocentric perspectives easiest to produce, but that it easier to understand addressee-based perspectives (Levelt, 1989; Miller and Johnson-Laird, 1976; Schober, 1993).

Furthermore, assertions have been made that spatial references create a joint perspective (Garrod and Anderson, 1987): speakers seem to use the mental model of the space that was used in the previous utterance. Doing this, they minimize their cognitive effort since communicators do not need to assess other's perspectives. Schober (1993) also points out that it is easier to build mutual orientations toward a physical space (versus a shared conceptual perspective) because the addressee's point of view is more easily identified in the physical world. Erickson (1993) proposes that objects can generate and catalyze interactions: he talks about "evocative objects" that can capture people's attention and encourage interactions. It is also obvious that objects can also catalyze direct interactions between people. In a research project examining how pairs collaborate in a MOO environment, Dillenbourg and Traum (1997) found that space supports grounding and building of a shared knowledge. Co-presence, even in virtual environment, creates a *micro-context* which supported verbal negotiation. It seems that mutual understanding was also improved by knowing where one's partner has been, this has also been shown by Nova et al. (2003). The virtual space helped to know what one's partner knows, a first step in building a shared understanding of the task

There has been very little research focusing on referential communication in virtual space. Computer widgets, like "What You See Is What I See" awareness tools has been designed in order to support referential communication. For example, tele-pointers or partner's mouse motion are often used. Newlands et al . (2002) analyzed interactions of two groups of pairs performing a joint task in two conditions: face-to-face and using a video conference system. They found that deictic hand gesture for the purpose of referential communication occurred more frequently in the face-to-face condition as expected (five times more than in the remote condition). It actually depends on the physical settings. In addition, there are also less mouse gestures in the remote condition than hand gestures in the face-to-face condition. This means that is less deictic act in the computer-mediated interaction. Consistent with this, shared virtual work space appears to be meaningful for reference to concept and relations that

are difficult to verbalize (Bly, 1988; Whittaker et al., 1991). Perhaps one of the most interesting results is the fact that virtual space narrows down the conversational context: proximity between an individual and an artifact eases referential communication in a 3D virtual environment (Ott and Dillenbourg, 2001). They found that distance was used to define the referential context. This results means that spatial awareness supports grounding by providing subjects with the contextual cues necessary to refer to objects.

Finally, recent researches in wearable computing have also shown how proximity affects a common human activity: search behavior (Takayama et al., 2003). The authors use a proximity-sensing application designed to help end-users locate people. This system uses distance estimation based on signal strength alone. They found that this application changed people's search behavior to reduce walking area, but may increase search times if the system demands too much of the user's attention.

In examining the relationships between persons and artifacts in space, another relevant topic is how people organize tools and objects in space. When manipulating artifacts, human beings organize information spatially so as to simplify perception and choice, and to minimize internal computation in the physical world (Kirsh, 1995) as well as in virtual and augmented reality environments (Biocca et al., 2001). Biocca explored how people organized virtual tools in an augmented environment. Users had to repair a piece of equipment in a virtual environment. The way they used virtual tools showed patterns of simplifying perception and object manipulation (for instance by placing reference material like clipboard well within the visual field on their right). Researchers has indeed observed that people modify their environment to help them solving problems (Kirsh, 1994). The spatial environment is hence used as an external representation employed to solve the problem they are working on.

Finally, the artifacts in the environments are a important source of information (e.g. Dix et al 1993; Gaver 1991). By their positions, orientations, and movement, artifacts can show the state of people's interaction with them. Artifacts also contribute to the acoustic environment: acoustically, physical artifacts make characteristic sounds as they are manipulated (e.g. scratch of a pencil on paper). The mechanism of determining a person's interactions through the sights and sounds of artifacts is called *feedthrough* (Dix et al 1993). In addition, the presence and the ability to touch artefacts in virtual environements is also a core aspect of the sense of place and presence as shown by McCall et al. (2005).

4. Relation 3: person/place

Another question the literature raises is about the complex relationships between people and space. Effects of geographic location on human behavior are an often neglected domain in environmental psychology (Edney, 1976). When dealing with people and location, the fundamental use of space concerns human territoriality. Edney reviews the numerous definitions corresponding to this very notion: those definitions include lots of concept like "*space, defense, possession, identity, markers, personalization, control and exclusiveness of use*" (Altman, 1970:8) defines territoriality as it "*encompasses temporarily durable preventive and reactive behaviors including perceptions use and defense of places, people, objects, and ideas by means of verbal, self-marker, and environmental prop behaviors in response to the actual or implied presence of others and in response to properties of the environment, and is geared to satisfying certain primary and secondary motivational states of individuals and groups*". In sum, territoriality reflects the personalization of an area to communicate a group (or an individual) ownership. There is a wide range of research concerning human territoriality and its various dimensions. Each of these dimensions are related to a specific psychological functions. First of all, territories support social roles among a community: specific contexts are related to specific roles (Prohansky et al., 1970). This means that the meaning of a particular place is endowed through its exclusive use. For each place thus corresponds a set of allowed behaviors.

Second, territory is linked to control: "*the ability of an individual or group to gain access to, utilize, influence, gain ownership over and attach meaning to a space*" (Francis, 1989). A simple meaning related to place control is the way it helps us to navigate in our daily environment. Control rely on three features: "*(1) priority of access to a spatial area; (2) choice of the type of activity that will occur in the area; and (3) ability to resist the control of other persons in that area*" (Holahan, 1982:267). Territoriality could hence be defined as a way to achieve and exert control over a segment of space (Prohansky et al., 1970) and then to maintain and achieve a desired level of privacy. As a matter of fact, individuals from a specific territory decide and know what information about themselves should be communicated to others. According to Minami and Tanaka (1995), "*Group space is a collectively inhabited and socioculturally controlled physical setting*". The activity then becomes a group activity in terms of interactions with and within space as well as control to the degree of space maintaining.

The third dimensions of territoriality it that it also "*serves as a basis for the development of a sense of personal and group identity*" (Holahan, 1982:261). This sense of group identity emerges from common territorial habits, knowledge and experiences (e.g. eating in the same restaurants, shopping at the same stores). The ways a group of people appropriates a territory is very large, ranging from residing in the same neighborhood to extreme territorial markers like wall graffiti (Ley and Cybriwsky, 1974). Beside, how different places and local settings shape identity formation is a very recent concern, in particular about geographies of youth cultures (Skelton and Valentine, 1998). The spatial environment, the inner city in particular, is the privileged locus for building a sense of group and spatial identity (Fried, 1963). According to Fried, The inter-relation between group identity (feeling that we belong to a larger human group) and spatial identity (based on our experience and knowledge about the environment) is of tremendous importance. One of the most striking feature is that the topic of territoriality in virtual space strangely received very little attention. Nonetheless, Jeffrey and Mark (1998) studied whether social norms like personal space, crowding or territoriality really exist in virtual space as in the physical world. They focused on virtual worlds like Active World or Online Traveler. They found that territoriality was an important feature in the context of virtual worlds. For example, building one's house in Active World is a way "*to provide a territorial marker and provide a feeling of ownership for the owner*" (Jeffrey and Mark,1998:30). Furthermore, it seems that people build their house in existing neighborhood rather than in uninhabited places.

This leads us to the fourth dimension of human territoriality, which is trust. Studies concerning neighborhood and social networks showed that people may trust one another simply because they live in the same neighborhood (Edney, 1976). Unlike interaction in the physical world, trust is more difficult to maintain in remote interactions. Rocco (1998) compared trust emergence in team of strangers in both settings (face-to-face and collective e-mail communications). She found that trust (in this context, trust correspond to cooperative behavior in a 28 turns social dilemma game) emerges only with face-to-face communication. A pre-meeting enables trust emergence in electronic contexts. This conclusion is however doubtful since lots of users employ e-commerce sites like Amazon without any face-to-face contact. In survey studies, coworkers report trusting people who are collocated more than who are remote. Interestingly, she also found that the people who spend the most time on the phone chatting about non work-related matters with their remote coworkers showed

greater trust than those who communicated using only faxes and email. It is another effect of proximity as explained previously.

Finally, place attachment is the last dimension associated to human territoriality. Several segments of space appear to be contexts within which interpersonal, community and cultural relationships occur. People are attached to both these social relationships and the physical aspects of this portion of the environment (Low and Altman, 1992). Place attachment is bonding to environmental settings but not only to the physical aspects of a space.

Another related concern linked to the topic of human territoriality deals with the visibility and the permeability of its boundaries. Even though there are fixed and impermeable communities' perimeters (closed by walls for instance), one can discriminate temporary group territories. Small conversing groups in public place are an interesting example: the fixed barriers are replaced by what Lyman and Scott (1967) calls "*social membranes*". Knowles (1973) conducted experiments in order to understand which factors affect the permeability of those invisible boundaries. Using spatial invasions, he showed that people tend not to invade other group territories even if they are in a public space or path (Knowles, 1973). The task consisted in gathering a stationing group of people in order to interrupt pedestrian traffic in a university hall. He varied group size and the age of the obstructing group members. It seemed that fewer passerby walked through stationary old groups than younger groups, and fewer through a group of four than a group of two. Furthermore, Cheyne and Efran (1972) found that group spaces are invaded if the boundaries become fuzzy or if the distance among group members becomes large. Beyond four feet (the limit of Edward Hall's personal distance as presented previously in relation1), the boundary becomes ineffective and passerby begins to walk through the group. Space thus models group interaction. One could establish a number of social rules that govern group interaction. Agreements on spatial territory (Lyman, S. M., and Scott, M. B. (1967) or the closeness of members (Cheyne, J. A., and Efran, 1972) are examples of such rules.

When tackling the issue of group use of space emerges the domain of spatial problem solving. There appears the notion of Schelling Points (Schelling, 1960). This very concept, though not related to space in particular, comes from the field of problem solving and game theory. Schelling Points provide a possible and unique solution to the problem of coordination without communication (Friedman, 1994). For instance, in the context of mathematics, if two persons confronted with the following list of

numbers: 2,5, 9, 25, 69, 73, 82, 96, 100, 126, 150 have to choose the same number, few solutions are available. According to Friedman, if they are mathematicians, they will both choose the only even prime. Non-mathematicians are likely to choose 100. Even if it is impossible for the players in such a problem to communicate, it may still be possible for them to affect the outcome by what they say. Such an outcome, chosen because of its uniqueness, is called a Schelling point, after Thomas Schelling who originated the idea. Applied to spatial coordination, a Schelling Point is an informal location where people are likely to meet each other. This notion is particularly bounded to urban life since each city offers such an essential coordination point. For instance Grand Central Station in New York or Shibuya Crossing in Tokyo (Rheingold, 2002). Joining a Schelling Point augments the chance to encounter people who belongs or not to a group and hence the likelihood of informal encounters. A related concern is "small" Schelling Point such as the coffee machine in organizations. This is the place, like an "anchor" in the environment to be to augment the chance of informal encounter and thus to gather crucial information about the community/team/organization. Coffee machines functions as small indoor Schelling Point in low-scale space like organizations buildings. Moreover, landmarks have always been recognized for their powerful role concerning navigation in both physical and electronic environments (Sorrows and Hirtle, 1999). Their key characteristics make them recognizable and memorable in the environment.

Finally, Halbwachs (1950) argued that collective memories usually contain a strong spatial dimension and are linked to certain places in the landscape. For instance, sacred places of the collective memory of religious groups from the Bible emerged from locations of specific events. There are hence examples of a "visible" past in space provided by conceptions of the landscapes: places reflect their history. In addition, the time factor is of crux importance with regard to the notion of territory. Interaction in the same place indeed forces the participants to deal with usual and ritual aspects. Then they are more and more familiar with the perceived environment.

5. Relation 4: space, place and activity

Relationships between space and human activity are intricate and implicit since it is where our actions take place. Place is defined in anthropological terms as a space that has acquired meaning as a result of human activities. Academics advocated for talking about place instead of space: "*Space is the opportunity; place is the understood reality*" (Harrison and Dourish, 1996). Their definition is "*a place which is invested with*

understandings of behavioral appropriateness, cultural expectations, and so forth. We are located in space but we act in place" (Harrison and Dourish, 1996). Erickson (1993) sums up this by stating that "Place is Space with Meaning". By building up a history of experiences, space becomes a "place" and then its significance and utility is put forward. Harrison and Dourish go on and states that place is a medium for significant actions: place affords a kind of activity. Erickson (1993) claims that spatial constraints can generate activity; he takes the example of the pedestrians who wait for the light to change, they study the headlines and perhaps decide to buy a paper. When the traffic is moving, people wait and tend to buy papers; when the light turns red and traffic stops, pedestrians hurry across the street, and are less likely to buy papers. In the real sense, the traffic light is helping to sell papers by making people pause. There is hence a behavioral framing that come from our sense of place, which makes us know what is appropriate to do in different place. Each location, beside a specific layout and spatial organization, has social meaning and cultural understanding about its function, nature and role. This feature is definitely clear in the physical world. The common understanding of a place defines what types of social interactions can take place and which activities would be "out of place". Benford et Fahlèn (1993) claims that spatial approach in collaborative systems is popular because of the benefit of usability through natural metaphors. This indicates that the strong relation to physical reality and then its intuitive nature. When we move on virtual space, the sense of place is much more difficult to support. Re-creating real places with technology is always challenging. Loosing the sense of place is a common consequence when using electronic media, from telephone to the Internet in order to bridge distance (Meyrowitz, 1985). A rather simple function of space here concerns the fact that people mostly act where they are. Proximity is the location of most human activity: social interactions, use of artifacts. Then "*proximity helps people to relate people to activities and to each other*" (Harrison and Dourish, 1996).

In examining the impact of inter-relation between place/space and social interaction, an interesting result is that physical settings constraints social interactions and conversely those interactions modify space. Seating arrangements thus appear to influence the interaction patterns of the group (Hare & Bales, 1963). The simplest example is that participants of a group generally welcome one into the group by repositioning themselves to form a circle thereby including the new member. Steinzor (1950) also suggests that interactions among people are affected by both content of what is being said and by non-verbal cues like postures, gestures and seating

arrangements. He found that participants of a meeting were observed changing his seat in order to sit opposite another member with whom he had previously an altercation. Furthermore, Steinzor showed that seating arrangement in small collocated groups help to determine the individual with whom is likely to interact: individuals in a circular seating arrangement interact more with individuals opposite rather than adjacent. It was observed that in four-person groups, more conversation occurred among persons seated closer together and facing one another, but only for those sensitive to rejection (Mehrabian and Diamond, 1971). Seating positions could also shows roles repartition and in particular who is the leader of the group. When considering group formations in virtual space (3D virtual world in particular), avatars often position themselves face-to-face and circle is also the preferred arrangement (Jeffrey and Mark, 1998).

Division of labor is another social function supported by spatiality. Indeed, Harrison and Dourish (1996) state that "*distance can be used to partition activities and the extent of interaction*". Partitioning activity in different locations occur in both physical and virtual settings. MOO rooms are for example used to support different tasks in collaborative learning: a room for teleconference, a room for class meetings (Haynes, 1998). Research concerning virtual place also claims that virtual room could defines a particular domain of interaction (Benford et al. 1993). Different tasks could correspond to virtual location: room for meetings related to a project, office rooms, public spaces an so on. Fitzpatrick et al. (1996) showed "*a structuring of the work environment driven by social world perspective*". Their study reveals that belonging to different virtual places provides a support for structuring the workspace into different area to switch between tasks, augment group awareness and provide a sense of place to the users. In his essay about space that foster interactions, Erickson (1993) claims that spatial elements may be used to structure activity. He takes the example of a research (Marine, 1990) that observed that people waiting to use an automated teller station typically left a gap between the head of the line and the person using the machine. This is due to the fact that entering a secret code to withdraw cash is regarded as private activity. Research in MOO environments (Dillenbourg and Traum, 1997) also showed that space could be one of the main criterion for division of labor. In this experiment, people collaborated and coordinated their work on a spatial basis (e.g. one explores the rooms in the upper corridor and the other in the lower corridor).

When dealing with the topic of human activity, the notion of Social Navigation (SN hereafter) should be put forward. According to Dourish and Chalmer's seminal paper

(1994), it describes situations in which a user's navigation through an information space is guided and structured by the activities of others within that space. They define social navigation as « *navigation towards a cluster of people* or *navigation because other people have looked at something* » (Munro and Benyon, 1999:3). The simplest example of SN is "following the leader" to the baggage claim: in this case, we see somebody (the first guy who jump off the plane) following a certain path (the signal). We decode this signal as a cue: this guy may be aware of the way one should follow to get to the baggage claim. SN is a matter of other's activity but also of artifacts change. Social space is built considering the traces left in the environment (virtual or not) by people. We all send signals into social space that can be decoded by others as trace for a potential use. Artifacts and modification of the environment like fingerprints, others were here, public crowds, recommender systems, brands (group identity), tags, graffiti, annotations constitute an indirect social space that could be decoded. From those cues, one can infer powerful things: others were here, this was popular, where can I find something, what's popular, what's happening? and so forth. Dourish use the term navigation to refer to all information-seeking activities. In this context, space is of tremendous importance when navigating. Navigation is embedded in three different frameworks: spatial, semantic and social. The first relies on the structure of space (using a spatial metaphor like an office or a street) whereas the second relies on the semantic structure of space (using semantic relationships between objects). The last relies on others'.

« *Imagine browsing in a bookstore. If I pick up a new book because it is sitting on the shelf next to one I've just been examining, then I'm navigating spatially. If I pick up another book because it was referred to in a citation in the first book, then I'm navigating semantically; and if I pick up yet another because it was recommended to me by someone whose opinion I trust, then I am navigating socially.* » (Dourish, 1999:19).

This SN process exists in both virtual and physical settings. Collaborative filtering and recommender/voting systems are the most common though old, examples of SN in virtual space. In 3D virtual worlds, SN occurs like in the physical space: following leaders, going where groups of avatars go… Perhaps the field of mobile and wearable devices offers much more possibilities for SN since they are way more rooted in space. Indeed, linking information to specific location (defined by a GPS point) is today often used for tourist applications, field studies or police work (Rahlff et al., 1999). A very wide range of applications using various technologies are used to attach information to

location: virtual post-its (Espinoza et al., 2001) or note for tourists (Cheverst et al., 2000) for instance.

Furthermore, providing virtual environment users with awareness information raises two problems: privacy violations and user disruptions (Sohlenkamp, 1999). Indeed, when people are involved in a task, they do not want all information about him to be revealed. User disruption is also important since information overload is a growing problem. Awareness Tool should not provide the user with too many details of others' activities.

Additionally, an important characteristic of places is their visibility. It is indeed possible in the physical world to understand the character of a place from the outside. Bruckman (1995) takes the example of a biker bar to show that it is possible to see from the street what kind of place it could be. In the context of virtual world, visibility is much more difficult to support, apart from 3D virtual world. Furthermore, the problem is that lots of "*virtual communities do not define what comprises appropriate and inappropriate behavior as clearly a<s real world spaces do*" (Dieberger, 1999:48). Apart from affording certain kinds of activities like we already mentions, places afford specific behaviors. For instance, we don't yell in a library, we wait in lines at the movies and so on. It is both a question of space layouts and cultural conventions.

Dieberger (1999) points out that social connotations may influence specific communication patterns in space. Different patterns of communication occur in lecture hall (interaction between one teacher and a group of student but not between students), meeting room (a focus person that change: turn taking occurs) or café (islands of communication). This kind of repartition does not necessarily occurs in virtual space. For instance, in the simplest chat, all users have the same distance from each other; the pattern of communication is hence simple and static. However, more complex virtual worlds allow different configuration: from chat rooms to 3D virtual rooms in which private communication or proxemics are supported. Teleconference systems like Centra[1] provide users with tools to support this kind of functions: turn-taking, applause or a sign that someone wants to ask a question.

Research conducted in MOO environments also shown that space modifies communication patterns among people (Dillenbourg & Traum, 1997). The authors found that pairs do not communicate in the same way when they are in the same virtual room or not. When the subjects are in the same room, they acknowledge more

[1] http://www.centra.com/

than when in different rooms. Moreover, the delay of acknowledgement is shorter when subjects are in the same room than when in different virtual rooms.

6. Relation 5: space and artifacts

Physical and virtual spaces are not empty. Objects and things occupy our places and hence do have a certain state and location that may be modified. Each artifacts in the environment could then have a role in social interactions in itself or by their modification. That is why relationships between artifacts and space allow us to define different functions.

To begin with, it should be noted that being in the same room provide access to the same tools (Benford et al., 1993). This is definitely obvious in physical settings, tools in the same room become collaborative as well as part of the same cognitive system, as stated by the distributed cognition theory (Flor and Hutchins, 1991). In virtual space like chat, users could also be provided with tools like shared board in different places. Chatting while standing in front of a board is hence possible like in the real world.

To broaden the view, there are a lot of examples of formal situations where spatial relationships between people and objects are used to reinforce social distinctions and thus to mould the kinds of social interaction to be expected within the spaces (Joiner, 1976). Joiner's studies about small office spaces reveal that room settings (furniture and artifacts) convey at last two types of information: about the occupant as well as how the occupant would like visitors to behave when in his room. He discusses for example findings about chair position and location that have a clear impact on interaction patterns. Actually, as Joiner states, "*the organization of the room provides cues for interaction through territoriality, zoning, distance and personal orientation*" (Joiner, 1976: 227). Barriers between regions (front, back, outside) in an office space are perceived as a symbol of status. Zone patterns could thus be inferred from furniture arrangements/seating orientations. Though, his phenomenon very from one culture to another and depends upon the organization considered. For instance, the academic has an open seating arrangement unlike business office.

Even though Social Navigation is related to place and activity, it is also a matter of artifacts. For example, like Dieberger (1999) pointed out, the number of car parks in front of a restaurant, as well as the waiting line before a theatre is an indication of the place popularity. Such objects located in space functions as indirect social navigation indicators. Virtual and augmented space offers these indirect cues: a post it left on a

pdf document, a virtual post-it attached to a GPS location or a counter on a webpage provide information about presence and popularity.

Additionally, environmental psychology studies that focuses on how human behavior and well-being in relation to the socio-physical environment gives us insights about this topic of space and artifacts. Indeed, those academics deal with how people plan their actions based on their understanding of a setting. For instance, Craik and Appleyard (1980) found that it was possible for professional planners to judge traffic volume and level of residents' concern about crime from photographs of residential street in San Francisco. Inferences on familiar settings hence appear to be powerful cues. Cherulnik (1991) also demonstrate the when finding a place to eat people rely on environmental inferences. In this context of unfamiliar settings, people also rely tremendously on spatial settings like restaurant facades. Visibility (the possibility in the physical world to understand the character of a place from the outside) is also an often-used characteristic.

7. Discussion

This document reported on social and cognitive functions of spatiality, gathered from various sources ranging from psychology (environmental, social and cognitive) to Human Computer Interaction. All the uses of space presented here should be seen as "social connotations" as pointed out by Dieberger (1999). This term refers to socially shared understanding of space based on cultural experience of the physical world as well as virtual space. One should however keep in mind that those spatial affordances may change over time. There is indeed a missing dimension in this review, which is time. We only focused on synchronous interactions that happen in both kind of settings and did not deal with how the affordances of space could change over time. Moreover, it is to be noted that spatial properties do not necessarily map well from physical space to virtual space. Indeed, even though we find proxemics, co-presence, neighborhood, close spatial interaction patterns in both settings, strong differences do remain. Table 3 proposes a summary of the affordances of space we reported here. Those functions presented in the table are the critical factors supported by spatiality in collaborative activities.

Such a list of how human beings use space is also meant to provide practitioners with a concrete framework about specific concepts of crux importance. Virtual and ubiquitous environment designers might pay attention to this list since it provides an efficient way to revisit the way we can support social interactions in virtual or physical

space. The mobile computing paradigm nowadays strengthens the necessity to take space and context into account.

One of most relevant issue for practitioners is the notion of place. Designers often have to deal with how can be created ‘virtual places’ that would provide participants with the same functions, roles and affordances as real places? How this can be achieved without spatial representations? This has been a lively debate especially in the web portal and weblog communities. A portal offers a spatial metaphor based on different areas all devoted to specific usage (newspages, personal document, group documents, discussion board, chat). Users of these platforms also employ different kind of tools that allow them to be aware of their partners’ activities as in real settings as we saw in the section about person-to-person relationships. Some interesting innovative tools has additionally been deployed to allow people to get real-time feedback for laughter, applause, turn-taking regulations or pacing. Through these pragmatic regulations cues a sense of being together is better conveyed. Finally, there are different levels of privacy that achieve the territoriality function. Relying on real space feature to design such environment seemed to be the most important source of inspiration so far. This lead to a new question: how could virtual space trigger innovative and unexpected behaviour among users, different from what happen in the physical world? and how could designers create way to support original affordances? For example, recent web applications like social software (as Friendster or Orkut) seems to achieve this goal through the emphasis put on explicitation of social relationships between people, which is not based on spatial features.

	Definition	**Functions**	**Physical space**	**Virtual Space**
Distance	Distance between the participants of a team	Marker that both expresses the kind of interaction that occurs and reveals the social relationships between the interactants (personal space)	x	x
Proximity	Low distance between the participants of a team	Initiating conversations, increasing frequency of communication and the likelihood of chance encounter, facilitating transitions from encounters to communication, community membership and repeated encounters, easier to conduct conversation, helps maintaining task and group awareness	x	x
Visibility	People see other people and objects in the environment	Understanding of the character of a place from the outside	x	
Copresence	People are mutually aware that they share a common environment	Great influence on friendship formation, persuasion and perceived expertise, eye contact and gaze awareness. Also provides access to tools	x	+/-
Deictic reference	Practice of pointing, looking, touching or gesturing to indicate a nearby object mentioned	Mutual spatial orientation, spatial references create a joint perspective	x	x
Territoriality	Personalization of an area to communicate a group (or an individual) ownership	Social roles among a community, control, privacy, group identity, trust and place attachment	x	x
Schelling Point	Provide a possible and unique solution to the problem of coordination without communication	Spatial coordination	x	x
Place	Space invested with understandings of behavioral appropriateness, cultural expectations	place affords a kind of activity, division of labor, social navigation	x	+/-
Space settings	Physical settings of the segment of space	Constraints social interactions and conversely those interactions modify space, action planning.	x	

Table 3. summary of the social functions of spatiality described in this document present (x) or not in physical or virtual space.

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