Ambient information for collaboration and discovery: Adapting from information practices in the field

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ABSTRACT

This paper presents a model for designing ambient interfaces for collaborative research oriented to cognitive needs of scientific discovery. Recent field research on information use in life sciences research defined a model for collaborative information use, supporting a design proposal for ambient peripheral information interaction for discovery.

Author Keywords

Ambient interfaces, Information behavior, Scientific collaboration

ACM Classification Keywords

H.5.3 Group and Organization Interfaces, H.5.2 User Interfaces

INTRODUCTION

Intelligent ambient environments show promise for many situations where individuals interact with complex technological devices, such as medical treatment facilities, smart homes and public spaces, and learning spaces such as museums and schools. Ambient intelligence (AmI) technologies, largely designed to sense individual presence, collect and organize appropriate data, and respond situationally, are here considered for application in the complex domain of scientific research laboratories.

Ambient intelligence covers a wide territory already, partly because it remains in the early stages of technological development. We find applications ranging from interactive visual displays to the smart homes and hospital environments prototypes by Philips Electronics. While many of the current ambient environment proposals may appear as early prototype technology solutions to often unclear human needs, the scientific research domain offers both need and a culture of early adoption. But while scientists and the needs of discovery may appear the perfect target for such a technology "in search of users," we suggest there may be numerous ambient interfaces currently applicable in the research laboratory. I propose a model for analyzing applications for collaborative research, building upon the real information needs of collaborating scientists working toward discovery

We start by learning from field studies in scientific discovery, and real-world data from collaborative life sciences research. We present a framework for locating ambient interfaces, information, and interaction within the context of research information for collaboration and discovery.

ORIENTATION TO DISCOVERY

Current practice and cognitive studies in scientific discovery have focused on specific cognitive and social behaviors that facilitate the emergence and recognition of "meaningful novelty" and patterns of discovery in scientific reasoning.

In studying lab meetings in molecular biology research centers, Dunbar [1] found over 70% of scientists' inductions, 50% of their deductions, and 70% of their causal reasoning statements were devoted to unexpected findings from experiments. Analogies were frequently generated in lab discussions, to formulate hypotheses, design experiments, or to explain results to other researchers. However, an interesting cognitive operation was found that scientists tended to forget their analogies and other "cognitive scaffolding" used in reasoning, and they recalled and subsequently relied on the results of their reasoning. While analogies are important in leading scientists to discovery, they were undervalued and even invisible. Dunbar also found that more than 50% of the reasoning that takes place at a lab meeting was distributed, shared and generated among a number of researchers, suggesting that distributed reasoning (and collaboration) is significant to the process of discovery.

Information Objects in Research Discovery

Dunbar [1] evaluated the primary sources of information objects in scientific research – the data points of findings emerging from experimental practice and data and interpretations shared in lab meetings. These data are the crux of research practice. The other sources of information objects are the articles, abstracts, and materials searched and selected from resources external to the laboratory, from journals, databases, and information services accessible through the institution's information ecology. While every researcher collects and analyzes experimental or research data directly relevant to their projects, they also conduct information research on periodic basis for experiments and research practice.

We find the following non-experimental information seeking practices reported from field findings:

1. Locating materials and methods, by searching, locating, and selecting information from the Internet, primarily using the Google search engine.
2. Seeking journal articles by searching, locating, and selecting from titles and resources listed in the university library website. Life scientists conducted this task using primary resources such as PubMed or MEDLINE, and specialized information services, such as Web of Science.
3. Direct searching and selecting of abstracts from primary search resources (e.g., PubMed), linking to desired articles through library gateway services.
4. Occasional access of disciplinary websites and tracking topics through email newsletters.
5. Regular scanning of 10-20 journals of specific research interest, typically online.
6. Continual use of local resources prepared and collected by the researcher for reading, reference, and immediate use in research work. Local resources include printed and annotated articles, reference lists, abstracts, and electronic versions of these artifacts.

These information behaviors are commonly treated as individual tasks, by the researchers. Without studying the assignments, motivations, and social influences behind information behavior, we might assume these research information tasks satisfy *individual goals*. The life sciences field study shows how these information tasks are driven largely by research project needs, and are not necessarily individual cognitive needs. In large research projects, all participants have a stake in both experimental data and published (external) information. In collaborative research projects, researchers filter information objects by selecting those most relevant, disregarding the majority.

Dunbar's investigation did not examine information seeking and exchange of published information; the discussions analyzed assumed these as background resources. For the purpose of augmenting discovery, the results of these 6 canonical information tasks should be considered directly applicable to the collaborative objectives of discovery.

Also, while Dunbar investigated scientific reasoning in co-located collaborations, we must anticipate design for *distributed* projects and supporting their special information needs in experimental discovery. Dunbar's findings are projected as follows to the needs of distributed research collaborations found in the life sciences field studies.

Unexpected findings – Findings deemed "unexpected" relate to the context of the hypothesis and general research inquiry. With co-located lab members, these findings are discussed in person as the need arises or in schedule meetings. In distributed collaborations, unexpected emergent findings are not easily shared with all participating collaborators. Ambient information services can augment research exchanges by providing channels for real-time remote display of data, meetings, or lab notes shared between labs.

Analogical reasoning – Analogies are generated in discussions, providing scaffolds for formulating and evaluating interpretations exchanged among collaborators. Dunbar's research shows existence of a real skill in constructing analogies, demonstrated in the effectiveness of more experienced researchers. Ambient intelligence might extend this faculty of reasoning by capturing information objects from the research, providing peripheral information tangentially related to the research topic. Visualization tools and broader, thematic representations might help researchers expand the narrow domain of their findings to adapt from other research methods, biological systems, research traditions, and other disciplines.

Distributed reasoning –A significant role is considered for ambient intelligence and interfaces to provide a virtual collaboratory space, by displaying current experimental results, data, and papers/issues under discussion between collocated and remote research teams. While distributed reasoning itself is not explicitly facilitated, a distributed representation of research issues and ideas can be generated, offering peripheral support to discovery.

COLLABORATION AND INFORMATION PRACTICE

Researchers are inundated in information already and at all times; information overload is a very real problem and electronic information delivery (email, newsletters, alerts) increases the flow of articles, links, snippets of science sent to their desktop computers. So why do we believe scientists might adopt such a system with additional, even continuous ambient information streams if many of the information objects are only peripherally related to their immediate research tasks? We address this with a model describing different types of collaborations, suggesting appropriate domains motivating "Collaborative AmI."

Ten research projects were analyzed, consisting of teams of 4-6 researchers; 6 of 10 projects involved external collaborators. Pharmacology researchers reported an average of 2.5 research projects each, most involving extra-departmental collaboration. Molecular biologists reported fewer projects, with most graduate students focusing on one major project. Across these disciplinary and project samples we categorized four types of collaborations, each representing a different type of relationship or network.

Collaborations of interest – Internal collaborations of learning and research form as networks, as aspects of larger research projects are shared among investigators with specific interests. These may be organically distributed (as members have time and interest) or specifically allocated networks (by investigator or research lead).

Collaborations of expertise – Non-overlapping knowledge, knowledge of literature, authors, and methods in the designated subdiscipline can be delegated and drawn from as necessary during different phases of research cycle.

Collaborations of facility – Equipment and facilities not available locally are often shared with larger research centers or other institutions as part of collaborative arrangements.

Collaborations for shared goals – Similar or overlapping work within the peer network may be combined for specific projects and goals, e.g. to strengthen a grant or research paper, leading to a better publication or farther-reaching proposal.

Many research projects show characteristics of two or more types of collaborations. In one project (interdisciplinary social sciences, education, and pharmacy) a collaboration begins with a shared interest, and becomes a "shared goals" project as the decision is made to pursue a joint project. Projects may not show clear boundaries between types; a facility shared between departments implies a shared interest, but at some point the facility requirement becomes central to the collaboration. This shifting of interests, priorities, and progression to a research commitment was fairly typical on the way to collaboration. This pattern of "socially constructing" collaborations may have implications for facilitating remote collaborators with ambient intelligence.

Table 1 shows the collaboration types drawn from field data, associating collaboration with each level of activity and context. Representative examples are defined for each association. The cells shown in bold indicate where collaborations might be augmented with ambient data, interfaces, or agents.

Not all collaboration types and contexts are oriented to scientific discovery. Even considering that facility collaborations may benefit from ambient augmentation, these collaborations are not defined here as oriented toward mutual discovery. To draw the distinction further, there seem to be three collaboration types (italicized in Table 1) focused on discovery as a shared objective. While other collaborations may support the discovery process, these two Expertise types and single Shared Goal type assemble with a shared research or project objective we might claim as discovery.

AMBIENT INTERFACES IN COLLABORATION

Essentially we are aiming to facilitate discovery by integrating information to support its known cognitive conditions (unexpected findings, analogous thinking, and distributed reasoning). A scenario for "ambient collaboration" considers the status and needs of each researcher's experimental work and their current and persistent information needs. Without ranging into exotic and potentially disruptive input systems (voice, gesture, tagged chemicals and experimental systems) we focus primarily on the output dimension (data display, feedback, visualization) in this proposal.

Since discovery may be accelerated by such simple social mechanisms as sharing new findings as they emerge, sharing analogies and interpretations, and sharing interpretations across collaborators, our design challenge appears as one of encouraging these exchanges without requiring synchronous, focused attention. While this notion has not been tested, the life sciences field research reveals a high-intensity everyday work practice that admits little time for ad hoc peripheral interactions or discussions. The regularly scheduled lab meeting will continue for some time to hold its ground as the basis for research-related exchange

Context	Interest	Expertise	Facility	Shared Goals
Scientific Discipline	Interest groups, Conferences, Informal networks	**Disciplinary networks, Cross-discipline groups, Journal editorial boards**	Facility or lab sharing, exchange	Conference or workshop organizing
Institution or Department	Journal clubs, Informal study groups	**Faculty networks, Departmental projects**	**Libraries, shared services & labs, Inter-department resources**	**Departmental projects, Major development efforts**
Research Program or Project	Informal networks of collaboration, Peer review and advising	***Interdisciplinary member collaborations, Expert review, Capability or skill required for research***	**Lab & equipment facilities required for research, Access to tools, sites, or materials**	***Researcher networks assembled for grants, projects***
Individual/Task	Peer assistance with lab or research tasks	***Expert knowledge collaboration to address experimental or research issues***	"Borrowing" facility, materials, or tools as needed	Students, peers collaborating on assignments or tasks

and “brainstorming.” While the social practices on the surface may suggest using the 1-1 or 1-many interfaces of online ‘collaboratories,” the reality of limited attention and participation with information tools suggests a less obvious approach. Rather than attempting a groupware-based system to facilitate discovery in multi-location lab meetings, an ambient intelligence approach should consider adapting to the human perceptual system through peripheral information space.

An ambient approach suggests peripheral, not direct, information interaction. Users are free to engage or dismiss the information streamed to multiple participants sourced from both peers and information servers. Ambient intelligence enables new genres of information use; information objects are not targets of searches, but are “pushed” or “syndicated” based on associations and complex filters constructed by interaction of all participants. A workstation interaction model is replaced by a common information space (CIS) as developed in CSCW. As an initial application, this might be as simple as a shared computer and display monitor in each participating workspace, displaying organized threads of data, findings, and article suggestions posted by other collaborators. By using electronic lab notebooks and automated data logging, streams of experimental data and lab notes forward to all participants linking to that researcher’s thread. As ongoing findings are logged and discussed (with exchanges envisioned as in blogs) and key ideas are tagged by participants, an analogy-agent searches information resources and presents analogous information objects (brief excerpts or keywords in context) to the shared space. While few of these “suggested analogies” may hit the target, the object should be envisioned as facilitating the interpretation process, and not aiming for an ideal of accuracy. The goal, using peripheral (unattended) information display and visualization, might be to augment the social process of discovery for collaborators on a continuous basis. A running stream of discovery-oriented analogies, tuned to match the research topics, may be attended to at any time as a peripheral, not central, task.

Over time these information collaborations will integrate vast amounts of data, translated to specific research objects that might be transferred and reused. Individual interaction and feedback with the system tunes collaborative filter algorithms and increases information specificity, serving to reduce data and noise to minimize attentional overload for individuals and other collaborators. The “intelligence” in such information collaboration develops as a network effect, as each participant and lab’s inputs, research data, and selected information resources are stored, developed, and selected.

Before adapting new information technology regimes and genres to the scientific workplace, we should analyze the social and institutional factors to understand the opportunity or space for design. In research practice, we find researchers working in ways proscribed to a great extent by the traditions and demands of their discipline, and the requirements of the institution. These factors may motivate acceptance or constrain the effectiveness of ambient interfaces in the discovery process. We propose evaluating collaborative research projects as a space for augmenting reasoning with ambient information. The cognitive conditions for scientific discovery (unexpected findings, analogous thinking, distributed reasoning) and the drivers for collaboration (extending research network, parallel experimental regimes, wider distribution of reasoning and feedback) together claim a significant opportunity for AmI for discovery.

REFERENCES

Dunbar, Kevin. (2000). How scientists think in the real world: Implications for science education. *Journal of Applied Developmental Psychology, 21* (1), 49–58.