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Technical Communication

Leveraging the potential of geospatial annotations for collaboration: a communication theory perspective

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This paper addresses a key problem in the development of visual-analytical collaborative tools, how to design map-based displays to enable productive group work. We introduce a group communication theory, the Collective Information Sharing (CIS) bias, and discuss how it relates to communicative goals that need to be considered when designing collaborative, visually enabled, spatial-decision-support tools. The CIS bias framework suggests that key goals for developing such tools should be: (a) the harnessing of a group's *collective* knowledge emerging from collaborative discussions and (b) reducing the repeat of information that has already been shared within the group. We propose that web-accessible, map annotation tools are ideally suited to advancing these goals and outline how the CIS bias framework informs *how* geospatial annotation tools can maximize the potential of collaborative efforts. We offer design recommendations for annotation tools that function to: (a) facilitate access to and recall of geographically referenced discussion contributions, (b) document ideas for private as well as public discussion spaces, and (c) elicit all group members to contribute information in a given collaborative effort.

Keywords: Geospatial annotations; Collaboration; Collective Information Sharing (GIS) bias theory

1. Introduction

Collaboration entails the exchange of ideas in the hopes of yielding greater collective knowledge. In this paper, we focus on the development of visual-analytical collaborative tools. We examine how collaborative discussion around map-based displays can be structured using annotation tools to enable productive group work. Providing collaborators with the capacity to annotate map-based displays can ease communication tasks particularly for spatial-planning discussions. Kinds of annotation considered include: geo-located text notes, direct drawing on maps of geospatial images (e.g. circling an area of interest on the map, using colour-coded annotations to indicate favouring or opposing an issue), geographically anchored photographs, annotations with fading properties (i.e. fade away or fade in colour intensity after a few minutes), and place-based aural notation (figures 1 and 2 illustrate several annotation types listed, black and white figures are illustrated in colour in the electronic version of this paper).

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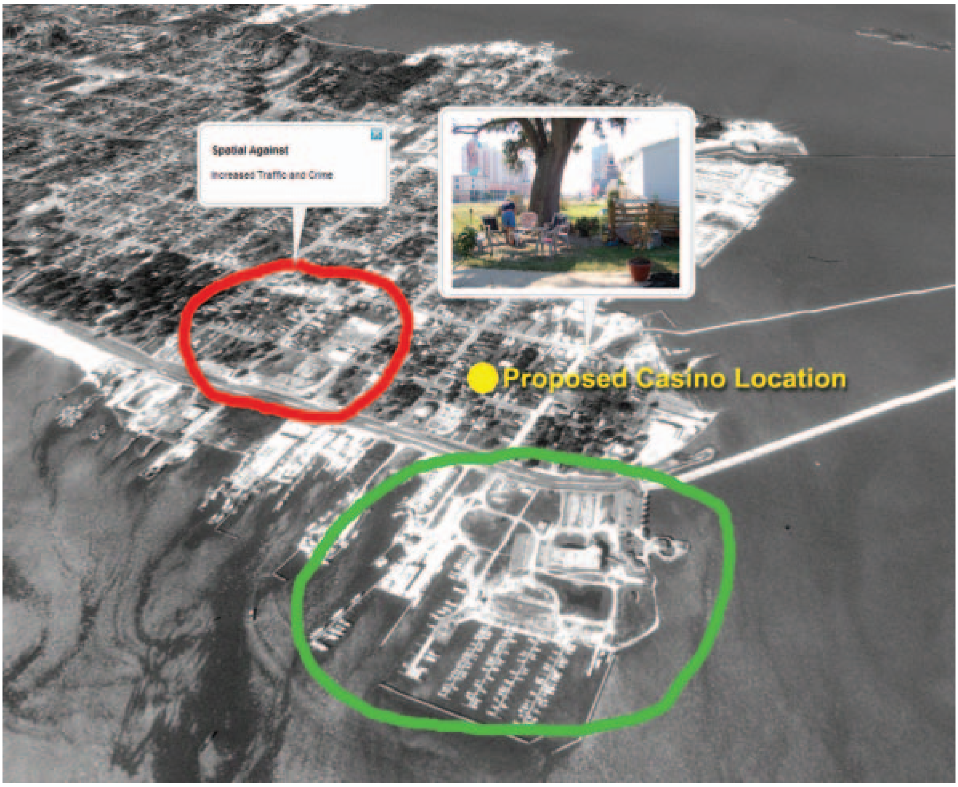

Figure 1. Multimodal geospatial annotations support spatial planning dialogue. The Gulf Coast community of East Biloxi, Mississippi experiences rebuilding challenges after Hurricane Katrina as the pressure to redevelop the city into a resort town grows. Many residents are unable to afford the cost of rebuilding their homes and have been forced to sell their land. Colour-coded line annotations are used to point out areas of redevelopment and changes in cultural community character. Green annotations signify 'go' to move forward with development of casinos. Red annotations signify 'stop' building casinos. Text annotations provide geospatial arguments (increased traffic and crime) to support positions. Photographs capture primary data from fieldwork and provide detailed information related to discussion about a place. Source of East Biloxi peninsula image data: NASA WorldWind, US Geological Survey. Our initial tools have been implemented by adding extensions to Google Earth. Owing to copyright issues with both images of the Google Earth viewer and the content it displays, we are illustrating the ideas with figures created using open-source web tools and data.

The design of any visual-analytical tool needs to be properly grounded in a relevant theoretical framework so that empirical testing of goals can be achieved. We introduce a perspective from group communication theory, the Collective Information Sharing (CIS) bias, as an approach through which geospatial annotation tools can enable collaborative discussion. We apply the CIS bias theory to develop guidelines for effective map annotation. Meaningful knowledge production emerges from the pooling of unique information. The CIS bias theory focuses particularly on the importance of harnessing *collective* knowledge from group discussions by minimizing the sharing of redundant information and increasing the sharing of unique information. Empirical group research guided by the CIS bias theory has shown that group members tend to repeat shared

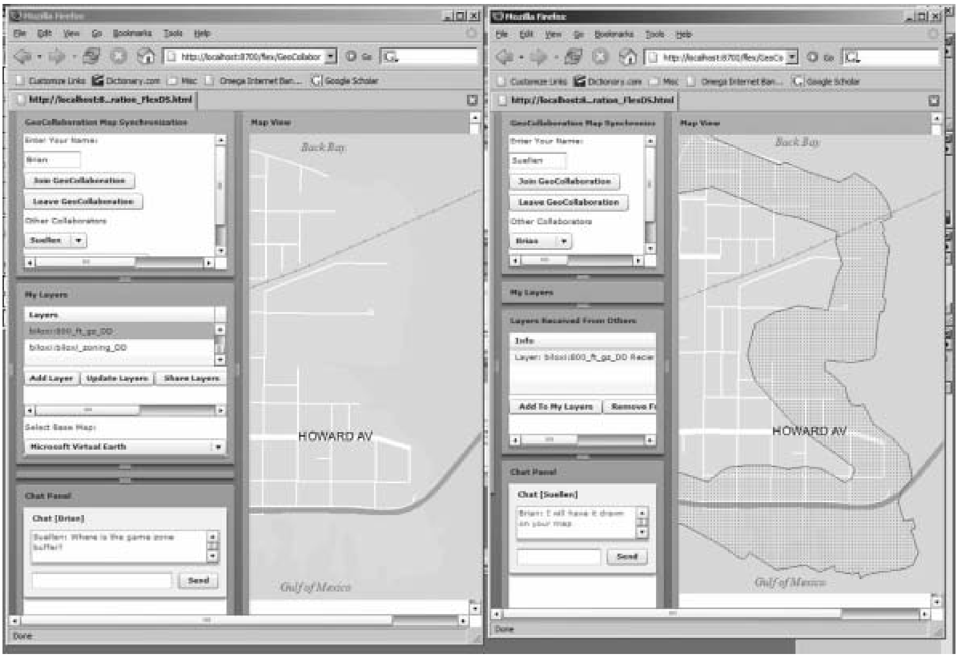

Figure 2. Annotation interface. Text and line annotations act as boundary objects (i.e. visual artefacts) to create a shared semantic framework. Information is shared about geographical areas of urban redevelopment and low-income housing in the Gulf Coast town of East Biloxi, Mississippi post-Hurricane Katrina. The collaborator in the right panel has drawn the area zoned for casino development and will draw the 'object to talk about' for the collaborator in the left panel.

information (i.e. information already known to all group members) early on during group discussions rather than contributing unique information (known only by one group member) (Stasser and Titus 1985, Stasser and Stewart 1992, Larson *et al.* 1994, Stasser *et al.* 2000, Wittenbaum *et al.* 2004). This communication phenomenon is a factor that often leads groups to make sub-optimal decisions. For this reason, the CIS bias merits attention when developing group-decision-support tools.

We are in the early stages of developing geospatial annotation tools to facilitate collaborative spatial decision support. Our research builds on prior efforts in which map-based displays have explicitly linked discussion contributions with geographic objects (Rinner 2001, 2005, 2006, Kolbe *et al.* 2003, Jankowski *et al.* 2006). We chose annotations as an initial focus in our work because the format shows promise to augment cooperative communication tasks. Annotation tools have an important role to play in eliciting unique information about geographical components of situations being considered by groups. We focus on cartographically indexed geospatial annotations, which we define as discussion contributions explicitly anchored to geographic objects or coordinates on map-based displays. Geospatial annotations distinguish themselves from other annotations in that they are anchored to a specific place on a map whose interpretation depends at a minimum on spatial context.

The structure of this article is outlined in the following way. First, we address the central role that geospatial annotations play in supporting collaborative spatial discussion situations around map-based displays. We narrow the scope of application to settings in which participants are located in different places. Temporally, these tools might apply to group members communicating with each other at the same or at different times (synchronously or asynchronously). A brief review is then provided on how annotation tools have been used for collaborative efforts in prior research (for a detailed review, see Rinner, 2006). In sections 4–5, we describe the CIS bias theory and how it may operate in group discussion at informational, social, and psychological levels. This theoretical perspective, in turn, has implications for designing geospatial discussion support tools. In section 6, we summarize recommendations for designing visual-analytical collaborative annotation tools guided by the CIS bias theory.

2. Role of geospatial annotations in collaborative spatial-planning discussions

The explicitness of annotations anchored to geographic locations on map-based displays act as boundary objects (MacEachren and Brewer 2004). Boundary objects include any object (including concepts, maps, equations, words, graphics, images) that is included in the different perspectives of collaborating group members and serves as mediator between one perspective and another (figure 2). Boundary objects provide a basis for understanding that supports discussions among collaborators from various backgrounds. For example, collaborators can circle an area to which they want to draw attention and obviate the need for specialized language in order to orientate the other group member to an object of communication. Having access to visual tools such as being able to attach an electronic post-it note with text, circle an area of concern, or connect photographs to map-based displays (figure 1) rapidly moves discussion beyond orientations of 'where we are' or 'what we are talking about' towards a meaningful exchange of information regarding who knows what about an area and how this might be relevant to solving a particular problem.

The different formats of geospatial annotations (e.g. text, hyperlink, icon, lines, photograph, audio) provide alternative communication channels. Each format delivers information of a slightly different qualitative nature. Text annotations provide the opportunity for rich descriptions (e.g. discussions related to low income housing development inside an area zoned for high-end commercial and casino development), while a photograph captures static yet detailed information about scenes (e.g. a neighbourhood street corner that has poor street lighting, living conditions post-Katrina in a FEMA trailer near a casino development; figure 1). Drawing (i.e. circling; see figures 1 and 2) rapidly orientates collaborators without having to use special language and can, in some cases, overcome language barriers. Aural annotations linked to a place are an easy way to document information for those on the ground who are physically located in an area. Aural annotations can reinforce meaning around visual images such as photographs. Furthermore, they provide an additional communication channel other than text that can render visual information more memorable (Giaccardi *et al.* 2005). All the annotation formats mentioned function to capture attention and contextualize discussion. Their multimodal properties act as persuasive messages in drawing group members' attention to a location, to evidence for arguments being made, to knowledge gaps, or to alternative explanations and chains of reasoning in deliberating about a problem. The latter function of providing alternative explanations and chains of reasoning fulfills a key analytical role for group collaborations (Thomas and Cook 2005). The following discussion addresses how annotations fulfil analytical roles.

Geospatial annotations play an important role in not only presenting but also analysing group information. Annotations can be designed to analyse stakeholder views and reasoning. If expressed in text or aurally, annotations could be computationally processed to produce graphic depictions that draw attention to whether a group's *collective* knowledge base is actually richer in resources than its members' individual contributions and recall of ideas (Pike and Gahegan 2003). Text and aural information could also be analysed by location, attribute, or participant (e.g. highlighting who has not contributed). Even freehand sketches can be analysed computationally to become meaningful instruments of analysis for documenting and sharing findings (Denisovich 2005a, b). Graphic depictions that draw attention to a group's knowledge base can augment a group's organizational memory, facilitate recall of shared information, and generate ideas (Ovsiannikov *et al*. 1999). The explicitness of visually depicting a summary of ideas also plays a role in reducing the repeat of information. Without annotation tools, the same information is likely to be repeated by group members.

At an abstract level, it is the exchange of annotations during collaborative discourse that results in meaning around maps being gradually defined (Marcante and Mussio 2006). Annotations make explicit the differences and similarities in how group members interpret a situation. Collaboration is enhanced when people involved contribute different kinds of knowledge and perspectives. Therefore, tools, which facilitate group members in understanding how their own knowledge and perspective differ from and compare to that of their collaborators, will be valuable to goals aimed at harnessing comprehensive thinking. Annotations thus play a central role in articulating the path of collaborative knowledge production. This is achieved by (a) the flexible ways in which collaborators can use annotations to express their ideas (i.e. the multimodality) and (b) the visual explicitness (i.e. externalization *onto* the map-based display) by which annotations articulate similarities and differences of ideas shared among group members.

3. Previous work using annotations to support collaborative spatial decision discussions

Annotations have been used for distributed group spatial decision-making by several researchers in contexts ranging from urban planning (Al-Kodmany 2000, 2001, Rinner 2001, 2005, 2006, Denisovich 2005b, Keßler *et al*. 2005), to bike route planning (Kolbe *et al*. 2003, Voss *et al*. 2004), to collaboration between professionals who have different expertise (Marcante and Mussio 2006), to recording stakeholders' views on land-use practices (Berardi *et al*. 2006), to distributed business teams making decisions (Cadiz *et al*. 2000), and for documenting aural annotations (Giaccardi *et al*. 2005).

Prior research by Kolbe and colleagues (2003) has focused on designing cooperative web maps that are user-friendly and allow users to control who sees their annotations. Voss and colleagues (2004) have built annotation systems allowing for many-to-many relationships, which provide more flexible ways of both analysing and presenting information. Research by Al-Kodmany (2000, 2001) has applied the use of collaborative annotation tools for neighbourhood revitalization efforts. Residents provided feedback to neighbourhood planners by annotating photographs of places in their neighbourhoods. Tools for adding annotation to map-based displays were designed by Al-Kodmany to support collaboration between planners and residents but not *among* residents. Rinner developed argumentation maps (i.e. Argumaps) which make explicit linkages between arguments and geo-objects in map-based displays. In contrast to Al-Kodmany's collaborative tools, Rinner designed cartographically indexed annotations that allow users to directly collaborate with *each other*. Building from Rinner's focus on geo-argumentative relations, our focus on designing collaborative visual-analytical tools aims to reduce repeat of similar information and harness collective group knowledge that has been gained through exchange of ideas. More generally, we argue for the importance of considering group communication processes that shape user behaviour when designing visual-analytical collaborative tools.

4. Collective Information Sharing (CIS) bias

The premise of the CIS bias theory is that decision-making groups bias discussion toward (shared) information that all members know at the expense of discussing (unshared or unique) information that a single member knows. The result is that groups have hidden profiles in the form of information that does not get out or that has less impact than it deserves (Stasser and Titus 1985, Stasser and Stewart 1992, Larson *et al*. 1994, Stasser *et al*. 2000, Wittenbaum *et al*.2004, McNeese *et al*. 2005). The exchange of unique ideas with other group members is a communicative goal that is likely to lead to a richer knowledge pool across the group as a whole promoting broader analyses of problems. Furthermore, the communicative goal of sharing unique ideas assumes that making unique information more salient and minimizing redundant information will enhance the quality of decision-making. In collaborative and spatial planning situations, typically, a diverse group of members work on tasks that require them to combine their efforts in a way that facilitates joint understanding of a complex problem.

5. How geospatial annotations can reduce the CIS bias and support group spatial-planning discussion

The CIS bias theory explains a group's information sharing behaviour as a function of whether group interactions are viewed as: (1) a process of sampling arguments (the Information Sampling Model (ISM)), (2) a process shaped by social influences (the Social Comparison Process (SCP) theory), (3) a process shaped by psychological influences (Mutual Enhance Effect (MEE)), or (4) a process shaped by pre-discussion preferences (Commitment to Initial Preferences (CIP)). These different perspectives from which group member information sharing behaviour can be explained suggest multiple ways to design discussion-support tools with the aim of pooling a group's collective knowledge and reducing redundant information.

5.1 *Increasing group member access to and recall of information: the information sampling model*

One way in which group information sharing in decision-making is understood is as a process of sampling arguments from an available domain of items (Burnstein and Vinokur 1977, Stasser and Titus 1987). Whether a given item of information is discussed by a group depends on the number of members who have that information prior to discussion and on the probability that members will mention it during discussion. This information-centric view of group communication is called the Information Sampling Model (ISM). The way in which discussion procedures are structured as they relate to group decision-making processes and outcomes is the focus of understanding group information sharing. A seminal study by Stasser and

Titus (1985) showed that groups rarely uncovered or shared all the information each individual possessed that was relevant to a decision. The ISM perspective focuses attention to how structuring discussion procedures can improve information pooling in groups. Discussion structure refers to the way in which group members share, access, and recall information. One presumption of ISM is that group members will mention information based on what they recall.

Information that is made visually explicit is more likely to be recalled and, therefore, discussed. For example, anchoring information to places on a map will draw attention to the individual and relative locations of those information fragments and is likely to prompt place-based discussion. Equally likely in using cartographically indexed messages (i.e. geospatial annotations indexed on map-based displays) is that geographic gaps in information depicted on map-based displays will make apparent what information individuals may hold that has not been shared and that might assist the group in understanding a problem. Geospatial annotations are seemingly intuitive in-context visual cues in map-mediated information exchanges that can facilitate coordinated group recall of unique information. The ISM perspective thus suggests that to improve the collective knowledge of a group, geospatial annotations should function to increase group member *access* to and *recall* of discussed information.

Improving access and recall could be achieved by designing a flexible annotation submission and retrieval system (in conjunction with the collaborative map). Members' needs to share and retrieve or view annotations will differ depending on their sub-context situation within the larger framework of ongoing spatial planning discussions. Annotation sharing and retrieval could be organized by (a) geographical area, (b) attribute/category, (c) group member (d) map object, and/or (e) map layer. One research group has already recognized the design challenges inevitable when permitting users to annotate freely (Espinoza *et al*. 2001). To prevent information overload and user disturbances, Espinoza and colleagues developed GeoNotes, an advanced and flexible annotation retrieval filtering scheme for the context of social group interactions.

5.2 *Creating private spaces for group members to document ideas: The Social Comparison Process theory*

A second way of understanding the CIS bias relies on social comparison processes (Festinger 1954). The Social Comparison Process (SCP) theory recognizes the role of social dynamics in group interactions. In a social framework, the CIS bias is understood by the extent to which normative factors, such as how critically group members evaluate information, bear on decisional group processes. Festinger (1954) claimed that during times of uncertainty, group members look to others to evaluate the relative importance of mentioned information. An example of group spatial planning discussions under conditions of great uncertainty might include disaster response decision-making. In this context, hearing that others possess the same information may make that information appear more valuable, important, and relevant. Encouragement and validation from others when shared information is mentioned may lead members to favour repeating or discussing such information without adding unique information (Postmes *et al*. 2001). Group norms, the informal (often unspoken) rules that small groups adopt to regulate group member behaviour, may have substantial impact on eliciting conformity to specific ideas or solutions (Levine and Moreland 1991). Group norms can promote the importance of consensus or the value of arriving at shared meaning and interpretation of events. This implies that perceived validity of information in a group context may in part be socially established. The SCP theory thus directs attention to the normative influences on human interaction during group discussions.

Having different annotation types, with one type functioning strictly as a depository of ideas that are to be used for brainstorming only might assist in psychologically freeing group members from the constraints of group norms. Equally important is providing group members the opportunity to document their ideas in private maps accessible only to individual (or small subsets of) group members. This additional communication platform still allows for making ideas explicit yet, initially, only to the individual (or subset) and not to the full group. Designing tools with private spaces has the potential to increase the number of unique ideas contributed overall (if shared with the collective group eventually) by offering parallel private brainstorming to occur prior to or during group information sharing. Private spaces preserve a degree of anonymity, which may reduce group members' inhibitions to record their ideas. One disadvantage of documenting ideas in private spaces is that other group members are unable to see all of the comments shared during synchronous discussions. Ziegler *et al*. (2000) suggest that reading others' ideas can lead to mutual cognitive stimulation.

5.3 *From cooperative to motivated information sharing using fading properties: The Mutual Enhancement Effect theory*

Group members may have evaluation apprehension related to contributing ideas. The Mutual Enhance Effect (MEE) theory brings attention to psychological factors influencing group member interactions during information sharing. MEE suggests that a group's tendency to discuss and repeat information known by all members (shared) more than they discuss information known by one member (unshared) is because of the group member tendency to evaluate those who mention shared information positively (Wittenbaum *et al*. 1999). Strategies from a psychological perspective focus on encouraging group members to share unique information by increasing their motivation or, alternatively, lowering their evaluation apprehension.

A strategy for promoting broader participation comes from work with the military by Steve Roth as reported by Gershon (2005). Roth observed that senior officers often added annotations to maps as part of group tactical decision-making activities, but that junior officers (although they offered ideas) did not add annotations. He guessed that the norms of military hierarchies inhibited the junior officers from adding direct annotations to the map that might contradict or otherwise compete with those by the commanding officer. His development team implemented the idea of temporary annotations that fade away over time, thus implying a subordinate idea to the permanent annotations. This strategy reduced the apparent inhibitions of the junior officers substantially, and they used the map annotation capabilities much more actively. Annotations with fading properties also function visually to indicate the timing of discussion points with faded ones reflecting earlier discussion contributions. Employing annotations with fading properties that facilitate increased participation during collaborative discussion is a strategy that has yet to be tested formally but it is one we are in the process of implementing.

5.4. *Using annotations to capture pre-discussion preferences: The Commitment to Initial Preference theory*

A fourth and final theory explaining the CIS bias is the Commitment to Initial Preferences (CIP) theory. This theory acknowledges that group members enter group discussions with pre-discussion preferences, which they are often reluctant to revise (Wright and Drinkwater 1997). The evaluation bias toward preference-consistent information often leads to premature consensus on suboptimal alternatives (Greitmeyer and Schulz-Hardt 2003). Work by the intelligence analysis community and by group communication scholars has examined the persistence of impressions even after evidence that created those impressions has been fully discredited. Experimental research has shown a tendency to interpret new information in the context of pre-existing impressions (Gouran 1986, Heuer 2001). Group members' advocating their initial preferences during discussion can result in premature consensus, which in turn can decrease the perceived need to seek additional information. Incorporating private spaces into the collaborative environment can function to capture pre-discussion ideas and views. Collaborators are provided the opportunity to self-annotate pre-discussion ideas. Through sketching, writing, or even aurally documenting ideas in private, these ideas, if indeed they are unique, will not be lost in collaborative discussion if the idea is discounted initially by other group members.

6. Design recommendations to enhance collaborative meaning production

It is anticipated that by applying group communication theory to the design of collaborative analytical annotation tools, broader analyses of problems and more comprehensive thinking will be fostered to support discussion-based decision-making. The CIS bias theory suggests several strategies for increasing collective group knowledge and reducing the repeat of information (see table 1 for summary). One strategy involves designing geospatial annotation tools to increase access to and recall of information shared by group members. Providing tools that allow users to query, present, and store annotations in multiple ways provides a flexible system that fulfills user needs to express ideas in different ways. A second strategy suggests the importance of providing users with private as well as public spaces to document information. Providing a space to document ideas privately serves several purposes. First, it frees individual group members from the constraints of being evaluated by others. Second, private space serves as an additional channel through which to document and potentially increase the number of unique ideas contributed. Third, a motivational (i.e. psychological) approach may result in greater collective knowledge by increasing participation of all group members. Implementing fading properties in the use of geospatial annotations shows promise to lessen evaluation apprehension and increase participation by group members to share a greater number of unique ideas during collaborative discourse. Employing a fading technique to increase participation as opposed to a private map has the advantage of having all members see the comments during group discussion. Seeing and reading other group members' ideas is thought to lead to mutual cognitive stimulation.

7. Concluding remarks

In a deliberating group, shared information (information held by many or most prior to discussion) frequently imparts a greater effect than unique information

Table 1. Design recommendations for geospatial annotation tools: informational, social, and psychological aspects of group information sharing.

	Informational	Social	Psychological
Information Sampling Model (ISM)	Geospatial annotation tools function to increase access to and recall of information		
Social Comparison Process (SCP)		Private maps function as additional channel to annotate ideas; frees user of evaluation apprehension; ideas remain private initially	
Mutual Enhancement Effect (MEE)			Geospatial annotation tools have fading properties that allow user to psychologically overcome evaluation apprehension; fading function is intended for increasing participation; participants can see all comments during information sharing
Commitment to Initial Preferences (CIP)		Private maps function to assess influence of pre-discussion ideas and to prevent premature consensus of solutions	

(information held by just one prior to discussion). Geospatial annotation tools can be designed to counter group communication tendencies to repeat shared information by attenuating the CIS bias and encouraging the sharing of unique information. Strategies are guided by the broader goals to (a) maximize the pooling of a group's *collective* resources, (b) support recalling of all potential solutions in final decision-making, and (c) reduce the sharing of redundant information. A collaborative map as tangible visual artefact augmented by explicitly indexed annotations makes apparent around which locations discussion has taken place. Equally important is how annotations explicitly indexed in map-based displays make apparent what place-based discussion has *not* taken place. The collaborative map as communication platform coupled with a supplemental geospatial annotation system can actively function to encourage the explicit contribution of unique information in a manner that is multimodal rather than unimodal, collaborative rather than personal, and dialogue-enabled rather than unidirectional (MacEachren *et al*. 2005). Furthermore, geospatial annotation systems accelerate rapid insight during group discussions into (a) what is known, (b) who knows what, (c) how a problem is understood by group members, and (d) how sense-making about a problem is negotiated by group members over time. Geospatial annotation systems for map-based displays thus support collaborative information sharing that has greater potential to be transformative.

Parsing out essential goals that improve the incremental process of greater knowledge is key to successful group work. Theory guides tool design by prioritizing goals the tool should fulfill. The CIS bias theory suggests that visual-analytical collaborative tools designed to facilitate collaborative goals should yield greater collective knowledge (i.e. a greater number of unique ideas) and reduce redundant information. Group members will come away from collaborative efforts with a greater pool of information. A greater collective knowledge is generated by the group as a whole when each member has learned something about what the others know and how their information might help others. Challenges remain in regulating and preventing cognitive overload of ideas being made explicit, of accessing knowledge by any group member, or supporting annotations over time while not interfering with access to information already contained in the map display. However, geospatial annotative systems can function to reduce redundant information, allow for a flexible, intuitive way of exploring the exchange of ideas, and facilitate group members overcoming apprehension to participate. Moreover, geospatial annotation tools can play an important analytical role by producing graphic depictions that draw attention to whether a group's *collective* knowledge base is richer in resources than its members' individual contributions and recall of ideas (Pike and Gahegan 2003).

A flexible annotation system (i.e. one that allows multiple ways of querying, analysing, and accessing geo-based information) is critical to increase access to and recall of unique and shared information. To the extent that annotations are used asynchronously, private group member work spaces could allow participants to sketch and externalize their ideas providing another means to document unique ideas before they are potentially stifled by biases toward shared knowledge when discussing collectively ideas with the group. Geospatial annotations for distributed conversation support make transparent information that is shared. Without geospatial annotations, groups are likely to repeat information. Second, the transparency of information shared through geospatial annotation tools will (a) make apparent geographic gaps in map-based discussions and (b) encourage the sharing of non-redundant information. Empirically investigating the utility of geospatial annotations to eliminate redundant sharing of information and to enhance unique contributions toward collaborative efforts is a rich avenue for further study.

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