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BOO: Behavior-oriented ontology to describe participant dynamics in collocated design meetings

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ABSTRACT

Facilitating meetings is not an easy task. To assist the facilitator, we have been designing intelligent support systems, which can help contextual sensemaking, decision making and action. However, these systems are constructed based on behavioral models that provide guidelines to understand participant behaviors. This paper presents an ontology to describe participants' behaviors in collaborative design meetings and rules that correlate them with the group's acceptance of the final product. This ontology describes the group dynamics at collocated meetings, using verbal and non-verbal cues of attention shifts and attention maintenance as its basic constructs. The objective of creating this ontology was to better understand face-to-face meetings to eventually help meeting facilitators identify issues that may lead to dissatisfaction with the final product through behavioral cues. The ontology was derived through extensive analysis of a series of engineering design session videos. The design group was composed of experts with similar backgrounds, but working in different divisions of the same company. Different points of view were argued and decisions were made at the end of each meeting. After each meeting, participants were asked to asynchronously commit to the decisions made in the group. Our ontology can be used to identify the factors that lead to an undesired outcome, and now serves as a basis for a new project, which uses rules to support design meetings, improve final artifact acceptance and reduce rework. Our conclusions point out correlations between designers' behaviors and future artifact acceptance and actions that interrupt or bring back group attention. The ontology was validated through application to other meeting situations. These findings may guide software developers in the creation of tools to support group design, and may be applied by an intelligent system.

1. Introduction

Nowadays, organizations must deal with complex problems, which demand discussion and decision making by a group of people. These individuals usually come together in the context of a project to discuss the problems and explore possible solutions, focusing on the best ones. Participants may have different roles, but they are committed and accountable for the final product of these meetings. In collaborative design meetings, a group of experts comes together to create a solution for a design problem. Because design is an open-ended activity for which there is no necessarily the right answer, but there are a number of alternatives that must be chosen from (Garcia, Kunz, Ekstrom, & Kiviniemi, 2004), the meeting process becomes even more important as a way to enrich the search space and also a way to make participants to commit to the team's outcomes. Large projects, such as oil platform design or urban planning, frequently require a team working together, extensive discussions brainstorming for possible solutions and metrics for evaluating them, enumeration of pros and cons and selection of the most appropriate alternatives.

A number of factors may reduce participants' productivity in meetings (de Vreede, Davidson, & Briggs, 2003), and certain techniques have been introduced to improve meeting productivity (Kolfschoten, Briggs, Appelman, & de Vreede, 2004). One strategy involves employing professional meeting facilitators to assist the group in reaching their goal. Facilitators design the meeting process and its activities in order to ensure the desired goals are reached, generally using pre-defined group dynamics techniques such as nominal group (Delbecq & Van de Ven, 1971), Delphi (Cochran, 1983) or thinkLets (Vreede & Briggs, 2001). Facilitators also run the meeting, for which the agenda flows were designed, making sure the necessary issues are being covered and the schedule is being followed. Thus, one of the facilitator's roles is monitoring the meeting and correcting any deviation in group dynamics. If the facilitator notices the group is steering away from

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its objectives, or that something may go wrong, he or she should try to get the group back on track.

Knowledge acquisition from multiple experts has always been a serious issue, as experts from the same domain act and reason differently. However, frequently they believe they reason similarly because they produce similar successful outcomes individually. Knowledge acquisition meeting goals are to reveal and synthesize knowledge. Therefore, it is important, in this process, to identify disagreements. Experts may present their disagreement with the knowledge being shared verbally or keep quiet, allowing conflicts to remain, believing they have no major consequences. However, there is usually a non-verbal indication of their agreement or disagreement, which is usually difficult to perceive. Building an ontology of these non-verbal behaviors may help design meeting facilitators to identify these types of situations, and also enables the design of a computer-based system to aid the facilitator in this identification.

Extreme collaboration (Mark, 2002) is a design technique that emphasizes work in a collocated environment to maximize communication and information flow. Design teams work in specially designed war rooms, where all participants may interact as needed. In extreme collaboration, individuals also have access to networked computers and all the necessary information. The facilitator leads the group in its exploration of the design space. Face-to-face interactions are very important for collaborative design: collocated engineers become immediately aware of specification changes, can quickly question or adapt to changing requirements, and can easily interact with one another whenever necessary.

We have been successfully applying the extreme collaboration meeting settings in real life project scenarios for almost four years. Each project would take 6–8 months to be completed and involves designing domain ontologies to be used as knowledge bases for decision support systems. In these collaborative knowledge acquisition meetings, engineers come together to create a formal description of their domain. Although the final objective was to build a computer system from multiple expertise (Liou, 1992), the focus was on the domain representation and on reaching a consensus of their domain perception or at least build bridges between each participant's perspectives. Recently, one of these ontologies was poorly accepted by the group, without any apparent cause or indication that the facilitator could catch, leading us to wonder whether there are subtle cues that may indicate whether the outcome of a meeting will be accepted by participants or not.

We have been working on facilitation support systems for a while now (Vivacqua, Marques, Ferreira, & Souza, 2008; Vivacqua, Marques, & Souza, 2008). These are systems that can help a novice facilitator identify problematic situations and intervene as needed. Given our observation, we felt the need to study the types of participants' behaviors in meetings and possible correlations to the dissatisfaction with the final product. These would then be modeled as heuristics to be incorporated into our facilitation support systems. We hypothesized that the non-verbal channel of communication might have been overlooked by the facilitator during meetings, leading to a false sense of consensus. It has been difficult for researchers to determine this type of correlation, but a few efforts have been made, towards inferring the focus of attention from the head pose (Ba & Odobez, 2009) and defining personality traits from visual and acoustic cues (Lepri, Mana, Cappelletti, Pianesi, & Zancanaro, 2009). We took a slightly different approach to non-verbal cues: instead of interpreting the visual scene, we look for changes in dynamics as the determining factor.

Thus, we started an investigation into the possible causes for the acceptance problem, and created an ontology to describe meeting behaviors that could later be used in a facilitation support system. This ontology maps the types of behavior and the final outcomes observed, so that the system may help spot problem situations and suggest intervention. Our approach was to analyze the process (which had been captured on video) and determine behaviors and their relations to acceptance levels observed at the final delivery. We build an ontology called BOO, behavior-oriented ontology, that describes behavior patterns in group knowledge acquisition meetings. Once the ontology is complete, we expect to create scripts to trigger action to affect participants' behaviors, using the ontological constructs as indication of the meeting flow, whether towards consensual agreement or immature closing on a subject issue.

This paper is organized as follows: in the next section we discuss the design process, followed by related work in Section 3, a description of the method used to construct the ontology in Section 4 and our ontology in Section 5. We present a discussion in Section 6 and finalize with conclusions in Section 7.

2. Group design

Design consists of defining a specification for an artifact that delivers a set of desired functionalities (Gero, 1998). Both for physical artifacts, such as a building, and abstract artifacts, such as a domain model, there is no unique result, which means different designers may reach different designs (sometimes multiple designs). The design process is a knowledge creation activity, through which known information is transformed into a final representation. It is frequently a group process, involving several people who bring distinct knowledge and viewpoints to the table. Given the multiple perspectives, this process frequently involves negotiation of fundamental elements of the design. Collaborative design may lead to better results due to the added discussion of alternatives and synergy among participants with complementary skills. However, conflicts often emerge during design sessions, which may produce delays. On the other hand, conflict can be productive, as discussions promote a broader investigation of the design space.

In open-ended projects, deadlines constrain the viable amount of discussion and exploration of the problem or domain, while participants' individual levels of acceptance of the final artifact generate a need for further exploration. The lower the acceptance level, the more discussion will be necessary. In this fashion, the design process hangs on a balance of time versus acceptance levels, which is usually managed by the group's facilitator. In extreme collaboration environments, the meeting facilitator elicits information from experts and submits it to discussion. He or she asks questions that lead to the introduction of new concepts and challenges the concepts introduced. When the design is starting to stabilize, the facilitator should steer the group towards decision making.

Besides participating in collocated meetings, participants may be given take-home activities. Activities that can be isolated may be assigned to participants to be performed at home. This helps the process progress in between sessions. Therefore, the facilitator also has to plan individual activities to keep the specialists in touch with the modeling activity and create engagement with the task. This creates a sense of ownership, which helps increase acceptance of the product at a later date.

An ontology is a description of a domain, constructed for a given purpose by a group of stakeholders that will use it. It is a shared conceptualization of the domain (Gruber, 1993). With the increase in the amount of information available, an added emphasis has been placed on ontologies as a way to model and ruse domain knowledge. Intelligent systems frequently use ontologies to process data. Thus, the knowledge acquisition process leading to the creation of the ontology is a crucial step, which may well determine the failure or success of the ontology-based application. We have selected ontologies as our method for representing knowledge for our intelligent systems.

3. Related work

In this section we discuss the roles of verbal and non-verbal communication during design meetings. Protocol analysis and discourse analysis are discussed, emphasizing their limitations, as they consider only verbal material. Non-verbal communication such as head pose and gesture are presented as a way to elicit attention focus and filtering information. The main point is to collect the message being sent through non-verbal communication about individual commitment towards the group's decision. This seems to be a central issue when developing expert systems to support meetings.

3.1. Knowledge acquisition from multiple experts

Face to face meetings are important project boosters, especially when participants commit themselves to the outcomes. There has been a great deal of effort on expert system development to incorporate meeting techniques from the project management domain when dealing with the task of acquiring knowledge from multiple experts (Chu & Hwang, 2008). Independent of the technique, making sense of participant behavior is an essential aspect of preventing undesirable outcomes, such as unconstructive debates, lack of focus and false commitments. A wrong assessment about a meeting may lead to future rework or failure on the group's final outcome. Therefore, understanding meeting dynamics plays an important part in evaluating the meeting and verifying the need for interventions, such as reopening a discussion or taking a break on an issue.

The main focus of knowledge acquisition from multiple experts is not only to create a formal representation of a domain, but, rather, to make the experts to commit to certain domain definitions and spread this commitment into the community they represent. They should act as "champions" in the community, facilitating acceptance of the new technology.

Knowledge acquisition meetings offer rich material for knowledge engineers (KE) to create domain representations. KE may take notes, but generally, due to the extent of the material, they follow traditional research methods, videotaping meetings for later analysis. Protocol analysis (Ericsson & Simon, 1984) and discourse analysis have been used with success for decades as research analysis frameworks. They differ on the procedure, but both methods involve analyzing verbal communication that happens during meetings or interviews.

3.2. Data analysis methods for building domain knowledge representation

Protocol analysis (Ericsson & Simon, 1984) is a data analysis technique that comes from clinical psychology. It takes into account a person's thinking processes while solving a problem. Thinking aloud processes are videotaped and transcribed (as protocols) for later analysis. Protocols are written material that describes the verbal communication that happens during knowledge acquisition meetings. This material must be analyzed based on a systematic breakdown of the information to produce a structured model. The goal is to identify the kinds of objects the expert sees, the attributes of those objects, the relationships among them, and the inferences drawn from these relationships.

Discourse analysis (Harris, 1991) is a similar data analysis technique, in which the knowledge acquisition sessions are videotaped and transcribed. Although full sessions are videotaped, only verbal material is analyzed. Most knowledge that is explicitly expressed by experts during meetings is verbalized. Visual material presented in these meetings such as figures and sounds can be also connected verbally. However, participants' commitment to the final product might be misleading when considering only the verbal channel. Protocol analysis and discourse analysis fail when relevant information is transmitted, among the participants, using non-verbal channels.

3.3. Non-verbal messages

The limitations of verbal communication in meetings have been noticed before. Nevertheless, the issues concerning the interpretation of non-verbal communication are vast, and include defining what exactly the researcher should be looking for, what should be done with this information and why this information is sought.

There might be a bridge between verbal and non-verbal channels that eventually would bring all information into the same analysis space, thus making it easier to build and maintain domain models. Busso and Narayanan (2007) claim verbal and non-verbal communication are internally and intrinsically connected. They study coordination and correlation between gestures and speech. Decoding non-verbal communication might lead to the emergence of the "hidden message" that is not explicitly communicated. In their research setting, gestures and speech are synchronously transmitted which can create a bias in their conclusions. Despite the bias, the correlation might be used as a way to filter noise from the communication. For instance, in a meeting, a person might be verbally agreeing with a decision, but gesturing disagreement. Understanding this disjunction between these two channels should lead at least to a request for confirmation.

An even subtler non-verbal message that needs to be understood is meeting participants' focus of attention. This information might help facilitators identify loss of interest in a discussion. Ba and Odobez (2009) have been working on identifying visual focus of attention based on a person's head pose using Gaussian and hidden Markov models. Although attention reflects a participant's degree of interest in a subject, it is difficult to predict, based on this aspect alone, the impact his commitment to the group's decisions.

There are many ways of communicating using non-verbal messages. The important idea here is that these messages should be considered during knowledge acquisition. It seems that non-verbal communication plays a very important role on the identification of meeting participants' commitment, possibly as much as adding new content. These backchannel messages should not be neglected when building expert systems to aid knowledge acquisition from multiple experts. One of the key issues of our research concerns identifying behavior though non-verbal cues during group meetings. After defining what should be perceived, coping with the continuous work of perceiving these visual cues is a technological challenge.

We believe that it is possible to identify behavioral patterns of meeting participants that help predict what will be their commitment to the final product. These behavioral patterns are the building blocks for building models for support successful meeting outcomes. Participants enact different behaviors at different moments. There must be a synergy among the participants' behaviors in order to achieve the group's goal. The meeting facilitator acts as a central controller, and must be able to identify which behaviors are active in each participant at any given moment. Robot behavior-oriented programming such as RoboGuard (Birk, Kenn, & Steels, 2002) and BODT (Smit, Griffioen, & Schut, 2008) is a parallel effort, which could be used to build meeting support systems.

4. Method

In this section we briefly present the method used to design the model for our facilitation support system. We used meeting analysis through video reviews. Our goal when conducting this study was twofold: first, to design an ontology to describe meeting behaviors, which could be used to analyze meetings. Secondly, to investigate whether there is a correlation between individual behaviors observed at meetings and acceptance of the product collaboratively designed during the meetings.

4.1. Activity theory

Activity theory is a framework to help describe how work is done. The framework takes an individual (subject) as the starting point for analysis. The subject manipulates an object using tools, to reach a desired outcome. In the framework, work is analyzed in three hierarchical levels: at the topmost level, an activity is motivated by a goal and executed by a community of people. This activity is broken down into actions, executed either by an individual or by a group, to reach specific goals. Each action is accomplished through operations, which are deeply ingrained into actors and are executed almost automatically, given certain conditions. They can be either automated by a machine or executed "without thinking" by a human. Activity theory has been successfully applied in a number of situations (Kuutti, 1995). However, activity theoretic studies usually follow the route of observing the actions and operations contribute to the execution of the activity.

For this research, we took the reverse approach: given an evaluation of the outcome of the activity, we elicited the problematic elements through interviews with participants and stepped back to study what went wrong through video reviews. We expect this line of analysis will shed more light on the process, emphasizing the operations that work against the completion of the activity instead of those that work for its completion (which are usually analyzed). This, in turn, should help us look for ways to prevent them from happening.

4.2. Video reviews and coding

Every design meeting that happens in our facility is videotaped and transcribed for later analysis. These tapes and transcripts can be used as a source for analysis. We use dialogue analysis and coding as our instruments. Videos and transcripts are time coded, so searches can be conducted for certain bits of video, if necessary.

A macro level video analysis defines the sequences to be studied for each major element. Later, these transcripts and the video guide the finer grained (or micro-level) observation and the fine grained coding task. Every meeting is coded according to a set of attributes, some of which are taken directly from activity theory (subject, actors, object, tools), plus others that were added as we perceived their need. The following attributes are used to code the videos:

1. Subject: what are the subjects underlying the group interaction.
2. Actors: who is in the scene.
3. Action: what the actors are doing.
4. Task: what task are they trying to accomplish (if any).
5. Disagreement: degree of disagreement among actors.
6. Participant's engagement: degree of engagement of the participants.
7. Change Scene reason: what happen to change the group dynamics.

Initially, a small set of tapes was reviewed to generate a set of tags (codes) for each of these attributes. After discussion and verification that these would cover most situations, we started a review of all videotapes and transcripts, coding each contribution to the discussion in turn. Later on, this allowed us to perform calculations on attribute occurrence and to look for correlations between these and acceptance, which would allow us to identify conditions that might cause a decline in acceptance of the final product, if they exist. A sample of the meeting data used is shown in Table 1.

4.3. Data sources and steps

To conduct this research, we took video recordings of design meetings for a finished project. The recordings have been fully transcribed, which makes it easy to search for key phrases and particular discussions. We also have the final product generated (a domain ontology) and a set of annotated slides, which were presented to the client at an exit meeting for the project. Annotations provide comments made by clients at the exit meeting. Both clients and designers pointed out a number of problems and rejected parts of the final design and requesting changes. The list of problems was also part of this study.

The following steps were conducted during this research:

1. Initial review: in an initial review, a set of tags for coding participant behaviors during meetings was generated. This set was used during the review of meeting tapes.
2. Identify focus concepts: concepts to be analyzed were listed and tagged as problematic or non-problematic.
3. Retrieve discussions on these concepts: each concept selected was found in the transcripts (we looked for where it was first discussed and for every discussion following that event).
4. Analyze discussion: once found, each discussion involving the concept was reviewed and coded using the set of tags generated during the initial review. Problematic concepts were analyzed first, followed by non-problematic concepts.
5. Build ontology: the ontology describing behaviors was built, structuring the concepts used for coding.

Table 1
Meeting data (sample).

Actor	Comm. Channel	State	Tag	Mode	Cause	Message	Evidence	Transcript
A1	Visual + verbal	Attentive mode	Explaining	Engaged		Gaze + speech	Looking at A2 and speaking about issue on target	
A2	Visual	Attentive mode	Attentive gaze	Engaged		Gaze	Looking at A1	
A3	Visual	Attentive mode	Attentive gaze	Engaged		Gaze		
A4	Visual	Non-attentive	Writing	Engaged		WhiteBoard		Confidential
A5	Visual	Non-attentive	Writing	Engaged		Paper		Material
A6	Verbal	Attentive mode	Interrupting	Engaged	Reinforce argument	Gesture + speech		
A1	Visual	Attentive mode	Attentive gaze	Engaged		Gaze		
A3	Visual	Attentive mode	Attentive gaze	Engaged		Gaze		
A7	Visual	Attentive mode	Attentive gaze	Engaged		Gaze		
A4	Visual	Attentive mode	Attentive gaze	Engaged		Gaze		
A0	Verbal	Non-attentive	Changing subject	Engaged		Speech		
A6	Verbal	Non-attentive	External factors	Pause		Speech		

6. Evaluate ontology: the descriptive ontology was then applied to other meetings, to verify its completeness and descriptive power. Alterations were made accordance with this analysis. This evaluation was conducted through usage: the ontology was used to describe design meetings for other projects, and few missing items were identified.
7. Search for correlations: a quantitative analysis was conducted to look for correlations between certain behaviors or meeting configurations and design non-acceptance. This was done with the data for only one meeting.

It should be noted that evaluating an ontology is quite a tricky task. To validate our meeting description model, we applied it to other meetings to see whether it was missing many concepts (completeness) and whether the concepts that were present appeared in other meetings (coverage).

5. Meeting observations

The initial step in the project was to frame the design activity in terms of the activity theory framework. This was done by reviewing several pieces of meeting video, some of the beginning, some of the middle and some of the end, to identify possible values for these elements.

The activity structure of ontology design can be seen in Fig. 1. The activity in this analysis is design (in fact, ontology design), and the model is the desired outcome. The design process transforms raw knowledge into a structured representation. The subjects are the experts involved in the meetings and discussions, including the knowledge engineer. The object is the experts' knowledge, including documents and tacit knowledge they have at their disposal. These they work on and transform into the domain model. The tools are flipcharts, shared displays, computers, pens and paper. This vocabulary was used to code meeting videos later on.

Activities are driven by goals. The main goals identified involve iteratively expanding and reducing the search space. To that end, the group cycles through actions involving the generation, organization and evaluation of alternatives and making decisions.

To measure behavioral influences on acceptance levels, levels of acceptance were qualified as high (complete acceptance, no complaints), medium (partial acceptance, some complaints and changes requested) or low (non-acceptance) of the final design and at each stage of the design. These are fairly subjective and dependent on the observation of the coder. Participation was also qualified in three levels, and measured for each discussion: participative (participant fully engaged in discussions), passive-attentive (participant participated occasionally, but paid attention to the discussion the rest of the time), passive-inattentive (participant seemed uninterested). Again, these are dependent on the observation of the coder.

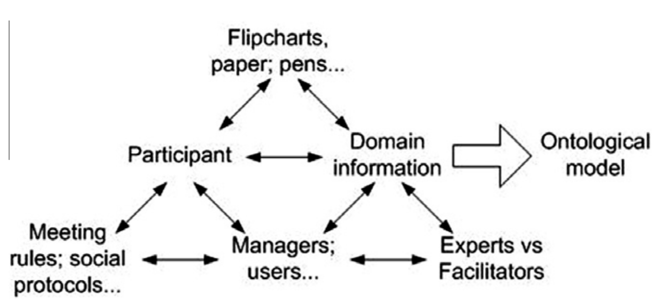

Fig. 1. Structure of the design activity.

5.1. Behavior-oriented ontology

The ontology describes each participant's behavior as focused or unfocused (shift in attention). Unfocused behavior can be of two natures: unproductive (does not contribute to the ongoing activity) or productive (even though it does not actively contribute to the discussion, it is related to the activity and may help at a later stage). The indication of unproductive attention shift most frequently noticed was lost gaze, or when the participant stopped directing his vision to the main discussion. A number of factors cause the shift to an unproductive state. Unfocused productive behaviors include working on a separate task, making annotations or branching the discussion into a different concept. Focused behaviors generate contributions to the discussion, which may be explanations of concepts or ideas or statements of agreement or disagreement. Interruptions cut the meeting flow and add to the discussion. Disagreements stem from a lack of consensus, which causes conflicts that may also lead to group partitioning. Partitioning is resolved by a regroup, with members going back to the theme at hand. The behavior ontology can be seen in Fig. 2, followed by a more detailed description.

Meeting PARTICIPANTs exhibit BEHAVIOR during meetings. Although these behaviors change over time, at a given moment each participant presents a behavior that can be either:

- ATTENTIVE BEHAVIOR: observed when the participant is paying attention to the discussion at hand.
- ATTENTION SHIFT (INATTENTIVE) BEHAVIOR: characterized by the participant changing his/her attention focus away from the ongoing discussion.

Attention shifts can be either PRODUCTIVE or UNPRODUCTIVE behaviors. Productive shifts are those that contribute to the meeting objectives, while unproductive attention shift are those that distract participants, thus degrading the meeting quality. There are many examples of productive shifts including:

- TASK EXECUTION: a participant may switch his/her attention to the execution of a task (possibly one that was assigned to him/her) while the discussion continues on, such as retrieving data, looking up regulations or searching for information.
- INFORMATION ANNOTATION: participants were often observed making notes about the ongoing discussion on available papers or printouts. This is a way for the individual to organize his/her ideas or arguments before presenting them to the group.
- CONCEPT SHIFT: a discussion about one concept would often spawn a discussion about a second concept, sometimes generating a separation of the group into two subgroups. While a shift in attention from the main discussion, this is productive because it advanced related discussions that would have happened later anyway, and sometimes led to the establishment of relations between concepts.
- RETURN TO CONCEPT: this was observed when one or more participants that had started working on a second concept in parallel returned to the main discussion.
- INTERVENTION: this is a particular kind of behavior, most frequently exhibited by the meeting facilitator, but sometimes also by other participants. The participant, noting a problem situation or group division would prompt others to regroup or come back to the main discussion.

The concept shift represents an addition to the discussion with correlated concepts. This shift is halted by a RETURN TO CONCEPT behavior. A concept shift may cause a TOPIC SHIFT and a group's PARTITIONING. An INTERVENTION halts a PARTITIONING and may also be a behavior to halt GROUP CONFLICT. A conflict has a

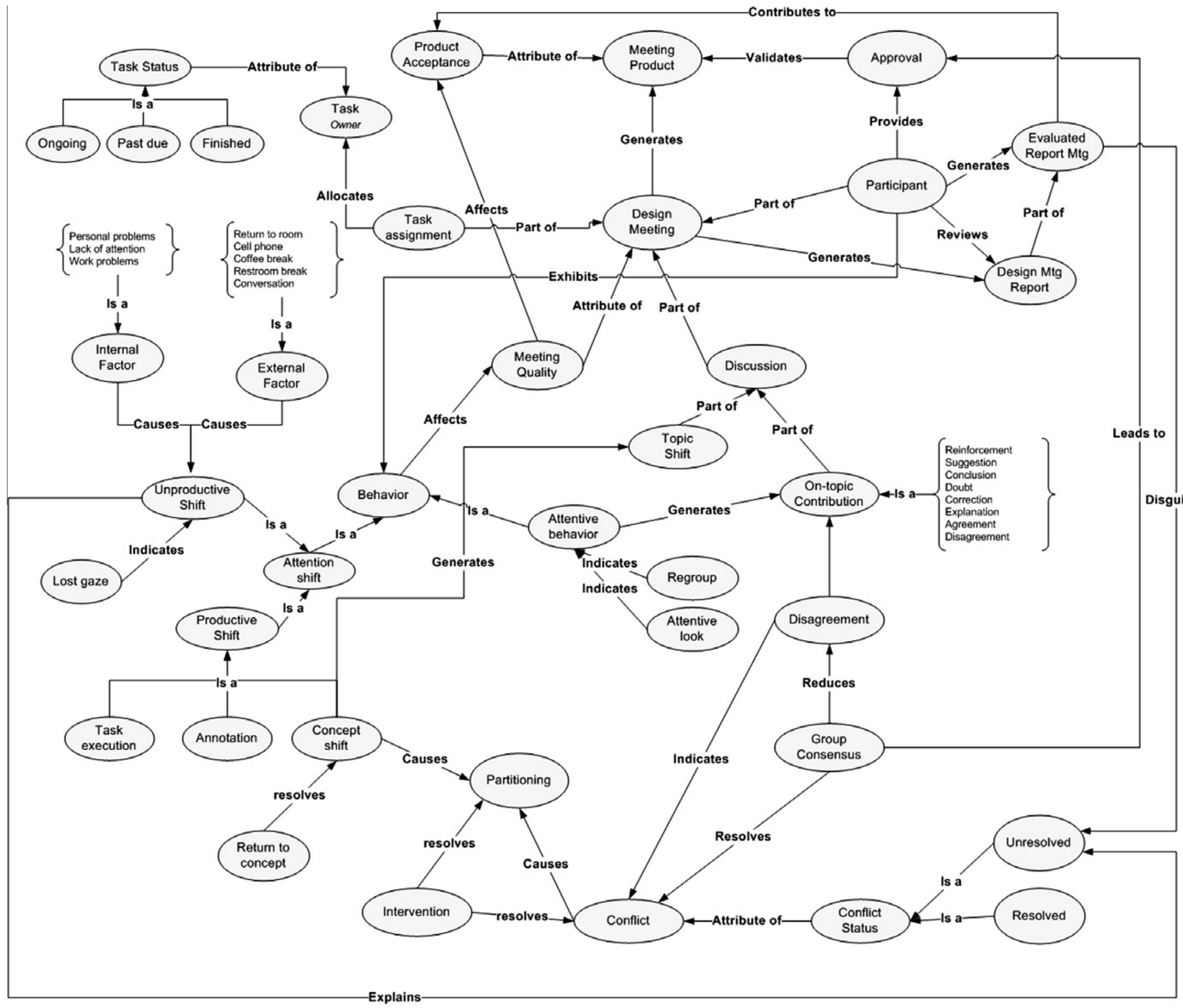

Fig. 2. BOO: behavior-oriented ontology.

STATUS of RESOLVED or NOT RESOLVED. Both scenarios are neither good nor bad for the final product acceptance. Nevertheless we tend to push towards conflict resolution in meetings as a way to speed up task completion.

A conflict indicates DISAGREEMENTs on PARTICIPANT's TOPIC CONTRIBUTION (a contribution to the discussion at hand) that, in general, may be:

- REINFORCEMENT: reinforcements are statements that strengthen a position or idea stated by another party. It means to reinforce the viewpoint, sometimes providing additional evidence.
- SUGGESTION: a suggestion interrupts the flow of the discussion to provide an alternative to an idea (e.g.: "we could also split this concept into two") or to the current sequence of activities (e.g.: "why don't we vote on this issue?").
- CONCLUSION: a conclusion finalizes a discussion, may happen through a vote or when the group reaches consensus.
- DOUBT: a doubt is an expression of confusion or sign of misunderstanding by one of the participants. These are situations in which the participant voices his/her doubts out loud, exposing them to the group.
- CORRECTION: these represent events where one participant corrects another's statement. While it contributes to the overall discussion, it sometimes weakens one the corrected participant's viewpoints, and may generate arguments.
- EXPLANATION: an explanation is an exposition of ideas, where the participant attempts to convey to others what he or she means with the ideas presented.
- AGREEMENT: an agreement is a statement of concordance with another's viewpoints, usually given during decision making.
- DISAGREEMENT: the disagreements are also voiced during decision making, and sometimes may lead to a vote, if no consensus is possible.

Participant's topic contribution is generally generated by ATTENTIVE BEHAVIOR perceived by ATTENTIVE LOOK or a REGROUPING of the participants.

In addition to INTERVENTIONs, a conflict can also be solved by GROUP CONSENSUS that reflects a reduction on DISAGREEMENTs.

A DESIGN MEETING is composed of a DISCUSSION in which PARTICIPANTS for whom tasks were or will be assigned take part. The DISCUSSION in a meeting is composed of participant's on topic contributions and topic shifts.

A DESIGN MEETING leads to a MTG REPORT composed by a series of discussions, a list of tasks assignments and a list of decisions made. MTG REPORTs are asynchronously reviewed by meeting participants, after the meeting, generating an EVALUATED MTG REPORT. The evaluated meeting report contributes to the FINAL PRODUCT ACCEPTANCE, but it may disguise unresolved conflicts that may be explained by unproductive behavior. For this reason, we should also consider, when predicting FINAL PRODUCT ACCEPTANCE, the MTG QUALITY that directly reflects the behavior of the participants during the meeting.

5.2. Ontology analysis

To validate our ontology's representativeness, we applied it to the description of nine meeting situations from three other projects. To measure this aspect of the ontology, we analyzed three meetings from three different projects, one meeting at the beginning (where more brainstorming is necessary, questions are more open ended and exploratory), one meeting from the middle of the project (where the discussion was more focused, deepening understanding of each concept) and one meeting from the end part (where definitions started to converge and decision making was the norm.) These project meetings also concerned collaborative modeling, involving groups of experts, for domains related to each project (distinct from the one initially studied), and had also been videotaped and transcribed, which made it possible to conduct this analysis.

We verified that the ontology's concepts could be found in other meetings (they were not meeting specific, but general). However, there was one concept missing from the ontology that appeared in these other meetings: study of related material (represents reading of related documents brought to the meeting by the experts), an instance of productive shift was added to the final version of the ontology. Thus, we believe that the ontology covers most meeting situations. Thus, we consider this positive indication that the ontology is indeed representative of most situations found in design meetings.

6. Behaviors and acceptance

Given that the final goal of our research is to map conditions that should be avoided in meetings, and create a representation for an expert system, we needed to further analyze behaviors and outcomes. Our initial observations lead us to believe that attentive behavior, group splits followed by rejoins on the same topic, plus the level of discussion and distribution of participation may have an impact on final design acceptance, individual satisfaction and the amount of rework needed to complete the project.

After coding meeting behaviors according to the ontology described above, we initiated a quantitative analysis to look for correlations between behaviors and acceptance. Initially, each element of the final product was labeled as accepted or disputed, depending on their acceptance during the project's final delivery meeting. Then, the number of occurrences of each behavior was computed, in order to draw conclusions.

The computed data indicates that the doubt behavior is a potential indicator of future trouble. In accepted concepts, we see fewer instances of doubt and corrections, and more instances of agreement than in problematic ones. This is understandable, as some of the disputed concepts were discussed quite emphatically, and the labels reflect these discussions. Overall, the sum total instances of doubt and corrections does not surpass the number of agreement statements in accepted concepts, but this does not hold for disputed concepts.

6.1. Attention and group partitioning

We have identified a number of behaviors that affect the outcome, but the negative one that appears most frequently is lack of attention. However, we also noticed that lack of attention can be of two natures: productive or unproductive. While attention shifts are usually bad both for the meeting and the outcomes, productive attention shifts should not necessarily be avoided. Sometimes, a user would shift his/her attention to a different task (such as checking documentation) and later return to the topic with new information or argumentation to contribute. An example of productive attention shift is shown in Fig. 3.

On the other hand, unproductive attention shifts are usually caused by external factors (phone ringing, incoming mail or pressing matters external to the meeting) or boredom (losing interest). Both problems could be overcome by creating more engaging meeting dynamics in order to capture participants' attention. Sometimes attention shifts lead to partitioning of the group, and parallel discussions may ensue.

Group partitioning also has a dual nature: partitioning due to unproductive attention shifts (e.g., side conversations about unrelated topics) should be avoid. The normal tendency would be to attempt to rejoin the group immediately, but productive group divisions are not necessary bad for the group: in some situations, while part of the group focuses on the main topic, a subgroup discusses related issues, exploring part of the design space separately and coming back to the group with new information that could help the group in its task. An example of group partitioning is shown in Fig. 4.

Fig. 3. Example of a productive attention shift.

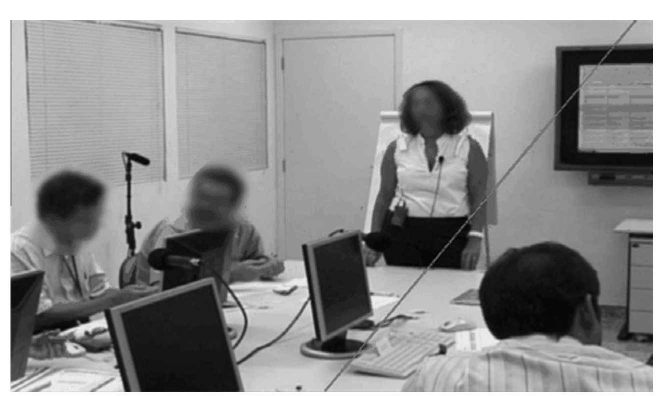

Fig. 4. An example of group partitioning.

The tricky issue in both situations is determining when the subgroup or individual has strayed too far off topic and should be steered back. While a certain level of digression is helpful, going too far from the original subject may not be.

6.2. Mental models

What we perceived was that the design process was in fact a process of mental model alignment. Individuals came in with their own mental models and perceptions of what the design should be. During the process, they first presented their beliefs (fashioned according to their mental models), then discussed these beliefs, in order to find a common ground to construct a joint model that represents the perceptions of all participants.

At each challenge an individual mental model could be altered, though reflection and the introduction of new information. Throughout the process, would align their models with the group model. The process inevitably involved initial resistance to change, but after extensive discussion ended with some sort of agreement.

Our observations are that the farther the individual mental model is from the group model at the end, the more difficult it will be to gain acceptance at the deployment stage. While we do not have an infallible way to change an individual's mental model, it is possible to elicit individual mental models by requesting private or anonymous opinions. If the models are too far apart, more discussion is necessary to reach an acceptable compromise position.

One interesting case, was that of participant R. This participant had medium levels of participation throughout (attentive at least, participative in many occasions), and agreed with decisions during the meetings. However, at the final presentation, he/she had several complaints about the final design, causing not only acceptance problems, but also discomfort with other participants, who could not understand the reasons for the sudden change of heart.

Throughout our study, it becomes clear that participant R did not change his/her mental model during the process. His/her behavior was indicative of "giving up": after a short time arguing, he/she lost interest and agreed with the group in order to dismiss the discussion. At the end of the process, he/she stated his real opinion and disagreed with the end result.

This type of situation could be avoided by encouraging further discussion, especially from the particular participant. Formally requesting an opinion or feedback, especially in between meetings or anonymously might yield the true individual opinions that did not surface during the meeting.

It should be noted that this participant had recently undergone training and had a theoretic background that others lacked. Additionally, he/she was the type of person who places value on detailed descriptions, and wanted to include much more detail in the final model than the rest of the group. Thus, the final construct might not have been as detailed as participant R would have liked. This type of conflict should be elicited and participants should understand what the appropriate level of detail is at the beginning of the activity.

6.3. Participation, acceptance and commitment

Each participant's participation in the meeting was characterized as participative, attentive or passive. Cross-referencing participation levels and acceptance, we can draw a few observations about the expected behavior of participants after the project is implemented in the corporation, which are related to their commitment to the project and interest in its success.

- Participative members who displayed high acceptance of the artifact will function as corporate champions of the technology, disseminating the new ontology into organizational culture. With these participants, there is a high probability that the design will be successfully adopted in the organization. These people have their mental models aligned with the group model (represented by the ontology). We identified two such cases in our group of participants.
- Attentive participants with high acceptance also lead to good chance of organizational deployment. These individuals have accepted the group model, even though there is no evidence of change in individual mental model. Inattentive participants who present high acceptance will not be champions or seek to propagate the technology, but they should also not work against the adoption of the ontology.
- Participative members with low acceptance levels may become problematic agents at the end of the project. Any failure during the test period will lead to the individual abandoning the project and the individual may try to work against organizational adoption, but arguments are weakened by the fact that he/she participated in the discussions and made compromises at that that point. This individual did not align his/her mental model during discussions, and this shows at this stage. We identified one such individual in this project.
- Passive participants with low acceptance will also avoid usage, and may create problems if usage is imposed. Inattentive participants who do not accept the technology will avoid adoption, but may use it through imposition. These individuals may create problems during the adoption phase, resisting usage and working against the project (we identified two cases in this project).

These observations were drawn from informal interviews, and no formal study was conducted to elicit participant behavior after project completion. However, this is an interesting avenue of research, which could be further explored.

7. Conclusions and future work

Facilitation involves designing meeting dynamics and overseeing the meeting at run time, to ensure goals are met. This usually involves intervening or otherwise adjusting the meeting to produce the desired results. Thus, a facilitator should be able to act according to perceived group dynamics or problems. It is not an easy task, and good facilitators are hard to come by. A skilled facilitator is able to perceive problem situations easily, but a novice is not.

Intervening involves a decision on the facilitator's part regarding whether, when and how to act. To make this decision, a facilitator requires information. Experienced facilitators should have no difficulty reading situations and finding appropriate actions to correct any problems. However, a less skilled or inexperienced facilitator may find it difficult to interpret a situation and understand different dynamics. Regardless of the case, a computer-based meeting support system should provide information to support the facilitator in his or her task of analyzing group dynamics and deciding when to act and how.

The main contribution of this research is a model that maps behaviors to acceptance, from which correlations can be extracted. These correlations may take the form of rules, with which an expert system could be constructed, which would help steer the meeting from problem situations. We are already developing scripts to map symptoms to solutions. These scripts could be used by an intelligent system to flag situations and suggest courses of action to the facilitator. Such a system functions as a facilitation aid, helping anyone facilitate a meeting.

Given our initial observations, we believe a support system should attempt to:

- Increase participation.
- Monitor discussion, to detect productive or unproductive attention shifts.
- Check the level of exploration of the design space.
- Check if the discussion was evenly distributed between participants.
- Check participation levels per participant.

We are also designing a set of rules for the system to use (probabilities for each situation given will still have to be discovered), and starting a new initiative to create rules for the system. Two of them are given below as examples:

- IF (behavior = attention shift) THEN DO(summarize topic) AND DO(gather feedback)
- IF (behavior = attentive look AND behavior <> contribution) THEN DO(summarize topic) AND DO(ask participant's opinion)

The first situation illustrates a division of the group, and the second illustrates one individual who is not paying attention to the discussion. Actions such as summarizing topics and gathering feedback will be defined in the system (for instance, popping up messages or questionnaire pages.) One open issue is that of automatically gathering behavior information to assess the meeting. However, with the current trend towards ubiquitous computing, we believe this will become easier in the near future. Research is already underway on new methods for capturing and analyzing human signals, and their real meaning (Pentland, 2008). When this happens, behavioral models will be necessary to fully realize the vision of ubiquitous computing.

Even though much work can still be done, our studies already yield some interesting observations, which we believe will help form a basis for future work on design meetings. Some new techniques are already being designed based on these findings. Despite the existence of other studies that describe factors that lead to production losses in meetings and how to identify them (e.g., Westley & Waters, 1988), these did not pertain to the design meeting context and there was no cross-reference with acceptance of the final design, which is part of our study.

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