A Reference Task for Collaborative Information Analysis and Decision Making

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Introduction

A pervasive and abiding challenge in science and engineering is ensuring the commensurability of methods, materials and procedures in order to justify and guide the integration and generalization of project outcomes. It is obvious why this matters: If results from different empirical projects cannot be integrated, then each investigation is in effect singular, and contributes little or perhaps nothing to subsequent investigations, or to the development of synthetic knowledge, such as theory. In experimental sciences there is a broad tradition of describing methods, materials and procedures in enough detail to permit a replication of one's experiment. In some sciences, experimental psychology, for example, paradigms are conventionalized and closely followed to enable direct comparisons among results obtained in different laboratories.

The challenge of commensurability is not the same as validity and reliability. Two research projects could both be *valid* (that is, they could employ measures that comprehensively operationalize theoretical constructs, and generalize to real world contexts) and *reliable* (that is, they could produce consistent and replicable outcomes), but still be mutually incommensurable if one could not also map an isomorphism between their methods, materials and procedures. One context in which the issue of commensurability arises is in carrying out meta-analysis of research projects: meta-analyses themselves are valid only if the studies considered employ consistent methods, materials and procedures. Less formally, the issue commensurability arises whenever we try to make sense of two or more studies addressing similar theoretical constructs.

Technology Demonstrations

Commensurable research practices are not well developed in information technology. This can be seen as a consequence of the strong focus on innovation in information technology research. Thus, in areas such as human-computer interaction (HCI), it is common for research issues to be investigated through technology demonstrations: For example, one of the key challenges in designing collaborative environments is ensuring mutual *awareness* among collaborators (Dourish & Bellotti, 1992); many awareness tools, including tools now standard, like radar views, were investigated chiefly by being implemented and demonstrated to the research community (Gutwin, Greenberg & Roseman, 1996; Ganoe et al., 2003). Indeed, technology demonstrations have proven so effective at codifying and communicating new technology approaches and applications that investigators now often use video and other media to mock up and "demonstrate" a new technology or application in use before they ever create a full implementation (Dubberly & Mitsch, 1987; Tognazzini, 1994).

Although technology demonstrations are an especially appropriate research approach for codifying and initially investigating novel technology possibilities, they are informal, improvisational, and inherently idiosyncratic. They are never documented in detail sufficient for replication or comparison among demonstrations. Technology demonstrations do not resolve technical questions such as how different awareness tools might evoke different information sharing practices among team members, or how they might differently support the evolution of project objectives and priorities through time. With respect to the challenge of ensuring the comparability of methods, materials and procedures in order to justify and guide the integration of project outcomes, technology demonstrations are ineffective.

The challenge of creating commensurable methods, materials and procedures in information technology research, and perhaps any engineering area, is more complicated than the analogous endeavor in a basic science, say, psychology. One reason for this is that computer technology and applications are typically far more complex and interactive that the manipulations or conditions configured for a psychology experiment. Thus, in specifying the conditions for a psychology experiment, one might say that participants rendered a series of judgments either seated in front of a mirror or seated in front of a blank wall (Duval & Wicklund, 1970; Carroll, Bever & Pollock, 1978). In contrast, characterizing alternative technologies employed in an HCI study might involve substantial descriptions of alternative user interface, application, and system designs, as well as their associated design rationales (Moran & Carroll, 1996; Burge et al. 2008).

Most empirical studies of people using information technology are evaluation studies, either *summative* evaluations, focusing on overall measures such as task completion times and error rates, or *formative* evaluations, identifying ways that a particular design instance might be improved (Scriven, 1967). Commensurability does not arise in formative evaluations because they are directed at understanding and meliorating particulars of a specific design. Summative evaluations do concern themselves with commensurability since part of their interest is to place alternative designs on a common scale of empirical outcomes. However, typically the scales employed are superficial (overall performance time and error rates for simple, standard tasks; Gray & Salzman, 1998). So-called *mediated evaluations* (Scriven, 1967) integrate and generalize scientific knowledge from evaluation studies through analytic representations of system designs and evaluation methods to compensate for the lack of direct commensurability in methods, materials and procedures (cf. Carroll and Rosson, 1995; Carroll, Singley & Rosson, 1992). These bridging representations are quite complex, and in fact mediated evaluations are rarely conducted.

Fieldwork

A second reason that creating commensurable methods, materials and procedures in information technology research is more complicated than the corresponding endeavor in psychology is that human behavior in the context of information technologies is *itself* complex and dynamic. Using interactive tools is an extended negotiation between designs and practices. The tools that are available to people quickly reshape the ways they carry out tasks, while at the same time, people typically appropriate tools that they use, improvising and adjusting the tools-in-use to better suit particular circumstances (Bannon & Bodker, 1991; Carroll, Kellogg & Rosson, 1991). People using information technology for intellectual work are constantly acquiring and adjusting skills (Carroll & Rosson, 1987). Moreover, the development of human appropriations of technology is highly embedded in social and organizational contexts; thus, even the same tool might have different use trajectories and outcomes in different workplace contexts.

The importance of emergent context in the use of information technology has led to an emphasis on ethnographic fieldwork, which maximizes external validity, but is difficult to generalize in detail. As Luff, Heath and Sanchez Svensson (2008) put it, such studies "contribute to a respecification of key concepts", in their case *awareness* (see also Dourish, 2006). Clarifying critical concepts is a vital pretheoretical contribution, necessary for articulating commensurable methods, materials, and procedures. The difficulty with fieldwork per se, from the standpoint of commensurability, is that phenomena and principles arising from such research are inextricably bound to the particular contexts and procedures of the fieldwork, and those contexts and procedures are utterly singular. Indeed, even same investigator carrying out the same investigatory actions in the same setting would not be able to carry out a commensurable study because all the actors and contingencies would be different.

These are staggering complexities that are of course part of *why* technology demonstrations, ethnographic fieldwork, and other approaches that do not employ comparable or replicable methods, materials and procedures are common in HCI, and other information technology research. However, there are ways to partially address these complexities, and therefore to enhance the comparability of research projects. For example, since 1992 the US National Institute of Standards and Technology (NIST) has sponsored an annual Text REtrieval Conference (TREC) at which a variety of systems "compete" to solve the same set of information retrieval tasks (Voorhees & Harman, 2005). The TREC effort investigated a simplified notion of retrieval tasks, leaving out issues of how the users of information retrieval systems think about information, or seek information, and how they go about seeking information. Nevertheless, by codifying a set of tasks and measuring the performance of various system design approaches on those tasks, it advanced the field of information retrieval toward converging on common objectives.

In this paper, we also confront the second challenge for creating comparable or replicable methods, materials and procedures in information technology research. We are investigating collaborative information analysis, planning, and decision-making. We are interested both in how people conceive of such tasks and in how information technology can support their performance. Thus, within our own research project we are investigating multiple complex conditions for human performance. Our approach includes developing collaborative *reference tasks* (Whittaker, Terveen & Nardi, 2000).

Reference tasks codify what is known about designs, rationales, and practices of a domain, and provide a common reference point for research in that domain. For information technology domains, like HCI, reference tasks are necessarily complex orchestrations of human activity that allow alternative technological support interventions to be contrasted at fine levels of detail. Reference tasks facilitate paradigmatic science in which comparable methods, materials, and procedures are employed across projects. We have focused especially on designing tasks that have realistic collaborative and informational complexity.

A major concern with experimental research strategies in complex domains is that the controls introduced by such research designs – the very controls that ensure the comparability of methods, materials and procedures in order to justify and guide the integration of project outcomes – also trivialize the research designs. For example, it is sometimes observed that real professional problems are "wicked" (Rittel & Webber, 1970) or "ill-defined" (Simon, 1977); they have no single right answer, and sometimes no right answer at all. Experimental tasks are usually well structured, and do have right answers. We share this concern, and our reference task design work has accordingly explored ill-structured tasks, including ones with both simple and complex solutions.

The balance of this paper proceeds as follows. First, we describe a reference task we designed to investigate collaborative decision-making emergency management planning task. Second, we describe a second reference task we designed for investigating collaborative decision-making in information analysis. In both cases, we identify sources of validity for the task designs, decisions we made and rationales we used, and open issues. We conclude with a discussion of issues for experimental research that investigates valid task models, abstracted from but representative of real workplace activity.

Planning an Emergency Relief Operation

For our initial study on common ground and development of team mental models, we developed an information sharing reference task modeled from ONR's Noncombatant Evacuation Operation (NEO): Red Cross Rescue Scenario (Warner, Wroblewski & Shuck, 2004). In the NEO scenario, planners in specific roles organize available resources to plan a rescue of Red Cross workers caught up in an island conflict. We formatted our reference task as an adaption of the "hidden profile" paradigm (Stasser & Titus, 2003). In the hidden profile, an optimal plan exists, but it is "hidden" from individual members, each of whom is provided with information biased toward a different suboptimal solution. This allows for measurement of if and how team members disanchor from their biased solution.

Our hidden profile task is solving an Emergency Management Planning problem: plan on the map the evacuation of a family from a flooded area to one of four possible shelters. This task models a realistic tabletop exercise that emergency management teams, made up of representatives from different agencies, perform during periodic planning meetings. The task is grounded in fieldwork where we "shadowed" the emergency management coordinator for Central Pennsylvania for a year (Schafer, Carroll, Haynes & Abrams, 2008). We found that coordination across these teams is difficult -- even in the Centre Region of Pennsylvania, which has a regional coordinating body to better-integrate local government and community groups (namely, the Centre Region Council of Governments). The various agency representatives are able to meet together face-to-face only 1-2 times per year and carry out tabletop simulation exercises, or, more occasionally, full scale emergency walkthroughs. The purpose of their exercises is to develop, debug, refine, and practice regional emergency plans so that the various contributing organizations will be able to effectively coordinate in a real emergency, and also so that they will have common ground upon which to base necessary improvisations that may be required in a real emergency. A key role of the regional emergency coordinator is to maintain these planning documents and organize the periodic group exercises.

In that fieldwork, we found that there was significant plan recall failure. People just do not remember the plans very well through the many months during which they are not practicing or reviewing the plans. They do not have a good understanding of what others are doing within the plan, which would be an obstacle to effectively improvising on the plan during a real emergency. In our terminology, they had rather low *activity awareness*. We talked to the regional emergency management coordinators of the Centre Regional Council of Governments and they told us that it would be useful to have a persistent information system, accessible to all of the participants and their organizations, that depicted the plans and allowed actors to see their roles and activities relative to those of others actors, and annotate and discuss the plans.

Our reference task study participants play a subset of those FEMA emergency planning roles (DHS-FEMA, 1997) Public Works, Environmental, or Mass Care expert). Each role contributes distinct expertise and information – all of which is required to perform the task successfully. Each member of the team is given a unique set of 9 location-based cons. For example, a con given to an Environmental expert would be that "Eaglesville Road goes through a floodplain". Given the problem rescuing a family from their home and delivering them to a suitable shelter during flood situations, the expert would use his/her knowledge to evaluate tradeoffs and suggest a solution: Choose a road through the north valley because it is less likely to wash out in the storm. Other cons might discourage that solution. Each individual's set of cons is biased toward a different shelter, but if the team pools its information across roles, a fourth shelter is clearly the best alternative: it has only 4 total cons versus 7 each for the other three shelters (see Table 1 below). The task emphasizes the need for sharing and coordinating relevant information in order to find an optimal solution – a key need for emergency management teams. In order to study the development of coordination in a working team, we had each team create three different plans in three repeated runs, each with different maps and sets of cons. Members played the same role in each of the three runs.

Plans/Roles	Public Works **(Route)**	Environment **(Time)**	Mass Care **(Shelter)**	Total **Cons**
A – unshared	a_1	a_2 a_3	a_4 a_5 a_6 a_7	7
B – unshared	b_1 b_2 b_3 b_4	b_5	b_6 b_7	7
C – unshared	c_1 c_2	c_3 c_4 c_5 c_6	c_7	7
D – shared D – unshared	d_1 d_2	d_1 d_3	d_1 d_4	4*
Total Knowledge	9	9	9	25

Table 1: Hidden profile design for the Emergency Management Planning task. Each participant is given a set of *cons* (e.g. a_1, etc.) that biases them toward a suboptimal solution. For example, the Public Works role is biased toward Plan A for which he only holds 1 con. Only by pooling all the information will it be revealed that Plan D only has 4 cons (1 shared and 3 unshared) vs. 7 total for each of the other plans.

More details of this reference task can be found in Carroll et al. 2007. While this Emergency Management Planning hidden profile reference task afforded us a mechanism for repeated measures closely observing the development of shared knowledge and understanding in small teams, it had some tradeoffs. First, the amount of information being shared between team members was limited, only 25 items. We wanted to consider larger sets of information. Second, the information was place-based, so each piece had no other relationship than its spatial location on the map. It did not represent an information environment where there might be other relationships between information than location. This includes time, both in that information might be temporal itself and where new information might be added as the task progresses. Third, with the primary solution being which shelter to take the family to, the task lent itself toward a right or wrong answer, rather than a finer grained solution where performance could be measured. These tradeoffs were given full consideration in designing our criminal conspiracy task.

Identifying a Criminal Conspiracy

In order to better study 1) team knowledge building processes as teams collaborate, 2) how teams develop representations of internalized team knowledge during collaboration, and 3) the information organization strategies that better support individual and team knowledge building processes and internalized team knowledge, we developed a criminal conspiracy information synthesis task that provide us opportunities to observe these team processes. First, the new scenario consisted of 222 pieces of information, which was much greater than the 25 pieces of information in the emergency management scenario. The larger sets of information elicited longer discussion surrounding the task and allowed us to obtain information artifacts created by the teams. Second, in addition to place-based information, the criminal conspiracy task contained information about time and social relationships. Levels of complexity were increased because different types of information needed to be integrated to correctly solve the task. Third, the solutions of the task permitted greater variability in performance scores. Teams' performance was scored based on the number of questions correctly answered in each part of the scenario. The questions were related to the goals of each part, including indentifying thieves, instigators, connections among the thefts, etc…. The greater variability in performance scores enabled more precise estimation of the correlations among processes and outcome variables.

This study employed a laboratory model of complex, collaborative and asynchronous information analytic decision-making. We plan to use undergraduate students at Penn State as experimental subjects. Thus, our research design entails specific risks to external validity with respect to the representativeness of the tasks and the subjects relative to Naval tasks and Naval personnel. An alternative approach that might avoid such issues, would be to study actual information analysts working through real decision-making problems in their real workplace. Field studies are a touchstone of external validity, but they are not without their own difficulties. We worked on a project in 2003 that employed a field study of information analysts in the National Geospatial-Intelligence Agency (NGA, at that time, the National Imagery and Mapping Agency). Only a few subjects could be identified for the study; they participated only briefly. We were not able to gather or even examine the raw data from this study because of its security classification. The study was implemented for us by a collaborator with high-level clearance, but with less expert empirical research skills (Rosettex Technology, BearingPoint, & Virginia Tech Center for Human-Computer Interaction, 2004).

In this project, we invested substantial effort to create an elaborate task scenario with prima facie validity in representing a class of tasks in which teams of information analysts weigh evidence from a variety of sources to identify likely causes/explanations, in our case, likely suspects. Our task scenario was based directly on the Navy's Special Operations Reconnaissance (SOR) scenario, itself created as a tool to investigate characteristics of collaborative decision making in intelligence analysis and mission planning (Warner, Burkman & Biron, 2008). In the SOR scenario a team of Naval analysts use role specializations to assemble and combine diverse sources of information. They collaboratively synthesize and make sense of a complex information space to reach conclusions and make decisions. The SOR task models work activity like that we studied in our NGA field study: a team of specialists analyze an information space in order to provide decision-recommendations to commanders.

We designed our task scenario as an analog of the SOR task mapped into a criminal conspiracy regarding stolen laptops at University Park. Our task involves three specialized roles, each with distinct responsibilities regarding information sources: An Interview Analyst, who managed information obtained from direct testimony, a Records Analyst, who managed information derived from bank/credit transactions, class schedules, etc., and a Web Analyst, who managed information from e-communications, Facebook, Twitter, etc. A total of 222 pieces of information was distributed among the roles (see table 1 for distribution of information pieces among roles). The different pieces of information were designed to help the analysts identify times and locations of events, and relationships among the actors. As would be true in a real decision episode, not all the information presented to the teams was equally relevant or important to reaching the correct analysis and making the right decisions. For example, in the appendices, bold fonts represent information directly related to solving the task. To simulate real decision-making, team members were asked to reach their decisions under time constraints.

Our data from experiments using this task provide further support for representativeness. For example, we found that the degree of information synthesis in team-generated artifacts, and the equity of contribution in decision-making interactions were keys to team success in this task. Chin et al. (2009) studied a single team of five experienced professional information analysts and reported analogously that information synthesis and team management of decision processes were key. The team they studied had difficulty visualizing information across multiple dimensions, such as time and space. They observed that the team compromised its process as time ran short.

Our richer data set suggests more fine-grained insights into *why* these relationships occur. For example, we found that whether team members can effectively synthesize information for collaboration is related to the degree to which team members are aware of the rationale behind each judgment the team makes. This more fine-grained insight into team process also suggests more specific strategies for designing tools to support team performance.

This is related to a second issue of representativeness and external validity pertaining to the use of university students as subjects. One reason for accepting these risks is that working with undergraduate subjects allows us to conduct a fairly elaborate experimental procedure with a fairly large number of subjects. Our decision-making task procedure requires slightly more than four hours of work for a team of three to complete face-to-face. We estimate that the asynchronous version of the task would be carried out through the course of 4-7 days, and might involve as much as eight hours of work. We ran 39 teams in the face-to-face/synchronous condition, and would hope to run a similar number in the computer-mediated/asynchronous condition proposed here. The use of a controlled task and undergraduate subjects makes this experimental research approach feasible.

Finally, *re-using* an experimental task through a series of experiments or conditions makes it possible to compare results across the conditions. We are interested in how asynchronous decision-making differs from synchronous decision-making, either face-to-face or computer-mediated. We want to use such comparative analysis to inform the design of interactive tools to support collaborative decision-making, as we did successfully in a prior ONR research program (N000140510549; Carroll et al., 2007, 2008; Convertino et al., 2005, 2007, 2008a, 2008b, 2009, in press 2011). Investigating this kind of comparison using field studies would make it impossible to have any controls on tasks or procedures.

In the section below, we will introduce the structure and rationale for the complex information synthesis task. Specifically, we will discuss 1) the three roles required for solving the scenario, 2) the goals of the three parts of the task scenario, 3) task structure and information pieces of the task, and 4) experimental protocol.

The three roles required for solving the scenario. Upon arrival, each participant was randomly assigned one of the three roles: Interview Analyst, Web Analyst, or Record Analyst. These were the roles they would be expected to play throughout all three parts of the scenario. Each team member was provided with unique information that other specialists lack. For example, Records Analyst had information on bank transactions, receipts, and class schedules, Web Analyst had information gathered from Facebook, Twitter, Ebay, and other online resources, and Interview Analyst had information gathered from questioning persons of interest and people they know, and tailing persons of interest in order to determine regular routines or contacts.

In each part of the scenario, the three participants were provided with information particular to their role and were told that only by integrating information and resources will they be able to provide accurate recommendations, or in other words, successfully complete each task. The three participants in each team were told that each was an expert in a specialized information-gathering field and that they had used their expertise to gather information to help police solve a crime. They were given briefing information to explain their role in the team's problem solving, and they were presented with a packet of information gathered for their team role. Team members were told that they needed to work together to solve past thefts and predict a future one. The participants were also told that in order to be successful they had to share information and make decisions together as each held important pieces to the puzzle.

Goals of the three parts of the task scenario. The scenario was divided into three parts and each part required the team to complete a specific information synthesis and decision making task. The three parts of the scenario and the solutions to each of the task was constructed considering the three aspects of crime: motives, means, and opportunity. The participants were expected to solve the tasks following the common steps of crime investigation, obtained from our search on crime investigation literature and interviews with subject matter experts (e.g., local police).

Part one of the scenario contained a total of 105 pieces of information, mainly on POIs' schedule and relationships (see Table 1). These information pieces divided evenly among the three participant role documents. In this part of the scenario, the teams were asked to narrow down a list of 26 persons of interest (hereafter referred to as POIs) to a list of the eight most likely suspects (8 points). The main determinant for the eight most likely suspects was opportunity: where they near the scene of the crime at the time of the theft.

In part two, participants were given an additional 48 pieces of information to add part one information: divided evenly among the three participant role documents. In this part of the scenario participants need to identify thieves for each of four thefts (4 points), the instigators of each theft (8 points), motives for stealing the laptops (4 points), and whether there were connections among the four thefts (1 point). For this part of the scenario, the solutions were based upon opportunity and motive: the thieves were one of the eight most likely suspects who either (1) were near the crime scene at the time of the theft and had motives based on the social relationships given, or (2) were near the crime scene at the time of the theft and had suspicious relationship with someone else who might have motives. The instigators were the persons of interest who had motives and were related to someone near the crime scene (means and motives).

In part three, participants received 69 new pieces of information, again divided evenly among the three members. These information pieces are about the weekly schedule of the five POIs who are potentially related to the future theft. This particular part of the scenario did not require the use of previous information. To solve this part of the task, participants needed to identify the people whose schedule overlapped with the victim and possessed a map with the location where the victim was during the overlapping time. Participants were given additional information at the beginning of part two and three.

Two parallel versions of the scenario were created to ensure the security of solutions to the scenario. The two versions were identical except for the names of people of interest were replaced with a different set of names. Participants had a set amount of time in which to complete each decision-making task: 50 minutes for part one, 45minutes for part two, and 30 minutes for part three. At the end of each task, participants needed to come to a joint decision and write down a team recommendation or answer for that phase.

Table 1
Distribution of Information Pieces

	Interview	Record	Web	Total information pieces in Each Phase
Phase 1				
Schedule	26	26	25	
Relationship	9	9	10	
Phase 1 Total Information Pieces	35	35	35	105
Phase 2	16	16	16	48
Phase 3				
Maps	2	1	1	
Information on Each Suspects				
Nicolas	4	6	5	
Percy	3	5	4	
Vanessa	6	4	4	
Kristin	4	2	4	
Sean	4	5	5	
Phase 3 Total Information Pieces	23	23	23	69
Total Pieces of Information				222

Task structure and information pieces of the task. The three parts of the scenario were based on different structure. The rationale behind part one of the task was that POIs can be the thieves if they have *opportunities* to steal the laptops. Therefore the information pieces of part one was generated based on the 26 POIs and their whereabouts when the four thefts took place (Appendix A). POIs were suspicious if they were near the crime scenes at the time of the thefts. Among the 26 POIs, eight of them were near two of the four crime scenes. Therefore, they were the most suspicious ones among the 26. The locations and times of the POIs when they were near the crime scene are information directly relevant to solving this part of the task (critical information; bold fonts in the appendices). These critical information pieces and other information pieces were evenly distributed among the three roles (Appendix B).

In this task, each role was dependent on one another to achieve the goal of each part of the task. For example, in part one of the scenario, two critical pieces of information needed to be shared for the team to identify POI Q as one of the most suspicious POIs: 1) he was checking materials for class presentation at the Pattee Library when the Aug 28th theft took place and 2) he was studying in Engineering Library when the Oct 5th theft took place. Interview analyst had the first information piece, and the record analyst had the second. Without both of them sharing the information, the team would not be able to identify Q as one of the most suspicious POIs (Appendix B).

As mentioned before, the goal of part two was to identify the actual thieves of the four thefts, whether there were instigators behind each theft, and whether there was a connection among the thefts. Part two was about identifying *motives* for stealing laptops and linking those with the *opportunities* identified in Part one. Therefore, relationships among the POIs are the focus of this part. In addition to the social relationship information provided in part one, in part two, each role receives additional 16 pieces of information about important events, bank transactions between POIs, and online merchandize posts. Two types of information were needed to provide evidences for stealing laptop: 1) the thieves needed to have motives for stealing laptops or have connections with someone who had motives, 2) there needed to be bank transactions or online merchandize posts that supported the connections. The important events, social relationships, bank transactions, and online merchandize posts directly relevant to solving this part of the task were considered critical information. These information pieces were shown in bold fonts in Appendix C.

Again, team members relied on one another's information to correctly solving this part of the task. For example, record analyst's document showed that Isabel sent $574 to someone. Web analyst had information about Tay receiving $574 from someone. The two pieces of information needed to be shared for the team to correctly connect the two POIs.

The goal of part three was to identify the thief, location, and time of a future theft. The underlying structure of this part was the victim and the four suspects' weekly schedule (Appendix D). To correctly solve this part of the task, participants needed to compare the four suspects' schedule with the potential victim's, and identify the two time periods during which the suspects and the victim were in the same building. This part of the task also contained four pieces of information about the maps that each suspects holds. The likely suspect was the one who had schedule overlapping with the potential victims and holds the map of that building. Therefore, the four pieces of information for the two overlapping time period and the information about P holding a map of the HUB were the five critical information pieces of this part.

The roles were also interdependent in part three. For example, Web Analyst needed to share the information that Vanessa was working in the Rec building Tuesday afternoon, and Record Analyst needed to share that Nicholas was working out in the Rec building Tuesday afternoon, for the team to correctly identify the overlap in schedule.

Experimental protocol. Each lab session was conducted using exact same procedure and set-up to minimize variability in team interaction or performance caused by experimenter or contextual factors. Specifically, a trained undergraduate research assistant conducted each lab session by following a strict experimental protocol. The experiment protocol includes 1) table and equipment set-up (see figure 1 for pictures of required table/tool set-up), 2) instructions to read to the participants, and 3) time to hand out experiment materials and give instructions. All of the experiment sessions were audio/video recorded for subsequent data analyses. To ensure that each team worked together with minimal interruptions, each of the experiment sessions was conducted in an isolated room without interference. Furthermore, except for giving instructions and handing experiment materials, experimenter stayed behind a one- sided mirror throughout the experiment sessions.

The collaborative area was around a table, with three roles seated at the three sides of the table. The seating assignment of three roles was counterbalanced to control for the effect of relative position on team interaction (e.g., the role sitting in the middle may present more leadership behaviors). In front of each seat were Mission Statement and General Instruction, part one role document, a questionnaire, a laptop computer, and tools that they could use to analyze the information provided. The tools were in the middle of the table and included large sticky notepad, blank calendars, weekly schedules, maps, a laptop (serving as an alarm clock to remind the team of time) and the team answer sheet. Mission Statement and General Instructions were identical for all three roles. It contained information about the task, the main goals of the scenario (the mission statement), and instructions (task rules). On important task rule specified in these documents was, "if someone is reported as attending an activity or class at a given time period, you should assume they attended and stayed until the activity or class ended. However, they might have a chance to sneak out for a 5-10 minute break depending on the type of class or activity" (excerpt from mission statement, instructions, and background information). This document also provided participants general information about the past crimes, such as time and location, as well as how many persons of interest there are in total. Role documents contained information specific to each intelligence discipline, or role. For example the records specialist received documents containing bank records and course schedules of person's of interest, whereas the web specialist received documents containing Facebook posts, connections to other people, and twitter messages.

Participants received new role documents in each of the three parts of the activity: provided as hard copies and digital PDF copies on a laptop. Participants were instructed to use the laptop computers only for search function, reading the documents, and responding to the surveys administered throughout the study. The entire process was captured on video. The video recorder was set-up to capture the entirety of the lab portion of the study, from the experimenter instructions to behaviors of all team members as the completed each part of the scenario. After participants completed a part of the scenario and wrote down their answers as a team, they were provided with correct answers and five minutes to reflect on the correct answers. The goal of the reflection session was to bring each team to similar levels of knowledge before starting the next part of the experiment. These reflections were also captured on video.

Discussion

In this paper we have described the motivation and development of reference tasks for information technology research on collaborative decision-making in complex domains. Information technology researchers understandably focus on developing and demonstrating technology prototypes to codify and explore the space of possible approaches and solutions, and on ethnographic fieldwork, to obtain detailed and valid social and behavioral user data. However, these approaches leave a gap: There is no explicit linkage between inherently complex technology prototypes and singular case studies of situated human behavior. Principled descriptions of technology, even if articulated through best practices of design rationale (Burge et al., 2008), provide little basis for predicting successful appropriation trajectories and outcomes in workplace contexts. Conversely, ethnographic field studies of workplace practices often highlight potential technology needs and opportunities, but because each case is unique and each adoption process is unique these potential openings for technology interventions are always underdetermined (Carroll, 1990).

Our position is not that technology demonstrations and ethnographic fieldwork are inappropriate research and development strategies. Rather, we merely emphasize that these approaches have limitations, and that they can be complemented by what Whittaker, Terveen and Nardi (2000) called the reference task agenda: Approaches that investigate valid task models, which are abstracted from but representative of real workplace activity. A key characteristic of our approach is to design cognitively and collaboratively stressful task models, and to constantly question the validity of the models, as illustrated in the two reference task designs described above. Such task models allow experiments in which groups of participants carry out comparable, representative activities using different technology support, providing *the linkage that is missing between technology demonstrations and ethnographic fieldwork*.

Our approach is not the only possible approach to designing reference tasks. An alternative strategy is to strip away domain details as much as possible, reducing tasks to schematic economic games. For example, a well-known line of research in collaborative decision-making is the shape factory research of Bos, Shami, Olson, Cheshin and Nan (2004). In this research, individuals buy and sell colored shapes from other participants to fill orders. The research investigates how various kinds of collaborative support and group identity manipulations affect the trading strategies people adopt. Unlike our reference tasks, the shape factory offers simple decisions and well structured decision criteria. Participants can align with one another, but they are playing an economic game and most basically each person is very literally maximizing the single parameter of profit.

Nevertheless, for a range of interesting social phenomena, such as the formation of in-groups and out-groups in a competitive/cooperative game, the shape factory is an example of a reference task.

An issue in designing reference task research is whether to include novice or expert teams as participants. Economic games, by presenting a contrived task, finesse this issue. There are no experts for the shape factory task. Navy research with the NEO and SOR tasks employed Naval personnel, though this research did not contrast information technology tools (Warner et al., 2008). We designed tasks that were isomorphs of the Navy scenarios but which employed less specialized domain semantics and pragmatics – rescue of families stranded by flooding and other hazards, and information analysis of a campus criminal conspiracy. We tried to leverage the considerable knowledge people have about relatively ordinary emergency mitigation and information analysis, and avoid the logistic complications of accessing relatively large numbers of technical domain experts (even the Navy work often used trainees as proxies for experts, who, after all, are fully engaged doing the actual domain work). Implementing our approach requires careful attention to details. For example, in our criminal conspiracy version of the SOR scenario, there is a sub-task in which one of the participants is given a sketch, and expected to recognize that it corresponds to an outline of buildings in one of the many reconnaissance photos the participant has already been given. This is a challenging task for someone who is not a trained image analyst. In our task design, we also informed participants that a person of interest has a floor plan for a named building on the map. The participants still needed to connect pieces of evidence, to share them with teammates, and to make appropriate analyses and decisions, but this extra bit of guidance helped them to see the potential significance of and interpret individual pieces of information, in this case, the sketch.

Our work to date with reference tasks for collaborative decision-making raises issues for further research. One direction is investigating dimensions of cost-benefit tradeoffs in approaches to reference tasks. Our experimental procedures are costly to design and to carry out, and they produce complex and voluminous data that is costly to analyze and interpret. It would be useful to systematically analyze the cost-benefit tradeoffs for a schematic reference task like the shape factory task, a rich reference task of the sort we have developed, and an ethnographic fieldwork approach to collaborative decision making. Each approach may be better at analyzing certain features of collaborative decision-making; each may have signature weaknesses. For example, we suggested above that the competitive/cooperative game theoretic view of human collaboration in the shape factory might be biased relative to a richer reference task, but what are possible consequences of that limitation?

Another question for further research is to identify the complexity bounds on our approach to reference tasks. For example, many collaborative decision-making interactions are largely asynchronous, involving people who not only cannot be co-present, but who also cannot work together at the same time. Can we model this, or must such work activity be investigated through more singular case studies? Asynchronous interactions, spanning several hours or several days, raise many practical issues for experimental designs. We are currently elaborating a version of our criminal conspiracy task to be carried out through the course of several days.

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Appendix A

Part One Task Structure

Time	8/28 8am Fri	9/3 4pm Thur	10/5 3pm Mon	10/9 10am Fri
Victim	A	H	J	F
Location	Pattee Library	BOA Career Center	College Ave. Starbucks	White Building locker room
A	study in Pattee Library	Class: International Relations (Kern) 1:30-4:40	Meeting for campus election (HUB) 3-5pm	Play tennis with K from election team (tennis course next to IM building)
B	B, G, L meeting for campus election campaign (HUB) 8-10 pm	Class (Wilard) 3-5pm	Part-time job (MacKinnon's Café Patee Library)1-4pm	B, G, L meeting for campus election campaign (HUB) 8-10 pm
C	**having breakfast in MacKinnon's Café (Patee Library) 7:50-8:10 before go study**	Class: Chinese I (Thomus)	At home in Maryland, will not be back until Tuesday(with C from dancing team)	**Basketball team practice from 9 to 11 (white building basketball court)**
D	In class from 8 to 10.	Meeting for business plan competition (Webster's Café downtown) 3-6pm	D went out with I for movie at college 9	In class from 8 to 10.
E	E is taking part onen family business, he leave every Thursday night and come back to school on Tuesday morning.	Meeting for business plan competition (Webster's Café downtown) 3-6pm	At home in Maryland, will not be back until Tuesday(with C from dancing team)	E is taking part onen family business, he leave every Thursday night and come back to school on Tuesday morning.
F	At home with roommate(University Clubs)	Swimming (White Building Swimming Pool) 3:40-5:00	Meeting for campus election (HUB) 3-5pm	White Building locker room
G	B, G, L meeting for campus election campaign (HUB) 8-10 pm	Class: Data Management (Keller) (2-5pm)	Class: Information Systems Management and Applications (Keller) 2-4pm	B, G, L meeting for campus election campaign (HUB) 8-10 pm
H	work out (Rec Building) 7:30-9:00	BOA Career Center	Work out (Rec Building) 230-400pm	Part time job: downtown starbucks 10am-1pm
I	breakfast with girl friend P from 7:30 to 8:30 panera	Meeting for business plan competition (Webster's Café downtown) 3-6pm	D went out with I for movie at college 9	basketball team practice from 9 to 12 (Rec Building)
J	breakfast with girl friend Y from 7:30 to 8:30am Dunkin Donuts	Class: Spanish in the US (RACKLEY) 2-4pm	downtown Starbucks preparing for business plan	Work out (Rec Building) 9-11am
K	At home with roommate(Allenway)	Part time job: Otto's (Kern) 1-5pm	Meeting for campus election (HUB) 3-5pm	Class: Introduction to psychology (Forum) 9am-12pm
L	B, G, L meeting for campus election campaign (HUB) 8-10 pm	Class: Japanese Literature (Willard) 3:15-4:30	Practicum: Japanese Translation Service (Schlow Centre Region Library) 2-4pm	B, G, L meeting for campus election campaign (HUB) 8-10 pm
M	**Part time job in Pattee Library 7:30-10:30**	Class: Circuits & Devices (EE West) 3:15-4:45	**Having lunch at Five Guys (2:40-3:30)**	Part time job in Pattee Library 7:30-10:30

Time	8/28 8am Fri	9/3 4pm Thur	10/5 3pm Mon	10/9 10am Fri
Victim	A	H	J	F
Location	Pattee Library	BOA Career Center	College Ave. Starbucks	White Building locker room
N	Swimming team practice (outdoor pool) 8-10am	Assistantship: Librarian (Pattee Library) from 3 to 5pm	Meeting for business competition (Business Building) 2-5pm with H& J, but meeting canceled for this week because N is out of town	Swimming team practice (outdoor pool) 8-10am
O	Meeting for class project with P 7:30-10:30	Running (West side of the campus) 3:30-4:30pm	part-time job (Garner Rd. Starbucks) 1pm-4pm	Meeting for class project with P 7:30-10:30
P	Meeting for class project with P 7:30-10:30	Class: Natural Disasters: Hollywood vs. Reality (Wartik) 2:5pm	Work out (Rec Building) 3-5pm	Meeting for class project with P 7:30-10:30
Q	**Checking materials for class presentation (Pattee Library)**	Work out (Rec Building) 3-5pm	**Study in Engineering Library (1-5pm)**	Work out (Rec Building) 9-11am
R	Work out (White Building) 7:30-8:30pm	Work out (White Building) 3-5pm	**Buy lunch from Subway (2:50-3:05)**	**Dorm (Atherton Hall)**
S	Statistical consulting practicum (Thomas) 8-11am	**Swimming (Swimming Pool-Outdoor) 4-5pm**	Running (North Campus) 2:30-3:30	**Statistical consulting practicum (Thomas) 8-11am**
T	At home with roommate(Parkway Plaza)	**Dr. Appointment at the Health Center (Student Health Center)**	Running (North Campus) 2:30-3:30	**Self Swimming (White Building swimming pool) 9:30-11:30**
U	Work out (White Building) 7:30-8:40 am	**Applying parking permit for new car (Eisenhower Parking Deck) 3:40-4:10**	**research assistantship (Applied Research Lab) 1-4pm**	Class: Media & Democracy (Kern) 9-12
V	Breakfast (Dunkin Donuts) 7:30-8:30	Dancing class (Fraser dancing workshop) 3-5pm	Workout (White Building) 3-5pm	Theatre production meeting (Music I) 9-11am
W	part-time job (Garner Rd. Starbucks) 8am-12pm	Class: Ballet (White) 3:15-4:05	part-time job (Garner Rd. Starbucks) 1pm-4pm	part-time job (Garner Rd. Starbucks) 8am-12pm
X	Class: Chemical Principle (Willard)8-11am	Class: Ballet (White) 3:15-4:05	Workout (Rec Building) 3-5pm	Class: Chemical Principle (Willard)8-11am
Y	Semester Long Internship in DC	Semester Long Internship in DC	Semester Long Internship in DC	Semester Long Internship in DC
Z	**Part time job in Pattee Library 7:30-10:30**	**Class (Computer building) 3-5pm**	part-tim job (Paterno Library) 2-5pm	Part time job in Pattee Library 7:30-10:30

Note. Critical information pieces are shown in bold.

Appendix B

Part One Information Pieces and Distribution

I. Information on people, time, and location

Interview Analyst				Record Analyst				Web Analyst			
Name	Event	Location	Time	Name	Event/Class	Location/Classroom	Time	Name	Event	Location	Time
D, E, I	Meeting for STARTUP business plan competition	Webster's Café downtown	9/3/2015 Thursday 3-6pm	A	International Relations	Kern 105	Thursday 1:30-4:40	C, E	E is at home in Maryland with C from dancing team, will not be back until Tuesday		Trip from 10/2/2015 to 10/6/2015
O	Running	West side of the campus	9/3/2015 Thursday 3:30-4:30	B		Willard 106	Thursday 3:00-5:00	D, I	Went to movie	College 9 theater	10/5/2015 2:50 to 5:00 pm
R	Workout	White Building	Thursday 3-5pm	C	Chinese I	Thomas 205	Tu/Th 3:30-4:30	F	Swimming	White Building Swimming Pool	9/3/2015 Thursdat 3:40-5:00
U	Applying parking permit for new car	Eisenhower Parking Deck	9/3/2015 Thursday 3:40-4:10	D		Henderson 306	Friday 8:00-10:00	H,J, N	Meeting for STARTUP business competition	Business Building	Monday 2-5pm (Except 10/5/2015)
V	Dancing class	Fraser dancing workshop	Thursday 3-5pm	G	Data Management	Keller 401	Thursday 2:00-5:00	I	Basketball team practice	Rec Building	Friday 9 to 12pm
A, F, K	Meeting: student presidential election Campaign for A	HUB	Monday 3-5pm	G	Information Systems Management and Applications	Keller 302	Monday 2-4 pm	K	Part time job: Otto's	Kern	Thursday 1-5pm
M	Having lunch	Five Guys	10/5/2015 Monday 2:40-3:30	J	Spanish in the US	Rackley 101	Thursday 2:00-4:00	N	Assistantship: Librarian	Patee Library	Thursday 3-5pm
Q	Study	Engineering Library	10/5/2015 1-5pm	K	Introduction to psychology	Forum 103	Friday 9am-12pm	N	Out of town		10/5/09
B	Part-time job	MacKinnon's Café Patee Library	Monday 1-4pm	L	Japanese Literature	Willard 211	Thursday 3:15-4:30	P	Workout	Rec Building	Monday 3-5pm
H	Workout	Rec Building	10/5/2015 Monday 2:30-4:00	L	Practicum: Japanese Translation Service	Schlow Centre Region Library	Monday 2:00-4:00	Q	Workout	Rec Building	Thursday 3-5pm
S, T	Running	North Campus	10/5/2015	M	Circuits &	EE West 109	Tursday	Q	Checking materials	Pattee	8/28/2015

Interview Analyst				Record Analyst				Web Analyst			
Name	Event	Location	Time	Name	Event/Class	Location/Classroom	Time	Name	Event	Location	Time
			Monday 2:30-3:30		Devices		3:15-4:45		for class presentation	Library	Friday 7:50-9:00
X	Workout	Rec Building	10/5/2015 Monday 3-5pm	P	Nature Disasters: Hollywood vs. Reality	Wartik 103	Thursday 2:00-5:00	R	Workout	White Building	8/28/2015 Friday 7:30-8:30
Z	Parttime Job	Paterno Library	Monday 2-5pm	S	Practicum: Statistical Consulting	Thomas 401	Friday 8:00-11:00	R	In the dorm	Atherton Hall	10/9/2015 stayed until 11:00
O	Parttime Job	Starbucks @ Garner	Monday 1-4pm	U	Media & Democracy	Kern 203	Friday 9:00-12:00	S	Swimming	Swimming Pool-Outdoor	Thursday 4-5pm
C	having breakfast before go study	MacKinnon's Café (Patee Library)	8/28/2015 Friday 7:50-8:10	V	Ballet	White Building	Thursday 3:15-4:05	T	At home with roommate	Parkway Plaza	8/28/2015 Friday left home around 10am
H	Workout	Rec Building	8/28/2015 Friday 7:30-9:00	X	Ballet	White Building	Thursday 3:15-4:05	T	Swimming	White Building swimming pool	10/9/2015 Friday 9:30-11:30
I,P	Breakfast together (boyfriend and girlfriend)	Panera	8/28/2015 Friday 7:30-8:30	X	Chemical Principle	Willard 016	Friday 8:00-11:00	U	Research assistantship	Applied Research Lab	Monday 1-4pm
J, Y	Breakfast together (boyfriend and girlfriend). Y left on Sep 1	Dunkin Donut @ Fraser	8/28/2015 Friday 7:30-8:30	Z		Computer Building 308	Thursday 3:00-5:00	U	Workout	White Building	8/28/2015 Friday 7:30-8:40 am
K	At home with roommate	Allenway Apartment	8/28/2015 Friday left home around 11am	T	Dr. Appointment at the Health Center	Student Health Center	9/3/2015 Thursday 3:30	V	Workout	White Building	Monday 3-5pm
A	Play tennis with a friend	tennis course next to IM building	10/9/2015 Friday 8:30-10:30am	R	Buy lunch	Subway @ Burrow	10/5/2015 2:50-3:05	V	Breakfast	Dunkin Donut @ Fraser	8/28/2015 Friday 7:30-8:30 am
C	Basketball team practice	white building basketball court	Friday 9-11am	H	Parttime job	Downtown Starbucks	Friday 10am-1pm	V	Theatre production meeting	Music I	10/9/2015 Friday 9:00-11:00 am
F	At home with roommate	University Clubs	10/9/2015 left home at 12pm	J	Workout	Rec Building	10/9/2015 Friday 9-11am	W	Parttime Job	Starbucks @ Garner	Monday 1-4pm
B, G,	Meeting for	HUB	Friday 8-10am	Q	Workout	Rec Building	10/9/2015	W	Part-time job	Starbucks @	Friday 8:00-

Interview Analyst				Record Analyst				Web Analyst			
Name	Event	Location	Time	Name	Event/Class	Location/Classroom	Time	Name	Event	Location	Time
L	campus election campaign						Friday 9-11am			Garner	12:00pm
E		E is taking part onen family business, and	He leaves every Thursday night, come back to school on Tuesday morning.	M	Partime job	Pattee Library	Friday 7:30-10:30	Y	semester long internship in DC		
N	Swimming team practice	Swimming Pool-Outdoor	Friday 8-10pm	Class Ends: 11-Dec-09				Z	Part-time job	Pattee Library	Friday 7:30-10:30
O, P	Meeting for class project	Panera	Friday 7:30-10:30	Class Begin:24-Aug-09							

Note. Critical information pieces are shown in bold.

II. Information on Social Relationships

Interview Analyst

1. **L & I knew each other in a bar and have been contacting each other since then**
2. D & V met each other at a bar
3. O and W have part-time job together
4. P and O are taking an art class together outside of school
5. L owes I money. I tried to ask L to return the money, but L has not intention to return.
6. **D helped Q on his exams. So Q can remain good status in school.**
7. **A owes R money. R tried to ask A to return the money, but A has not intention to return.**
8. W helped X with several exams in the class that they are taking together
9. Y has $500 credit card debt to be paid

Record Analyst

1. D & Q have the same major. They have taken several classes together.
2. E & S have the same major. They have taken several classes together.

Phone Record

3. B called G & L to discuss the upcoming presidential debate (Candidate B)

Company Record

4. E and V interned in the same company

Credit Check

5. Z needs money to pay credit card

Police Records

6. M accidentally hit C's car on the road

Previous School Records

7. G and B are high school classmates
8. **L and T stole things when they were in elementary school**
9. B and G stole money in high school and got caught

Web Analyst

1. L, M, H were walking together talking about a dancing competition next week and their competitors A, C, and E.
2. L & T were elementary school classmates
3. I is P’s significant other
4. A & R were senior high school classmates
5. **Z & R are cousins**
6. D & K are boyfriend and girlfriend
7. I and S are brother and sisters
8. J and Y are boyfriend and girlfriend
9. **T saw F vandalized his car**
10. W and X are taking the same class this semester

Note. Critical information pieces are shown in bold.

Appendix C

Part Two Information Pieces and Distribution

Interview Analyst

Dates	Events
8/30/09	Intramural soccer competition final
9/4/09	Student election debates
9/8/09	Intramural swim heats
9/11/09	**Product design plan submission deadline for STARTUP business plan competition**
9/11/09	**Zahra's credit card payment date**
9/18/09	Luke's birthday
10/12/09	Student election information table
10/13/09	Yadir's credit card payment date
10/15/09	Midterm exam for Circuit and Devices (Mikayla is taking the class)
10/20/09	Off-campus dancing performance
10/23/09	Intramural flag football semi final
11/3/09	Student election advertisement day
11/13/09	Intramural flag football final
11/19/09	Intramural swim competition final
11/23/09	**Final plan submission deadline for STARTUP business competition**
11/26/09	Penn State dancing competition

Record Analyst

Date	Name of the account	Debit	Credit
9/1/09	Isabel	$300.00	
9/2/09	Sean		$300.00
9/3/09	Riley		$1,000.00
9/7/09	Isabel		$820.00
9/7/09	**Riley**	**$600.00**	
9/7/09	Whitney	$256.00	
9/8/09	**Zahra**		**$600.00**
9/8/09	Xavier		$256.00
9/11/09	Jordan	$650.00	
9/14/09	**Isabel**	**$574.00**	
10/3/09	**Dante**	**$450.00**	
10/6/09	Luke		$315.00
10/8/09	Dante		$1,500.00
10/10/09	**Dante**	**$1,050.00**	
10/15/09	Tay		$1,680.00
10/17/09	Brandon		$1,000.00

Web Analyst

Market Place	Date Posted	Account Owner	Price
Ebay	**2015-08-30, 8:16AM EDT**	**Riley**	**$1,040.00**
Craigslist	2015-08-30, 1:15PM EDT	Cristian	$1,000.00
Craigslist	**2015-09-04, 3:24PM EDT**	**Isabel**	**$820.00**
Craigslist	2015-09-06, 5:19PM EDT	Ursela	$835.00
Ebay	**2015-10-06, 12:47AM EDT**	**Dante**	**$1,545.00**
Craigslist	**2015-10-10, 10:32PM EDT**	**Tay**	**$1,680.00**
Ebay	2015-10-15, 12:16AM EDT	Whitney	$1,500.00
Ebay	2015-10-16, 2:49PM EDT	Greg	$1,530.00

Date	Events
9/14/09	Dance performance on campus
9/25/09	Intramural flag football heats
10/7/09	Intramural swim semi final
10/16/09	**Marketing strategy plan submission deadline for STARTUP business plan competition**

Name	Dates	Income
Yadir	9/11/09	$650.00
Tay	**9/15/09**	**$574.00**
Kristin	10/3/09	$450.00
Quentin	**10/12/09**	**$1,050.00**

Note. Critical information pieces are shown in bold.

Appendix D

Part Three Information Pieces and Distribution

I. Information about maps (critical information piece is shown in bold)

Police searched S, P, V, and K's home and found that each of them possess a suspicious drawing:

1. S has a floor map of Patee library. *(I)*
2. P has a drawing of Hub first floor with a small area circled. *(R)*
3. V has a drawing of Willard ground floor with a room circled. *(I)*
4. K has a drawing of the locker room in Rec building with one of the locker circled. *(W)*

II. Information about weekly schedule

N's Weekly Schedule

	M	T	W	T	F
8	Swimming team practice (outdoor pool) *I*		Swimming team practice (outdoor pool) *I*		Swimming team practice (outdoor pool) *I*
9		Class: International business (Business Building) *R*		Class: International business (Business Building) *R*	
10					
11	Lunch and study (HUB) *W*		**Lunch and study (HUB) *W***		Lunch and study (HUB) *W*
12					
13		**Work out (Rec Building) *R***	Class: Project Management (Willard) *R*	Work out (Rec Building) *R*	Class: Project Management (Willard) *R*
14	Meeting for business competition (Business Building) *I*				
15		Assistantship: Librarian (Pattee Library) *W*		Assistantship: Librarian (Pattee Library) *W*	
16					

Note. Critical information pieces are shown in bold.

P's Weekly Schedule

	M	T	W	T	F
8					
9	Class: Real Estate Law (Chamber) *W*	Par time job (HUB student book store) *R*	**Part time job (HUB student book store) *R***	Par time job (HUB student book store) *R*	Work out (Rec Building) *W*
10					
11					
12					
13	Class: Employment Law (Business Building) *R*	Class: Spanish (Thomas Building) *I*	Class: Employment Law (Business Building) *R*	Class: Spanish (Thomas Building) *I*	
14					Study group meeting (Downtown Starbucks) *I*
15	Work out (Rec Building) *W*		Work out (Rec Building) *W*		
16					

Note. Critical information pieces are shown in bold.

V's Weekly Schedule

	M	T	W	T	F
8		Part time job: ID Checker (Rec Building) *W*			
9	Class: musicical theatre performance (pavilion) *R*		Class: musicical theatre performance (pavilion) *R*		Theatre production meeting (Music I) *I*
10				Class: theatre production practicum (pavilion) *I*	
11					
12	Class: Introduction to costume design (Computer Building) *R*		Class: Introduction to costume design (Computer Building) *R*		
13		**Part time job: ID Checker (Rec Building) *W***			Part time job: ID Checker (Rec Building) *W*
14					
15	Workout (White Building) *I*	Dancing class (Fraser dancing workshop) *I*	Workout (White Building) *I*	Dancing class (Fraser dancing workshop) *I*	
16					

Note. Critical information pieces are shown in bold.

K's Weekly Schedule

	M	T	W	T	F
8					
9	Basketball team practice (Rec Building) *W*	Part time job: Otto's (Kern) *I*	Class: Experimental Chemistry (Whitmore) *R*	Part time job: Otto's (Kern) *I*	Class: Introduction to psychology (Forum) *W*
10					
11					
12					
13			Basketball team practice (Rec Building) *W*		
14		Class: Chemistry Principle (Forum) *R*		Part time job: Otto's (Kern) *I*	
15	Meeting for campus election (HUB) *I*				Basketball team practice (Rec Building) *W*
16					

S’s Weekly Schedule

	M	T	W	T	F
8		Statistical consulting practicum (Thomas) *I*		Part-time job: life guard (outdoor pool) *R*	Statistical consulting practicum (Thomas) *I*
9					
10	Class: Applied regression analysis (Thomas) *I*		Class: Applied regression analysis (Thomas) *I*		
11					
12					
13	Class: probability (Willard) *R*		Class: probability (Bouke) *R*	Independent study (Thomas) *W*	Class: probability (Willard) *R*
14		Part-time job: life guard (outdoor pool) *R*			
15					
16	Swimming (outdoor pool) *W*		Swimming (outdoor pool) *W*	Swimming (outdoor pool) *W*	Swimming (outdoor pool) *W*