Sharedness of mental models in design teams:

The role of the architect and the client

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Abstract: In this paper we study the influential role of mental models in the coordination and sharedness of team activities in design problem solving. The study focuses on the development and sharedness of mental models in architectural design teams, mainly between the architect and two clients. It aims at understanding how changes in mental models affect the kind of coordination, and how sharedness develops over time. In particular, it explores what is the individual contribution of the architect and the clients to coordinate the process, and who has what kind of impact on the development of the sharedness of team mental models during the early stage of idea generation. A central claim is that when a certain degree of sharedeness of individual mental models is attained, less verbal communication is needed (Badke Schaub et al. 2011). Accordingly, sharedness is believed to be reached in the earlier phases of the design process. The paper will present empirical analyses from which conclusions about differences in design problem solving processes of an architectural team characterized by members with heterogeneous backgrounds are offered.

Key words: Mental model, sharedness, coordination, architectural design, design problem solving

1. Introduction

Design problem solving is a complex activity that embraces multidisciplinary teams working in collaboration. As in most other design disciplines, also in the architectural domain effective communication in the team is of major importance for the design process and the design result. However, the specific interaction between architects and clients is determinant to arrive at successful outcomes.

The way of communication influences both the design process and the design result. Thus, an analysis of team communication seems promising to gain insight into how team members acts and behaves, and more concrete, how they arrive at common decisions. This activity requires an integration of social/ team related activities, and cognitive aspects. One of the most relevant factors for establishing and reaching a common goal is coordination, which comprises a complex variety of activities, knowledge, beliefs and motivations among team members during the problem solving process (Badke-Schaub and Buerschaper 2001; Cannon-Bowers 1993). These different perceptions refer to individual cognitive representations, also known as mental models (Marshall 2007). Human beings develop mental models in order to respond to the world in a fast and reliable way while facing changing conditions.

A question still not answered is how effective communication of individual mental models should look like to achieve coordination, and sharedness in the teams. It is claimed that when a certain degree of sharedeness of individual mental models is attained, less verbal communication is needed (Badke Schaub et al. 2011). Accordingly, sharedness is believed to be attained in the earlier phases of the design process.

The study centers on the development and sharedness of mental models in architectural design teams, mainly between the architect and the clients. It aims at understanding how sharedness develops over time, and how changes in mental models affect the kind of coordination. Specifically, it explores what is the individual contribution of each team member to coordinate the process, and who has what kind of impact on the development of the sharedness of team mental models. We present a theoretical framework on the categorization and development of mental models, and a methodological approach for measuring data from a meeting of a design team in which an architect and two clients participated.

2. Design practice: the architect and the client

The increasing complexity of design problems has derived into an activity that for the most part is carried out by teams. In the architectural domain, for example, the work of the individual designer has converted into an activity that is performed by many different actors, including specialized architects and clients. The latter can be private ones, but more often are governmental, institutional, and corporate. Clients that attend the meetings with architects are in many cases representatives of companies and institutions. In general, they are extremely motivated participants who have an important contribution to the design process, and the development of the solution. However, despite their mutual interest to set up a business relation, clients and architects have little knowledge about one another.

Architects and clients play different roles during the dynamic relation that develops in successive work meetings. This contributes to shape the way that they think, feel, act, and behave along the design process. The primary role of the architects is to act as an advisor of the client. With the aim of arriving at a satisfactory building (Simon, 1996), they attempt to develop their best idea solutions for the project. Clients, on the other hand, make available information about different needs and requirements that should be fulfilled, express their views and preferences, and provide their support and agreement.

The interaction between architects and clients is intense and intricate, and demands involved and open minded participants. All of them have to work as a team through different design phases, including idea generation, design development, construction documents, and administration of construction issues (Cuff 1991). In these phases a discussion about the design is generally accompanied by the use of visual information, i.e., technical drawings, sketches, mock-ups, and photographs, which serve as a frame of reference to explore ideas, raise and clarify issues, and support the graphic dialogue (Goldschmidt 2007).

It is not infrequent that the relation developed by clients and architects can be conflictive, and characterized by a dissimilar perception and understanding of the design project (Delvin and Nasar 1989; Ivory 2004). Not few challenges need be faced in order to find a match between the parties. In her book "Architecture: The History of Practice" Dana Cuff (1991) illustrates some of them. For example, trying to understand individual approaches, positions and thoughts about the design, and determine whether mutual compatibility may be possible is a most important one. Building rapport and affinity is another challenge. In order to create alliances and develop common agreement with their clients, architects should defeat preconceptions, and gain trust. Eventually, these actions contribute to improve communication and avoid conflict. Defining procedural strategies to advance in the design process is another critical aspect that is at the core of the design activity. It is about making clear what methods of action and procedures are necessary to proceed towards the project completion. Procedural strategies may embrace the production of different kinds of documents, such as drawings, sketches, summaries of the decisions and agreements made in latest meetings.

Although in the design of any architectural project the most important actors are the architect and the client, little has been investigated about their individual differences when working in collaboration as a team. In particular, what kind of mental model are needed to coordinate their design activities. Therefore, more research is needed in order to gain further insight into this intricate relation, and understand better their personal contribution to the success of the team.

4. Mental models and design teamwork

Mental models are defined as theoretical constructs that enable representing and inspecting cognitive processes by conceptualizing content representations and reasoning. They are also referred to as the internal representations that people build in order to interact with their environments, including other people and artifacts (Craik 1943; Johnson-Laird 1983; Norman 1983). The construct of mental model can be seen as a simplified representation of reality that serve for processing of new information, and acting in unknown situations with little mental effort (Badke-Schaub et al. 2007; Badke-Schaub et al. 2011). Another key function of mental models is that they enable the understanding and prediction of individual or team performance, and behavior in problem solving (Cannon-Bowers et al. 1993). Therefore, they can be very helpful to improve team communication (Klimoski and Mohammed 1994), and to guide the behavior of team members when tackling new and ill-structured design situations (Stempfle and Badke-Schaub 2002).

Mental models can also aid understand the kind of knowledge individuals and teams have, and how they manage it when approaching design problems. A main characteristic of team mental models is that they can help to coordinate and adapt actions and behaviors as requested by the design situation (Cannon-Bowers et al. 1993).

The way that team members approach reality can be affected by their personal background, and this may influence their individual mental models. This situation can be even more radical in multidisciplinary teams, in which designers differ in their knowledge, skills, and experience. Team members with a heterogeneous background have different individual goals and interests, and thus their mental model of the design situation may diverge to a large extent with regard to other teams. The development of mental models in heterogeneous teams represents an interesting but also complex topic of study (Peeters and van Tuijl 2007). Interaction among team members with a different milieu such as architects and clients, can aid reflecting over the designer's own preconceptions and values. Diversity of expertise and background is assumed to offer opportunities that the designer in an individual condition would certainly fail to see (Denton 1997).

In the process of interacting and exchanging communications with the team, designers are supposed to develop gradually their individual representations of the design situation, and adapt them to construct common mental models that are shared by the other team members. However, questions that still need to be addressed in heterogeneous teams is what the differences of mental models are, and what could be the individual contribution of each member.

3.2 Studying and measuring the development of mental models in an architectural design team: coding scheme

A number of empirical studies demonstrated that the successful work of a team is affected by the extent to which its members shared their individual mental models (Badke-Schaub et al. 2011; Mathieu et al. 2008). Accordingly, an increase in communication exchange leads to an augment of the information that is shared by the team. Shared mental models can be defined as the degree of superposition among team members regarding the content of known elements, and the structure between elements (Mohammed et al. 2000). However, the way that mental model components and their possible connections can be measured over time is not completely understood. There were some attempts to unveil how designers reason and act in real environments (Badke-Schaub and Frankenberger 1999), as well as in artificial settings (Badke-Schaub et al., 2007; Bierhals et al. 2007), but the process of how mental models develop remains unclear. Therefore, studying the development of mental models can throw light to our understanding about team coordination and sharedness (Klimoski and Mohammed 1994; Schaub 2007).

In this study we offer a convenient method for analyzing the development and sharedeness of mental models that is partially based on the on the work done by Badke-Schaub et al. (2011). It consists on the analysis of explicit verbal communication of team members produced during the problem solving session. The frequency of verbal utterances was expected to increase in the first part of the session in order to achieve sharedness, and thereafter decline through time after sharedness was attained.

Verbal utterances are coded in terms of categories and corresponding sub-categories related to four types of team mental models that are detailed in Table 1: (i) taskwork, in regard to the communication of knowledge related to the problem at hand, that includes content and process issues, and (ii) teamwork, in reference to how team members work in collaboration as a social group, that embraces cohesion and social atmosphere aspects.

Table 1. Categorization system for verbal activities (explicit coordination) in teams

Task	PD	Problem definition	Definitions that are mentioned in order to define the problem
	SI	New solution idea or new solution aspect	Stating a new idea or a new solution for a problem or sub-problem, or new aspects of an earlier solution idea
	SA	Solution analysis	Analysis of characteristics and application of a solution idea
	SAE	Solution evaluation	Evaluation of a solution idea by assessing its value and feasibility
	SAX	Explanation	Clarification of aspects and questions related to design issues, i.e., user, technical, budget.
	SD	Solution decision	A final and definitive decision
Process	PL	Planning	Aspects related to when to proceed and what to do
	PR	Procedure	How to proceed to approach the task, strategies and which methods may be used
	RF	Reflection	What the team has been doing so far and what variables have shown influence
Team cohesion	AP	Appreciation	Approval of other team members supporting an idea, an explanation or a problem definition
	C	Confirmation	Positive statements confirming other team members' statements
	RJ	Rejection	Disapproval of other team members about an idea, an explanation or a problem definition
	H	Help	Aid or assistance provided to other team members
Team atmosphere	IT	Informal communication	Statements not directly related to the task at hand
	L	Laugh	Laugh spontaneously expressed

Verbal activities were coded by the two researchers that authored this paper, and Fleiss' kappa (Fleiss 1971) was found to be 0.72 on the level of the subcategories.

5. Goals

The study centers on the development and sharedness of mental models in architectural design teams, mainly between the architect and the client. It aims at understanding how sharedness develops over time, and how changes in mental models affect the kind of coordination. Moreover, it explores what is the individual contribution of the architect and the client to coordinate the process, and who has what kind of impact on the development of the sharedness of team mental models during design problem solving.

5.1 Methodological approach

For the sake of showing the use of our methodological approach, we analyze a case study from the Design Thinking and Research Symposium, DTRS 2007 in London (see McDonnell and Lloyd 2009). A video and a verbal transcript of a design team meeting were available to the attendants of the symposium for its analysis. The data set involved one meeting by an architectural design team. During the meeting, team members were requested to generate ideas and solutions for a new building. Transcriptions from the videotape were parsed into utterances, and coded with regard to a categorization system. The analysis inspected the manner that communication among team members developed through time. Design meetings were divided into two parts containing an equal number of lines as supplied in the transcripts. Categories were classified into task, process, team cohesion, and team atmosphere. Mangold InterAct (version 9.3.5 http://www.mangold.de) software was applied for information coding. This software program supports the coding and rendering of behavioral data per time unit, and statistical calculations of the coded results in an easy way. The team consisted of a municipal architect, the manager of the existing facility, and an officer from the local government on behalf of the municipality.

6.2 Design task and procedure

The architectural task consisted in the design of a municipal crematorium to be situated nearby an existent one. The brief contained a series of facilities that comprised a cremation room, waiting rooms, a vestry, a chapel for 100 people, as well as parking zones. The purpose of the meeting was to discuss the development of the design project in response to all the matters raised in a previous meeting, and to continue talking about other aspects related to the design outcome.

7. Findings on the development of sharedness in the architectural team

This is an exploratory study concerned with architectural design team behavior that involves a comparison between two phases of the design meeting. In order to study patterns between the two phases, a chi-squared test of independence was carried out in order to check whether the frequencies differences between the phases comprise statistically significant deviations from expected values based on the overall occurrence probabilities of the different mental model categories and subcategories.

7.1 Sharedness with regard to mental model categories

Table 2 illustrates the cumulative activity counts of the design team regarding the first and second phases of the meeting, measured by task, process, team cohesion, and team atmosphere mental models. There were a total of

1214 utterances, 51% of which belonged to the *Task*, a 20% to *Process*, 24% to *Team cohesion*, and 5% to *Team atmosphere*. These indicate that the *Task* mental model plays a critical role in the team, followed by *Team cohesion* (See Figure 1).

A chi-squared test of independence between the first and second phases of the design meeting showed that the observed utterance counts for the mental model categories were significantly different than the expected utterance counts overall, x2 (3, 1214) = 50, $p<0.001$. Analysis of the adjusted residuals indicated that observed task and atmosphere-related utterances were higher than expected in the first phase of the meeting (both residuals $p<0.001$, two tailed), but observed cohesion-related utterances were not significantly different than expected between both phases. On the other hand, observed process-related utterances were higher than expected in the second phase ($p<0.001$, two tailed).

Table 2. Mental model categories counts in phases 1 and 2

Mental models		Task	Process	Team Cohesion	Team Atmosphere
Design Meeting	Phase 1	309	78	140	44
	Phase 2	261	165	152	16

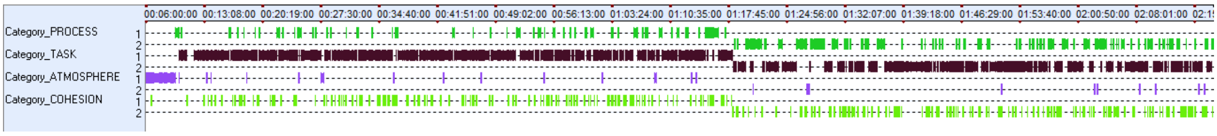

Figure 1: Activity focuses according to main design acts belonging to the mental model categories developed over the course of design

7.2 Sharedness with regard to mental model sub-categories

An additional analysis was performed in terms of the design activities concerned with the subcategories into which each mental model was described. Tables 3-6 shows the cumulative activity counts of the design team in both phases of the meeting, measured by task, process, team cohesion, and team atmosphere mental model sub-categories. *Analysis of Solutions* and *Explanations*, *Reflections* and *Procedures*, *Confirmations*, and *Informal talk* were the design activities with higher frequencies (See Figure 2). A chi-squared test of independence between the first and second phases of the meeting indicated that the observed utterance counts for the different mental model sub-categories were significantly different than the expected utterance counts, x2 (13, 1214) = 68, $p<0.001$, two tailed). For the *Task* mental model, analysis of the adjusted residuals revealed that the observed frequencies of *New ideas* and *Analysis of solutions* were significantly higher than expected in the first phase of the meeting (both residuals, $p<0.01$). However, observed *Problem definition*, *Explanations* and *Solution evaluation* frequencies were not significantly different than expected between both phases. Moreover, no solution decisions were taken at any time (See Table 3).

Observed *Procedural* and *Reflection* frequencies were significantly higher than expected in the second phase of the meeting (both residuals, $p<0.001$). On the other hand, *Planning* was stable over time, and thus no significant differences were found between the first and second phases (See Table 4).

Moreover, it was observed that team members struggled to reach *Team cohesion* all over the design meeting. In consequence, no significant differences were found between the initial and final phases of the design for *Confirmations*, *Rejections*, *Appreciations*, and *Help* aspects (See Table 5).

Part of the *Team atmosphere* utterances was more frequent in the first part of the meeting. Whereas *Informal talk*-related utterances were higher at the beginning (p <0.001), no differences were found for *Laugh* utterances through the meeting (See Table 6).

Table 3. Task mental model sub-categories counts in phases 1 and 2

Task mental model		Problem definition	New idea	Analysis	Clarification	Evaluation
Design Meeting	Phase 1	30	34	196	65	14
	Phase 2	19	15	158	79	9

Table 4. Process mental model sub-categories counts in phases 1 and 2

Process mental model		Reflection	Planning	Procedures
Design Meeting	Phase 1	42	8	28
	Phase 2	92	15	58

Table 5. Team cohesion mental model sub-categories counts in phases 1 and 2

Team cohesion mental model		Appreciations	Confirmations	Rejections	Help
Design Meeting	Phase 1	15	111	11	3
	Phase 2	27	108	9	8

Table 6. Team atmosphere mental model sub-categories counts in phases 1 and 2

Team atmosphere mental model		Informal talk	Laugh
Design Meeting	Phase 1	30	14
	Phase 2	8	8

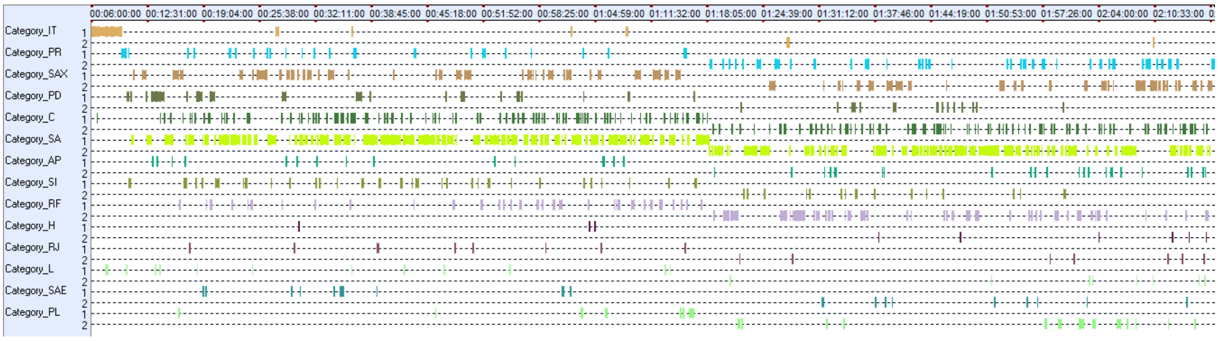

Figure 2: Activity focuses according to main design acts belonging to the mental model sub-categories developed over the course of design. IT: Informal Talk; PR: Procedure; SAX: Explanation; PD: Problem definition; C: Confirmation; SA: Solution analysis; AP: Appreciation; SI: New Idea; RF: Reflection; H: Help; RJ: Rejection; L: Laugh; SAE: Evaluation; PL: Planning

8. Findings on differences in design activity between architect and clients

In order to study what is the individual contribution of the architect and the clients to coordinate the process, a chi-squared test of independence was carried out in order to check whether the frequencies differences between team members comprise statistically significant deviations from expected values based on the overall occurrence probabilities of the different mental model categories and subcategories.

8.1 Design activities of architect and clients and mental models

Table 7 shows the cumulative frequencies of design activities per team member, belonging to *Task*, *Process*, *Team cohesion*, and *Team atmosphere* mental models. For the entire sessions, a chi-squared test of independence revealed that the observed frequencies of the overall utterances were significantly different than the expected utterance frequencies among the architect and the two clients, chi^2 (6, 1214) = 43, $p<0.001$, two tailed). Analysis of the adjusted residuals reveals that the observed frequencies for *Task* utterances were significantly higher in the architect ($p<0.001$, two tailed), whereas observed *Cohesion* and *Atmosphere*-related utterances were significantly higher in client one ($p<0.001$ and $p<0.01$, two tailed). No significant differences between architect and clients were found for *Process*.

For the two phases individually, a chi-squared test of independence showed that the observed frequencies of the overall utterances were significantly different than the expected utterance frequencies among the architect and the two clients, chi^2 (14, 1214) = 62, $p<0.001$, two tailed). Analysis of the adjusted residuals reveals that the observed frequencies for *Task* and *Process* utterances were significantly higher in the first phase for the architect ($p<0.001$ and $p<0.05$, two tailed), whereas observed *Cohesion* and *Atmosphere*-related utterances were significantly higher in the first phase for client one ($p<0.001$ and $p<0.01$, two tailed).

Table 7. Mental model categories counts for architect and clients in phases 1 and 2

	Mental model	Task	Process	Team cohesion	Team atmosphere
Architect	Phase 1	161	38	37	12
	Phase 2	114	61	38	8
Client 1	Phase 1	131	31	76	30
	Phase 2	110	73	31	8
Client 2	Phase 1	48	8	37	2
	Phase 2	55	32	8	0

8.2 Comparing the development of mental model sub-categories in architect and clients

We further analyzed data in terms of the design activities per team member related to the subcategories into which each mental model was described. Table 8 illustrates the cumulative frequencies of design activities, measured by task, process, team cohesion, and team atmosphere mental model sub-categories.

For the entire sessions, a chi-squared test revealed that the observed frequencies of utterances were significantly different among team members, chi^2 (26, 1214) = 104, $p<0.001$, two tailed). The analysis of the adjusted residuals in the *Task* mental model showed that the frequencies of utterances in the subcategories of the task *Analysis of solutions, and New ideas* were significantly higher than expected for the architect ($p<0.01$and $p<0.001$, two tailed). The analysis of the adjusted residuals in the *Process* mental model also indicated that the observed *Procedure* utterance frequencies were significantly higher than expected for the architect ($p<0.001$, two tailed). No differences were seen for the other design activities.

On the other hand, *Appreciation* and *Confirmation* utterances as subcategories of the *Team cohesion* mental model, were significantly higher than expected for client one ($p<0.05$and $p<0.001$, two tailed), whereas *Rejections* were significantly higher than expected for client two ($p<0.001$, two tailed). *Laugh* utterances as part of the *Team atmosphere* mental model were significantly higher than expected for client one ($p<0.01$, two tailed). No significant differences were found for the other design activities.

For each individual phase, a chi-squared test of independence among architect and clients indicated that the observed frequencies of the overall utterances were significantly different than the expected utterance frequencies, chi^2 (27, 1214) = 79, p<0.001, two tailed). The analysis of the adjusted residuals in the *Task* mental model showed that the frequencies of utterances in the subcategories of the task *Solution analysis, and New ideas* were significantly higher than expected in the first phase for the architect (p<0.001, two tailed). The analysis of the adjusted residuals in the *Process* mental model also indicated that the observed *Procedure* utterance frequencies were significantly higher than expected for the architect in the two phases (p<0.001, and p<0.05, two tailed), whereas *Reflections* were significantly higher than expected for client two in the second phase (p<0.05). No differences among team members were observed for the other subcategories in any phase of the process.

Furthermore, *Confirmation* utterances as subcategories of the *Team cohesion* mental model, were significantly higher than expected for client one in the first phase (p<0.001, two tailed), and for client two in the second phase (p<0.01, two tailed). *Rejections*, on the other hand, were significantly higher than expected for client two in the second phase (p<0.001, two tailed). *Laugh* utterances as part of the *Team atmosphere* mental model were significantly higher than expected for client one in the first phase (p<0.01, two tailed). No significant differences were found for the other design activities.

Table 8. Mental model sub-categories counts for architect and clients in phases 1 and 2

		Task					Process		Team cohesion					Team atmosphere	
		PD	SI	SA	SAE	SAX	PL	PR	RF	AP	C	RJ	H	IT	L
Architect	Phase 1	8	25	99	8	21	4	19	15	6	27	3	1	11	1
	Phase 2	6	9	60	4	35	5	30	26	9	26	1	2	4	4
Client 1	Phase 1	17	4	73	6	31	4	7	20	9	70	4	2	18	12
	Phase 2	7	4	64	5	30	8	21	44	16	53	3	4	4	4
Client 2	Phase 1	5	5	24	0	14	0	1	7	0	15	4	0	1	1
	Phase 2	6	2	34	0	13	2	8	22	2	28	5	2	0	0

9. Discussion

Considering the exploratory nature of the study and the small number of participants, we are not able to generalize differences observed along the process. However, there were some remarkable findings with respect to the differences in the distribution of the design activities for the different mental models developed during the design process in the team. These results suggest that certain design activities were more prolific than others, and therefore had a dissimilar impact in the coordination of the team. Regarding sharedness of mental models by the design team, findings indicate that at the beginning of the session, team members dedicated most of their efforts to exchange information concerned with the design task. This was achieved under a pleasant atmosphere aimed at encouraging and supporting their design actions. We propose that differences in background among architect and clients may possibly cause them try to arrive at a common understanding through the meeting (Bradshaw 1989). As a result, no significant differences in the frequency of communications of cohesion-related aspects were found over time. It is suggested that in order to achieve sharedness, the team looked for continuous feedback from its members in order to corroborate their ideas and opinions.

Additional results relate to the design activities concerned with the subcategories into which each mental model was described. Concerning the task mental model, a decrease in the frequencies of new ideas and analysis of solutions suggests that the team was capable of developing sharedness for these activities from the outset. Remarkably, they continued defining problems, and producing explanations and evaluations during all the meeting. This might be a possible reason since they did not take final design decisions.

Regarding the process mental model, an increase in exchange of communications in the number of planning, reflections and procedures in the second phase of the meeting indicate that no sharedness was attained among team members. Probably, difference in knowledge played a major role in the lack of understanding for this type of mental model, and therefore they directed vast efforts to enhance an overview about what they were doing, and how they proceeded during the whole process. Moreover, the development of an encouraging atmosphere among pairs is critical for building sharedness, and accomplishing a common understanding. It is probable that informal talk at the beginning of the session helped to deal with the lack of familiarity and differences in design interests among team members.

We further investigated the individual contribution of each team member to coordinate the process, and his or her influence on the development of the sharedness of team. Task utterances occurred more often in the architect, while cohesion and atmosphere utterances occurred more in client one. This result suggests that the architect devoted most of his communication efforts to foster activities related to the successful completion of the problem at hand by mainly transmitting task related content. Client one, who had a less technical background, mainly struggled to arrive at general understanding of the design problem. She also invested her efforts in fostering the social aspects of work collaboration that embraced essential communication aspects to maintain a encouraging and friendly climate (Badke-Schaub et al. 2011). The fact that these related utterances were higher in the first phase of the process, suggests that the architect and client one play a significant role in attaining sharedness in each corresponding mental model.

An additional analysis concerned with the individual contribution per team member in relation to the subcategories into which each mental model was described revealed interesting results. *New ideas and Analysis of solutions*, as well as *Procedure* were the most dominant activities carried out by the architect. This result indicates that the pattern of behavior of the architect, which was the more creative team member in terms of the number of ideas generated, was mainly characterized by the generation and inspection of novel solution ideas, all aspects related to the task that took place mainly at the beginning of the meeting. It is remarkable that the number of evaluations of solutions was rather low, indicating a preference for generating ideas rather than for assessing their value into depth. Moreover, the high number of activities related to *Procedural aspects* suggests that this was a main channel used by the architect for communicating information to the clients about how ideas and solutions could be implemented in practice.

It is interesting that the two clients had a completely different contribution to the design session. The activity of client one was characterized mainly by confirmations and laughs developed in the first phase of the meeting. This may suggest that in order to contribute to the sharedness of cohesion and team atmosphere mental models, she devoted her efforts to provide supportive feedback, and a positive climate to the team. Client two, on the other hand, had a rather secondary role with a low contribution along the whole design session. His design activity was mainly represented by reflections about the process, and rejections to idea solutions towards the last phase of the meeting. It can be characterized mainly by a disapproval of other team members about their problem definitions, ideas, or explanations or, as well as by thoughts about what they have achieved so far. His passive and slightly antagonistic role did not contribute to a large extent to the sharedness of the team mental models.

10. Conclusions

This study centered on the measurement of sharedness in an architectural design team, based on the categorization of observed data, and how the models develops over time and influences coordination. In addition, it analyzed the individual contribution of an architect and two clients to coordinate the process in a heterogeneous group. Information obtained from the study sample was coded with regard to mental models, categorized into task, process, team cohesion, and team atmosphere activities. These were analyzed by considering the function of mental models in the transition from explicit to implicit coordination. Accordingly, the frequency of certain verbal utterances was suppossed to increase at the outset of the session in order to accomplish sharedness, and then decline through time after sharedness was attained.

Generally speaking, assessing the development of the proposed mental models through two design phases was found to be appropriate for dealing with the temporal features of sharedness. When comparing the influence of each team member on the development of the sharedness of team mental models, remarkable differences were observed between the architect and the clients. One of the clients showed to play a more significantly active role than the other, and her attention was mostly directed to foster activities related to cohesion and atmosphere, reflecting a social concern for strengthening collaboration among team members. The architect, in contrast, mainly focused on more cognitive and content oriented activities related to the design task. Moreover, the most important contribution of the architect and the more engaged client was observed in the first phase of the design, showing their attempts to achieve sharedness from the outset.

A limitation of this study is that it investigated one design team, and therefore findings should be taken with caution. Another concern is that the content of the mental models can be only analyzed from the exchange of communication acts. Therefore, it is not possible to differentiate between situations where low transference of communication is due to implicit understanding and good sharedness among team members, or from circumstances where a decrease in utterances is related to a wrong assumption that they are sharing a similar mental model (Badke-Schaub et al. 2011). Notwithstanding these limitations, a unique contribution of this investigation to the field is its methodological approach, based on qualitative and quantitative data for both visualizing and measuring cognitive and social elements of the design activity from the viewpoint of mental models.

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