Hand Images in Virtual Spatial Collaboration for Traffic Incident and Disaster Management

Final Report

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16. Abstract (Limit: 250 words)

Purpose: To develop demonstration technology that can overlay hand videos on spatial images such as traffic maps, and assess the impact of this technology on virtual collaboration. This work explores to what degree gestures impact collaboration effectiveness in the task of traffic incident management, with the goal of informing design of tools to support virtual collaboration in this domain. **Methods**: Eighteen participants worked in pairs to solve three traffic incident scenarios using three different interaction approaches: 1) face-to-face: participants worked together by marking up an electronic map projected on the table in front of them; 2) separated: participants were separated by a soft wall while they worked together on the electronic map with electronic drawing tools; or 3) hand images: same as 2 with the addition of the partner's hand images projected on the map. Participants were video recorded. The questionnaires were given to participants after each trial to evaluate workload, positive interactions, team behaviors, connection to teammate, and frustration. **Results**: Participants spent more time on the task and perceived a higher level of time pressure when using hand images than when working face-to-face. When working face-to-face, participants felt more like their teammate was at the same table and felt less disconnected from their teammate than when working separately or using hand images. **Conclusions**: The results indicate that adding hand videos to a virtual drawing tool for the task of traffic incident management can increase team behaviors and change the way in which team members communicate information.

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Table of Contents

List of Figures

List of Tables

Executive Summary

The goal of this work is to inform the design of virtual collaboration tools which can effectively support spatial map-based reasoning and rapidly connect people who are physically located at various agencies. We will do so by gaining a deeper understanding of the modes of communication that support collaboration between multiple people managing traffic incidents or disasters. Traffic incidents (such as a truck crashing and turning sideways on the highway, blocking all lanes of traffic) and disasters (such as the fall of the I-35 W bridge) require the rapid coordination and response of many groups. Such groups may include state highway patrol, medical emergency response teams, and city employees. Jointly, these groups must rapidly develop coordinated responses so that injuries can be attended to, environmental and human safety hazards can be contained, detours around the incident can be planned, and road barriers and detour signs appropriately placed. There is rarely time for all parties to meet jointly, so much of this multi-organizational planning and coordination currently happens via phone. Much of this information refers to spatial locations on a map.

However, research in linguistics, psychology and virtual collaboration indicates that hand gestures, which are lost in phone conversations, are very important for communication of spatial concepts. Examples of spatial concepts in these tasks include traffic flow patterns, detour routes, and locations of incidents, emergency vehicles, and police. Spatial concepts can often be conveyed through words alone but doing so may require more effort than using a combination of words and gestures. The absence of gestures has been experimentally demonstrated to create a communication impedance in virtual collaboration for tasks such as mechanical assembly (Kirk, 2006) and engineering design (Cornelius, Nguyen, & Hayes, 2011; Cornelius, Hayes, Nguyen, & Makena, 2012).

In this work, our goal was to understand whether 1) the absence of gestures also creates communication impedances in virtual collaboration for traffic incident management, and 2) whether the presence of gestures has a positive impact on virtual teamwork. We answered this question by recruiting 18 civil engineers to participate in an experiment. The participants worked in pairs; each pair was asked to create plans for responding to three different scenarios involving traffic related incidents, using three different collaboration interfaces. In all interfaces participants could jointly view and draw on an electronic map of downtown Minneapolis. The interfaces were a) **Separate**: virtual collaboration without gestures, b) **Hand Images**: virtual collaboration with videos of the virtual teammate's hands projected on the map, and c) **Face-to-face** (in contrast to *virtual* collaboration): participants sitting at the same table using the electronic map. The pairing of the interfaces and scenarios was systematically varied so that the same interface and scenario were not always paired together. After completing each scenario, subjects were each asked to independently fill out a questionnaire to assess the cognitive difficulty of the task and the degree to which they felt connected to their team mate.

The results did not indicate that the addition of hand gestures reduced workload in virtual collaborations in the domain of traffic incident management, or that their absence created a communication impedance. However, there was a significant boost to team behaviors when hand gestures were added to the virtual collaboration environment. Thus, we conclude that gestures are helpful in promoting teamwork in this domain, but it is not clear that they reduce workload.

Chapter 1. Introduction

1.1 Goals

The primary scientific question explored in this work is the following: can we help geographically dispersed teams of traffic managers and emergency responders to be more effective by providing them with virtual collaboration tools that allow them to use natural gestures superimposed on a shared virtual map? More specifically, to answer this question in this work, we:

1) Developed demonstration technology to support virtual collaboration between two groups at different locations. This technology can overlay hand images and draw over spatial images such as traffic maps. The goal is to allow participants to communicate quickly and effectively about concepts and routes on the map through gestures.
2) Experimentally assessed the impact of this technology on virtual collaboration in traffic incident management tasks. Can it reduce the effort and frustration of collaborating across distance?

The underlying assumptions of this work are that firstly, traffic incident and disaster management is inherently a spatial task. Examples of spatial concepts in this domain include the location of incidents, proximity to other roads and population concentrations, and the location and direction of detour routes. Secondly, that it will be easier for traffic experts and emergency responders to convey such spatial concepts by pointing, gesturing or drawing on a map, than it is to verbally describe them via phone (measured in terms of cognitive work load).

1.2 Traffic Incident and Disaster Management

Emergencies and disasters frequently occur on the road: a tanker truck may roll over and block traffic; a gasoline leak near the roadway may necessitate closing that section of the road; an evacuation due to flooding in a residential area can clog all roadways leading out of the area. To manage such disasters quickly—and mitigate the impact on citizens—traffic managers, police, and emergency responders at different agencies from the state, county, and city frequently need to collaborate, plan and coordinate from different locations. The bulk of this inter-agency collaboration is currently done via phone. While the job gets done, it can be difficult to discuss locations of accidents, placement of detour signs, alternate routes, and other spatial concepts through voice alone.

1.3 Virtual Collaboration

Virtual collaboration happens anytime two people at different locations work together. Thus, traffic management experts and emergency responders are already virtually collaborating when they collaborate by phone. However, given the spatial, map-based nature of the task, there may be other ways of virtually collaborating that may support the spatial aspects of the task more naturally. In this work, we explore to what extent a simple shared visual environment, that allows people at different locations to gesture and draw on a shared virtual map, can help them to solve traffic and map-related problems.

However, current tools for virtual collaborations do not provide much support for communication of spatial concepts, beyond shared images and videos. In particular, what is lacking is an easy, natural way to convey hand gestures when discussing spatial concepts. This is a serious void, as gestures are very important for communicating spatial information (Alibali, 2005). If listeners cannot see the gestures of the speaker when discussing special concepts, it results in more misunderstandings and more time to complete tasks (Minneman & Bly, 1991). The virtual collaboration test bed developed for this work enables traffic management experts to communicate spatial information associated with incidents and disasters in a more convenient and natural way. The aim is to reduce the effort required to collaborate from multiple locations, for more effective virtual teamwork, and more rapid response to traffic incidents and disasters.

1.4 Gestures and Communication of Spatial Concepts

Work from linguistics, engineering and other fields indicate that gestures, in conjunction with spoken words, play a large role in communication of spatial concepts. Communication of spatial concepts can still occur with words alone, but it may be more difficult, frustrating, or error prone. Thus, an assumption underlying the work reported here is that the task of traffic incident management is made more difficult and frustrating when collaborators communicate only by voice (phone) versus when they can additionally see each other's gestures. Work in other spatial tasks has shown that participants' mental workload is reduced when virtual collaborators are allowed to see each other's gestures versus when they cannot. Kirk (2006) found this to be true in an assembly task where a remote helper instructed a worker on how to complete the task. Cornelius, Hayes, Nguyen, and Makena (2012) also found this to be true in a virtual engineering design and sketching task. In both cases, gestural communication was accomplished by projecting video images of the virtual collaborators' hands on top of the workspace (e.g. a table covered with pieces to be assembled, or an electronic drawing.

However, while all of these different task domains are highly spatial: assembly, design and traffic incident management, they are not identical, and it is not yet well understood by the scientific and engineering community which task-domain characteristics influence whether gesturing is useful. Thus, regardless of whether gestures turn out to be important in the traffic incident management domain, an additional goal of this study is to understand what task-domain characteristics make this so.

1.5 Approach

In order to answer this question, we adapted Cornelius' collaboration test bed initially created for engineering designers, and adapted it to traffic management by adding a map as the background for the collaborative drawing tool. Thus, participants can work together in a virtual space in which they can pan and zoom on a map, make markings on the map, and gesture over it. We ran an experiment in which 18 civil engineering students were asked to work in pairs. Each pair was asked to solve three map-based traffic incident or disaster scenarios using three different collaboration interfaces, e.g. three versions of the test bed. We will call the three interfaces: Separate, Hand Images and Face-to-face:

1) **Separate.** Pairs of participants sat at tables on opposite sides of a partition. Each participant could hear, but not see their team mate. However, they could view a shared

electronic map which was projected on the table, draw on the map with an electronic pen, and verbally discuss the problem.

2) **Hand images.** This interface was identical to the Separate interface except that we additionally projected video images of the hands and arms of their teammate onto the map. As in the Separate interface, participants were seated at tables on opposite sides of a divider. The map was down-projected onto the table. Participants could both draw *and* gesture over the map, and have them be seen by the other participant projected onto his or her table.
3) **Face-to-face.** Unlike the first two interfaces, in this interface participants were seated on the same side of the partition at the same table. They used the same collaboration software as was used in the Separate interface; an electronic map was down-projected on the table, and they could draw on the map with electronic pens. However, no hand images were projected on the map, nor was it necessary since they could each see each other's gestures directly.

The Separate and Hand Image interfaces allowed us to compare identical virtual collaboration environments with and without the ability to see the hands, arms and gestures of one's team mate. The Face-to-face interface provided a baseline for collaboration performance under the most traditional method for collaboration: working together in the same room.

The traffic incident and disaster scenarios which we asked the participants to address were: a tanker rollover inside a highway tunnel and a resulting gasoline spill in the tunnel, a tanker crash and fire on the highway, and an evacuation in response to a bomb threat in a major downtown building. After completing each task, participants were asked to fill out the NASA TLX (Task Load Index) questionnaire in order to assess differences in cognitive workload, e.g. perceived difficulty, effort, frustration, etc. (Hart, 2006). Additionally, they answered questionnaires on the degree to which they felt connected to their collaborator. The results provide insights for development of future tools to support virtual interactions between multiple agencies that must collaborate to rapidly develop coordinated plans to address major traffic incidents and disasters.

Chapter 2. Literature Review

The work described in this chapter is divided into two types: examples of implemented systems in which people project hand images or gestures onto a virtual work surface to facilitate virtual collaboration, and research on gestures in general and their impact on ease of communication of spatial concepts.

There is much work from psychology, linguistics, computer science and engineering that underscores the special role of gestures in communication of spatial concepts (Bly, 1988; Tang & Minneman, 1991b; Clark, 1996; Emmorey & Casey, 2001; Fussell et al., 2004). Gestures are often used in conveying route information (Emmorey, Tversky, & Taylor, 2000). People produce many types of gestures including: representational gestures, which convey semantic meaning through hand shape, position or motion; and beat gestures, which are simple rhythmic gestures without semantic content. Studies show that when a speaker knows that the listener can see his or her gestures, the speaker produces more representational gestures than in situations in which the listener cannot see the speaker. However, speakers still produce representational gestures even when they know listeners cannot see them (Alibali, Heath, & Myers, 2001). Furthermore, Rauscher, Krauss, and Chen (1996) found that when people were prevented from gesturing, their speech was less fluent, but only when using spatial language—speech with non-spatial content was unaffected by the ability to gesture.

There are communication advantages when listeners can see the gestures of the speaker because gestures play large a role in expressing, communicating and thinking about spatial information. They can improve listeners' comprehension of communications about spatial concepts. Furthermore, the opportunities to use gestures "may actually influence the course of spatial reasoning and problem solving" (Alibali, 2005).

2.1 Contextually Embedded Gestures in Virtual Collaboration

There have been many systems for enabling people at distant sites to jointly view the workspace (whether physical or electronic) and to communicate through gestures for the purpose of creating joint artifacts. These systems are too numerous to describe so we will describe a few examples implemented in a variety of task domains. Also note that while many researchers have implemented virtual collaboration tools to support contextually embedded gestures, few researchers have experimentally evaluated their efficacy in particular task domains, outside of Ou, Fussell, Chen, Setlock, and Yang (2003); Fussell et al. (2004); Kirk (2006); Kirk, Rodden, and Fraser (2007); Cornelius, Nguyen, and Hayes (2011); and Cornelius et al. (2012). It is critical to understand whether gestures actually provide benefits in a particular task domain before implementing them in broadly used tools to support virtual collaboration in that domain. We aim to assess whether gestures provide measurable benefits in the task domain of traffic incident management, so as to inform the design of future virtual collaboration tools to support it.

2.1.1 Examples

There many possible ways to support contextually embedded gestures in a virtual collaboration tool. Following are a few examples:

Commune was based on a "pad of paper" metaphor. It was designed to support two or three distant collaborators in jointly designing artifacts through a shared sketching process (Bly & Minneman, 1990; Minneman & Bly, 1991). Participants were connected by phone, and each participant sat at a horizontal digitizing table on which they could make free-hand marks with a stylus. The marks made on each participant's tablet showed up on the tablets of the other participants. A video camera at each site recorded views of each participant's face which were shown on vertical displays at each of the other sites. Simple "gestures" could be made in the context of the drawing by moving the cursor (to point), or drawing temporary lines and arrows.

VideoWhiteboard implemented a "frosted glass wall with shadows" metaphor; it allowed two distant collaborators to jointly create sketches in a shared, wall-mounted drawing surface (Tang & Minneman, 1991b). The distant participants could be seen on the drawing surface as shadowy images. At each site, participants stood in front of a wall-mounted, translucent, rear-projection screen. Participants drew on the screens with ordinary markers. A video camera and projector were mounted behind each screen. The video captured the participants' markings on the screen and shadowy images of their hands, arms and upper bodies behind it. The image captured at each site was then projected onto the back of the screen at the other site. Participants could hear each other through an audio link. It appeared to participants that they were working with someone standing and writing on the other side of a translucent screen. One of the interesting things about this application is that the shared drawing space was created with a low-tech physical drawing board, rather than with a shared software drawing application. While there was no joint electronic artifact created, markers and whiteboards are more flexible, familiar, and less cumbersome to use than most electronic styluses. Tang and Minneman (1991a) also implemented a horizontal tablet version, VideoDraw, which used overhead cameras to capture images of participants' hands and arms on the drawing surfaces.

DOVE (Drawing Over Video Environment) was designed to support a worker who is observed and instructed by a distant helper to perform physical tasks such as bicycle repair (Ou et al., 2003; Fussell et al., 2004). The worker and helper could hear each other through an audio link. The worker wore a head-mounted video camera that captured the part of the environment at which the worker was currently gazing, and displayed it on the helper's screen. In some versions the helper could make free-hand marks on the screen, or point to objects in the screen with the cursor. Everything on the helper's display was replicated on a display next to the worker. However, unlike Commune and VideoWhiteboard, the perspectives seen at each site were not equal. From the helper's perspective, DOVE was like a window on the worker's world, where marks could be made on the window glass. From the helper's perspective it was like having a disembodied but beneficent "big brother" watching everything you do, and providing advice though voice and notations made on a picture of your world.

GestureMan, like DOVE, was also designed to support remote instruction in a physical task: how to use equipment (Kuzuoka, Oyama, Yamazaki, Suzuki, and Mitsuishi, 2000). However, the distant instructor was embodied in a robot that could move in the student's space. A camera

and laser pointer were mounted on the robot; the instructor could get a different view of the student's workspace by moving the robot and camera. The instructor could also point directly to objects in the worker's space with the laser pointer. Like DOVE, the instructor viewed a video of the student's world, but from the robot's perspective. Unlike DOVE, the student did not have to look at a screen to see where the instructor was pointing, but instead looked where the robot pointed in the workspace.

RGT (Remote Gesture Technology) (Kirk, 2006; Kirk et al., 2007) – Kirk did not actually give his system a name, but he described it as a remote gesture technology framework, so we will use that label in lieu of a name. Like DOVE and GestureMan, it was designed to support a worker who is watched and instructed by a distant helper in a physical task: assembly of Lego models. It implemented a "shared workbench with a ghost helper" metaphor. A worker sat at a table with Lego blocks spread on it. The helper sat at another site in front of an empty table. Overhead video cameras captured images of the hands and objects (or images) on the tables at both sites. Each of these images was then projected on the table at the other site. The helper could additionally create electronic free-hand sketches (with a stylus) that were projected on both tables. It was similar in many ways to the VideoDraw system (a tabletop version of VideoWhiteboard), but adapted for student teacher instruction. It also had some similarities with DOVE, except that the big brother now appeared not as a disembodied voice making marks on a screen, but as a set of somewhat ghostly hands that could pass over objects, but not move them.

MirrorFugue was designed to allow a remote instructor to teach a student by showing the student how to position and move his or her hands on the keyboard, so that the student can learn by copying (Xiao & Ishii, 2011). MirrorFugue implemented not one, but three metaphors: shadow, mirror, and organ. In shadow mode, the hands of participants were captured by an overhead video camera and projected on each other's keyboards (like the shadow hands projected on the workspace of Kirk's RGT system). In mirror mode, participants saw each other's hands "reflected" on the vertical panel at the back of the keyboard, but since the participants saw not their own hands, but the hands of the other participant, it was more like looking through a glass strip (like a very narrow strip-shaped version of VideoWhiteboard with clear glass). Through the "glass" strip one sees another keyboard and the hands and arms of the other participant, as if he or she were facing the observer. In organ mode, participants saw the arms and keyboard of the other projected on the strip behind the keyboard, but as if seated beside the participant. It appears as if the remote participant's hands are playing a second keyboard behind the first keyboard, similar to the multiple keyboards for an organ. Both mirror mode and organ mode were accomplished by back projecting an overhead image taken of the other participant's hands onto a vertical projection strip positioned at the back of the keyboard. Thus, it was a similar arrangement to VideoWhiteboard, but using an overhead camera instead of a camera behind a translucent projection screen, and no drawing capability. Early tests suggested that students most preferred the organ mode.

CollabraTable. Cornelius, et al. (2011; 2012) implemented a test bed collaboration environment, very similar to Tang and Minneman's Videodraw system (1991a) which was a horizontal version of VideoWhiteboard (Tang & Minneman, 1991b). CollabraTable was designed to support virtual collaboration in engineering design and sketching tasks.

2.2 Communication and Gestures in Distance Collaboration

It is always more difficult to communicate over distance (Olsen & Olsen, 2000). When people engage in virtual collaborations much information is lost; some of that lost information is important to communication and development of relationships between distant team members. For example, even when groups communicate through high-resolution video and audio teleconferencing in which a wall sized video of the other room is shown at each site, participants may feel as if they are separated by a glass wall, which is not conducive to the feeling of belonging to one common team. However, it is not yet scientifically well understood what information is most important for effective distance collaborations (Lee, Dourish, & Mark, 2006).

What is needed to support communications appears to differ depending on the nature of the task and the nature of the interaction. For example, the "glass wall" teleconferencing situation described above may be appropriate for negotiations between two organizations, but very inadequate for collaboration among traffic engineers (or traffic engineers, police and medical emergency responders) who are jointly figuring out how to best respond to an incident. Ideally, if they were in the same room, they might prefer to work face to face while referring to various maps and traffic images.

2.3 Gestures and media Richness

Bly (1988) performed an experiment in which she took away subjects' ability to communicate through hand gestures. Pairs of participants were asked to collaborate to jointly create a mechanical design under three different conditions: face-to-face, with a video link which allowed each participant to see the hands and sketches of their collaborator, and telephone only. For the telephone-only condition, each participant drew on their own sketch pad without being able to see the hands or sketch of the other. The face-to-face condition was a very "rich" communication media, and the telephone-only condition was by comparison a relatively "impoverished" communication media. When using only the telephone as a communication device, participants were still able to complete the task, but it required far more time than in either the video link or the face-to-face condition; performance was best in the face-to-face condition. It was a big advantage to sit beside each other and point and gesture over the same drawing. Furthermore, as the communication media became more impoverished, participants began to feel less engaged in the task, and less connected to each other. From this Bly concluded that gestures combined with voice are simply a more efficient way to communicate spatial information than are words alone; a spatial concept can be conveyed far more simply and naturally with a mixture of gestures and words. For example, a traffic incident may be described by "the incident occurred here (points) when a west bound truck (gesture westbound movement with the right hand over the relevant location on the map) slid over the median (path of hand veers), and collided with a car in the other lane here (fingers of right hand collide with left hand as it is moves "east"), and they came to rest here (moves hands together towards point on map)". The same thing can be said in words only, but it requires more words, and misunderstandings are more likely. The additional work required as the richness of communication went down may in part explain the feeling of increased "distance" from team mates, and reduced engagement in the task.

2.4 Co-Presence

An additional reason for enabling distant collaborators to see each other's hands is to increase the perception of co-presence, i.e. the feeling that others are "present" even when they are not really there (Stewart, Bederson, & Druin, 1999). Fussell et al. (2004) developed a prototype tool to support virtual collaboration between teacher and student in a spatial bicycle repair task. Teacher and student were connected by a voice connection. Additionally, the teacher could look at a live video of the student working on the bicycle. The student could look at a screen next to the bicycle on which was shown a still image of the bicycle. The teacher could "gesture" to an extent with the cursor on the bicycle image by pointing to various parts of the bicycle, but the teachers' hands were not visible. The teacher instructed the student in bicycle repair tasks both with and without the cursor gestures. Fussell and colleagues found that the task was accomplished much more quickly when teachers could gesture with the cursor. However, cursor gestures do not allow as rich of gestures as do hand images, nor do they provide a feeling of co-presence.

2.5 Mental Workload and Frustration

Cornelius et al. (2011) created a prototype tool to allow designers to virtually collaborate on a joint spatial task: creating sketches of conceptual designs. The tool projected a CAD interface on a table at two sites. At each site, participants could interact with the CAD tool using infrared pens (to replace the mouse). Their hands and arms were captured on video as they moved over the drawing, and this video was projected at the other site. Pairs of participants created joint drawings under three different conditions: face-to-face, virtual sketching only (i.e. they could see the cursor and lines drawn by their partner, but they could not see their partner's hands or arms), and virtual sketching with hand gestures. The researchers found that virtual sketching only was significantly more physically, mentally, and temporally demanding than virtual sketching with hand gestures, and the former required more effort and resulted in more performance failures and frustration than the latter. Furthermore, there were no statistically significant differences between the face-to-face condition and the virtual sketching with hand gestures. The researchers concluded that being able to see the hands and gestures of one's collaborator resulted in much more effective, less frustrating collaborations than did the virtual sketching condition which provided only "cursor gestures."

We anticipate that similarly, in traffic incident management, allowing collaborators to see the hand gestures of their colleagues will enable more effective, less error prone, and less frustrating communication of spatial concepts.

Chapter 3. Experimental Test Bed

3.1 Overview of the Hardware

The setup consists of two collaboration cells separated by a soft wall so that participants could hear each other but could not directly see each other except through the tool (see Figure 1 and Figure 2). Participants sat or stood on opposite sides of the wall, except during the face-to-face condition where they sat on the same side of the wall.

Each collaboration cell consists of:

- A ceiling mounted projector to project images on a table top,
- A ceiling mounted infrared sensor (a modified Wiimote), to pick up signals from an infrared pen,
- A ceiling mounted webcam to capture hand gestures in the context of the drawing,
- A white table onto which the user interface is projected,
- An infrared pen which in combination with the Wiimote allows the table top to be used as a touch screen,
- Software: A collaborative Paint-like application.

Figure 1: Two of the software developers demonstrate virtual collaboration on a shared electronic map. They are separated by a soft wall; they can hear but not see each other (except through the interface). Each side has a projector, infrared sensor, and camera directed at an ordinary conference table. Participants control the application using the infrared pens in their hands.

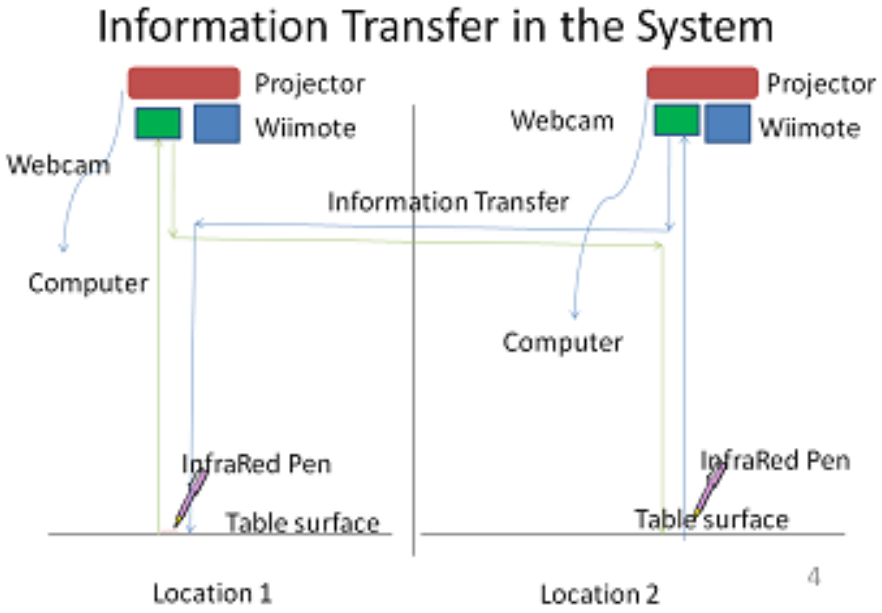

Figure 2: Schematic view of two collaborative cells (from Cornelius et al., 2012).

In each cell, a projector is mounted on the ceiling facing downwards towards the table. The projector is connected to a computer to project the computer screen on the table surface. Also in each cell is a Wiimote (which has an infrared camera) connected to the ceiling. It detects infrared (IR) signals from the IR pen when the user draws. The IR pen plays the role of a mouse in this system. Every time the IR pen's button is pressed, it is like the mouse button being pressed.

The interaction between the IR camera in the Wiimote and the IR pen creates the touch screen. For the touch screen to work properly, a four point calibration is performed to match the screen coordinates to the desktop coordinates. The other important hardware components are the cameras which are also mounted on the ceiling to capture images of the user's hands. The same apparatus setup is used in both collaboration cells.

These components are sufficiently flexible to allow other configurations. For example, one could project on a wall-mounted white board, or upwards on the bottom of an etched glass table. However, our goal was to create a simple, inexpensive open source test bed, made from common components that would allow us to test our experimental hypotheses.

We initially set up the two collaboration cells side by side in order to make it easier to test and debug the prototype. It also makes it much easier to set up and run an experiment with a single experimenter.

3.2 Overview of the Software

The software was used to create an image made of three layers which were down-projected on each participant's table. The layers included:

- **A map layer** using Google Maps functions and APIs. Users could specify a street address (via keyboard), and zoom and pan the map (each using an infrared pen). When one user changed his or her view of the map (e.g. by zooming or panning), the view projected on the other user's table would change too.
- **A drawing layer.** A paint-like drawing tool allowed users to draw on the map in colored lines (via an infrared pen). When one participant marked on their map, the marks also appeared on the other participant's map. When participants zoomed or panned the map, the drawings zoomed and panned with it.
- **A hand image layer.** The video camera above each table captured real-time videos of the hands and arms of each participant. To interact with the gesture layer users simply needed to move their hands over the map, as they would naturally when discussing the traffic scenario. They did not need a keyboard, mouse, or IR pen to use this layer. Image processing software separated out everything in the video image that was not part of the projected map or markings, which could include the hands and arms of the participant as well as other objects placed on the table such as pencils or post-it notes (provided they contrasted sufficiently with the background). These objects (hands, arms, pencils, etc.) were then projected onto the map of the other participant, in the same location on the map. Thus, if one participant pointed to the Foshay Tower in downtown Minneapolis, a shadow-like image of the hand pointed to the Foshay Tower on the other participant's map.

To create the three different interfaces used in the experiment, we combined the elements of the test bed and the software layers in different ways:

- **Separate interface.** Participants were seated on opposite sides of the wall, as in Figure 1. They used collaboration software composed of the map layer and the drawing layer only (i.e. no hand image layer). Figure 3 shows what one participant would see when using the Separate interface.
- **Hand Images interface.** Participants were seated on opposite sides of the wall and used software with all three layers: map, drawing, and hand image. Figure 4 shows one participant (of a pair) using the Hand Images interface.
- **Face-to-face interface.** Participants were seated together on the same side of the wall. The software included the map layer and drawing layer, but not the hand image layer.

Each collaboration cell included a collaborative Paint-like application that allowed participants to pan and zoom around a map. Figure 3 below shows a screenshot of the interface after a pair of participants solved a traffic-planning scenario (specifically, the Evacuation scenario, described in detail in Appendix C). The map interface used information from Google Maps and functioned similarly. Users were also able to draw on the map using line drawing tools. Any marks made by the drawing tool stayed in the same geographic location on the map. For example, if a user marked an X on an intersection and then panned or zoomed, the X remained on that same intersection.

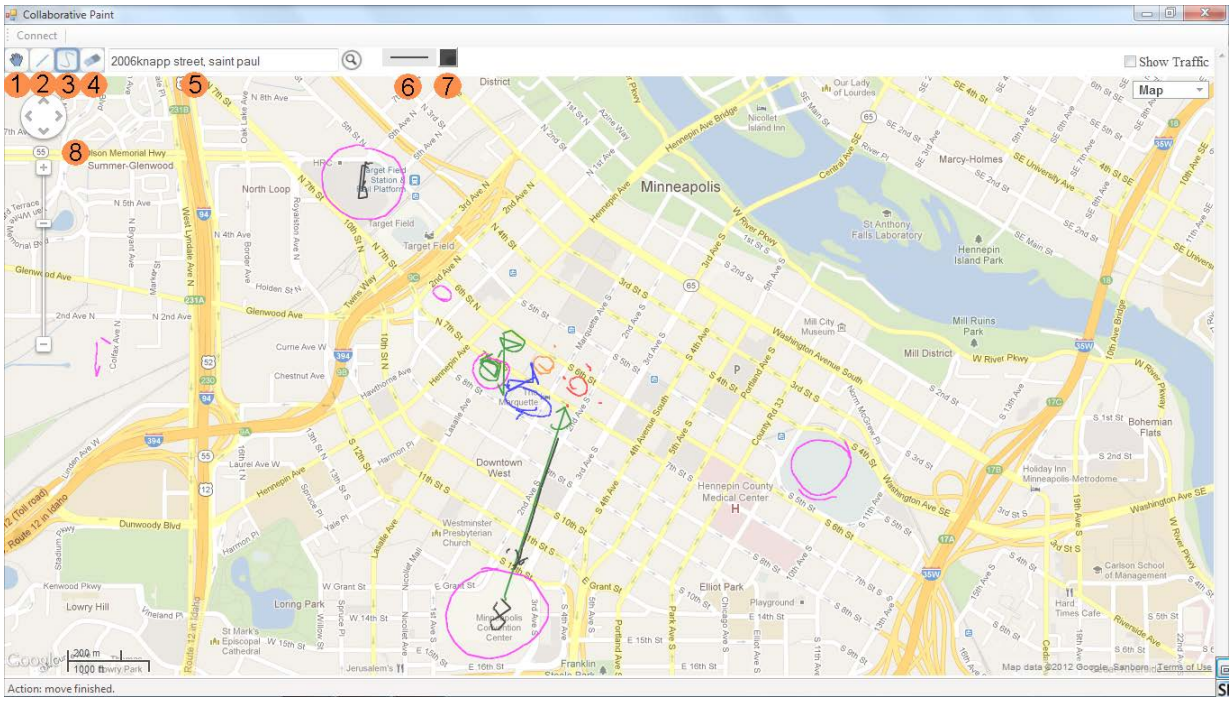

Figure 3: The Separate interface: markings on the map produced jointly by a pair of participants using the collaborative map/drawing tool. Each participant (on different sides of the table) sees the same image. Each can make markings which will show up on the other's map.

The controls for the map and drawing can be seen along the top left side in Figure 3. The location of each control is indicated in Figure 3 by a numbered circle:

1) *Straight line tool*: Allows the user to draw a segmented straight line by clicking the IR pen on the end points for each line segment.
2) *Curved line tool:* Allows the user to draw freehand by holding down the IR pen button. As long as the button is held town, the IR pen draws as though the user is pressing an ink pen against a piece of paper.
3) *Erase function*: Wipes the map clean of all drawing marks.
4) *Search function*: The user may type in a street address to display that location (in the experimental trials, this function was not used frequently since the keyboard was not within easy reach for the users).
5) *Line size*: The user can select line weight from a drop down menu.
6) *Line color*: The user can select pen color from a drop down menu.
7) *Zoom and pan controls*: These functions are as in Google Maps. They allow the user to zoom and pan.

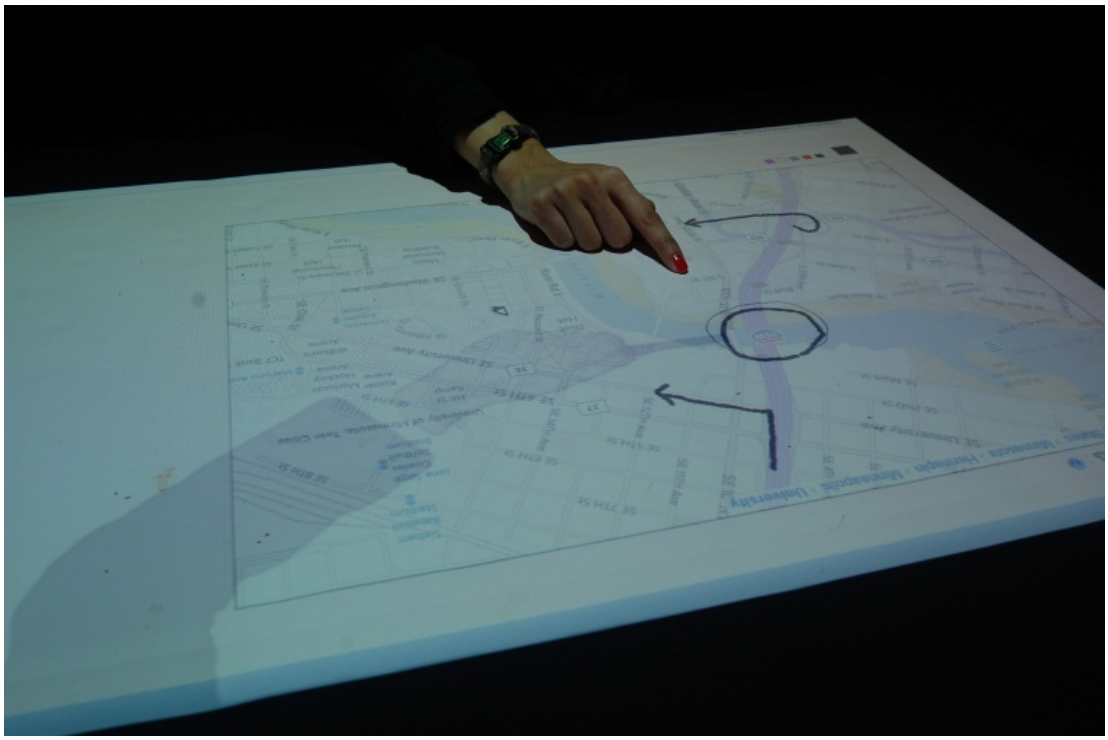

Figure 4: The Hand Images interface. Each participant can see the projected hands of the other on top of the shared map. Participants can also electronically "draw" on the shared map with infrared pens.

In the Hand Images interface, the participants had all the map and drawing tools that were available in the Separate interface, but additionally they could see a transparent, real-time video of their virtual team mate's hands and arms projected onto the shared map (Figure 4). The virtual images are transparent so that the map details can be seen through the virtual teammate's (somewhat ghostly looking) arm.

Chapter 4. Preliminary Testing

4.1 Focus Group

In order to develop and test the scenarios that were to be given to participants in the experiment, we first developed several possible traffic incident and disaster scenarios with John Hourdos (a civil engineering professor). The scenarios were all set in or near downtown Minneapolis and included a tanker rollover, a natural gas leak, and a bridge collapse. We then invited two of Hourdos' more experienced students, Gordon Parikh and Veronica Richfield, to use the "Hand Images" version of virtual collaboration test bed to collaboratively solve the scenarios. Veronica and Gordon are upper-level civil engineering students with knowledge of traffic incident management, and are familiar the layout of roads in the Minneapolis metropolitan area.

The feedback from the focus group pertained to multiple aspects of the scenarios:

- Feasibility
- Time required for completion,
- Interface features, annoyances, and missing information.

While Veronica and Gordon were able to develop solutions for the scenarios, it required far more time than was practical for the experiment. The tanker rollover scenario took approximately 80 minutes, while the natural gas leak scenario took approximately 40 minutes. The bridge collapse scenario was deemed too complicated and was not completed. Furthermore, for some tasks, we noted that they tended to divide up tasks by role—MN/dot and City—rather than collaboratively solving the problem and interacting through the interface. We employed Veronica Richfield (in collaboration with John Hourdos) to develop simplified and improved versions of the scenarios. She focused on 1) making it possible to complete them in less than 20 minutes by participants familiar with traffic management concepts, but less experienced than Veronica and Gordon, and 2) structuring them to require interaction through the interface. For example, to simplify the scenarios, instead of asking participants to generate all solutions themselves, participants in a pair were each given several solution options (for rerouting traffic, etc.) which were different from their team mate's options. In order to encourage discussion, the instructions for participants asked each to explain their options to their team mate using the shared electronic map, and then to jointly discuss and come to agreement on the best solution. The tanker rollover was split into two scenarios:

1. Tanker rollover and leak – This scenario required shutting down I-94 Westbound and then removing the fuel from the sewer.
2. Fire on the interchange – This scenario required shutting down all of the I-94 / I-35W interchange.

The natural gas leak scenario was discarded because it was too difficult, and was replaced with an evacuation scenario: a bomb threat on a major downtown Minneapolis office building. In this scenario, one participant had information on the occupancy of nine buildings that needed to be evacuated, and the other participant had information on the locations of "safe" evacuation areas. Participants were to work together to evacuate the threatened building and the immediate

surrounding buildings. They had to decide how many people to direct to each exit and the direction of travel on city streets towards evacuation areas.

The map given to the focus group included red, yellow, and green lines overlaid on the streets to indicate current traffic density (a Google Maps feature). Feedback indicated that these lines should be removed since they tended to block the street names and made it more difficult to see the streets. Thus, we removed the traffic density information from the map, and instead included it in the written materials provided with each scenario. Lastly, the focus group suggested that it would be helpful if the users could draw lines in more than one color. For example, so they could draw detour routes in one color, and sewer lines in another.

4.1 Face-to-Face Study

We conducted a pilot study with two civil engineering students recruited by Veronica Richfield. The participants used all three interfaces: Face-to-face, Separate, and Hand images. This also served as a pilot test of the three scenarios. When working face-to-face, the participants used many more gestures and pointed to the map to indicate locations and routes. When working separately, they relied on verbal descriptions of routes and gestured much less often. Interestingly, they used the map interface (including panning, zooming, and drawing) much less often when working separately than when working together.

Additionally, the evacuation scenario resulted in a conversation that was more one-sided than the other scenarios, even though the participants were using the Hand Images interface. The participant with building occupancy information did more of the talking and decision making, possibly since he had so much information to process and communicate. The participants discussed the problem for 35 minutes before the study had to be ended to fit in the two-hour duration. Even after 35 minutes, the participants had not decided on what streets to use.

To promote discussion and allow the scenario to be finished sooner:

1. The nine buildings to evacuate were reduced to six buildings.
2. The information on buildings and evacuation zones was split between participants so that each had information on three buildings and two evacuation zones.
3. Streets did not need to be specified, only the exits, the number of evacuees using each exit, and which evacuation zone they would go to after exiting.

Chapter 5. Experimental Design

5.1 Participants

Eighteen participants worked in pairs to solve three different scenarios using three different interfaces. Participants were recruited from civil engineering undergraduate and graduate students. They were selected for a basic traffic-planning knowledge, an understanding the practical implications of traffic rerouting, and a basic familiarity with the road system in Minneapolis.

5.2 Independent Variables

The independent variables were the interface and scenario. Interface was the primary variable of interest. While we were not specifically interested in how different scenarios impact performance, it was necessary to use multiple scenarios so that participants would not repeat the same task for each interface. Interfaces and tasks were systematically varied so as to avoid conflating interface and task.

1. **Interface** (3 options):
   - *Separate.* Pairs of participants sat at tables on opposite sides of a partition. Each participant could hear, but not see their team mate. However, they could view a shared electronic map which was projected on the table, draw on the map with an electronic pen, and verbally discuss the problem.
   - *Hand images.* This interface was identical to the "Separate" interface except that we additionally projected video images of the hands and arms of their teammate onto the map. Participants were seated on opposite sides of a divider. The map was down-projected onto the table. Participants could both draw *and* gesture over the map, and have them be seen by the other participant projected onto his or her table.
   - *Face-to-face.* Unlike the first two interfaces, in this interface participants were seated on the same side of the partition at the same table. They used the same collaboration software as was used in the "Separate" interface; an electronic map was down-projected on the table, and they could draw on the map with electronic pens. However, no hand images were projected on the map, nor was it necessary since they could each see each other's gestures directly.

2. **Scenario** (3 options):
   - *Leak*: a tanker rollover inside a highway tunnel and a resulting gasoline spill in the tunnel,
   - *Fire*: a tanker crash and fire on the highway,
   - *Evacuation* in response to a bomb threat in a major downtown building.

5.3 Dependent Variables

1. **Time to complete task** (in seconds). The video was used to determine the time in seconds required to complete a scenario, measured from when the participants began

reading the scenario instructions to when they completed the scenario and summarized the solution as specified in the scenario description.

The six NASA-TLX variables (described in more detail in Appendix A):

2. **Mental Demand**: How much thinking, deciding, calculating, remembering, looking, searching, etc., did you need to do?
3. **Physical Demand**: How much physical activity was required?
4. **Time Pressure**: Did you feel under pressure to complete the task in the time available?
5. **Performance**: How satisfied were you with your level of performance?
6. **Effort**: How hard did you have to work?
7. **Frustration Level**: How insecure, discouraged, irritated, stressed and annoyed did you feel?

The Post-Scenario Questionnaire (included in Appendix B): A set of questions to measure perceptions of communication effectiveness, engagement with task, engagement with teammate, team cohesion, and teammate presence:

8. **Discussion quality.** The overall quality of the discussion was: Poor – Good (seven-point Likert scale).
9. **Joint planning**. I made suggestions about how to do the task to my teammate: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)
10. **Leadership.** Did either of you emerge as leader? Yes, I did; Yes, my team mate did; No.
11. **Presence.** To what extent did you feel your teammate was at the same table with you? Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)
12. **Encouragement.** I felt encouraged by my teammate's actions and ideas: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale),
13. **Task frustration.** I felt frustrated by the task: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale). Note: this variable is different from the NASA TLX variable in that it drills down into the causes of frustration.
14. **Received positive feedback.** My teammate expressed positive opinions about my actions and ideas: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)
15. **Team perception**. I felt we were a team rather than two separate individuals: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)
16. **Joint work.** The solution was truly a joint effort: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)
17. **Social distance.** I felt disconnected from my teammate: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)
18. **Gave positive feedback**. I expressed positive opinions about my teammate's actions and ideas: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)

19. **Engagement.** I felt disinterested in the task: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)
20. **Frustration with teammate.** I felt frustrated by my teammate: Not at All – To a Little Extent – To Some Extent – To a Great Extent – To a Very Great Extent (five-point Likert scale)

Questions 8 – 20 are designed to elicit information about the relationship between the participants, their interactions, and their feelings of being connected as part of the same team. More specifically the questions can be grouped around the themes:

A. ***Positive interactions*** between participants: questions 12 (encouragement), 14 (received positive feedback), and 18 (gave positive feedback);
B. ***Team behaviors***: questions 8 (discussion quality), 9 (joint planning), 15 (team perception) and 16 (joint work);
C. ***Connection to teammate***: questions 11 (presence), 17 (social distance), and 19 (engagement); other researchers have observed that when participants feel more connected to their teammates, they also feel more engaged in the task (although it is not clear which is the cause and which the effect).
D. ***Sources of frustration:*** questions 13 (task frustration), 20 (frustration with teammate), and NASA-TLX frustration;
E. ***Workload:*** the six NASA-TLX questions;
F. ***Leadership***: question 10 (leadership). Question 10 did not fit clearly into any of the groups above, so it was treated separately.

5.4 Counterbalance

To counterbalance for order effects, the order of presentation of the interaction method was systematically varied. Additionally, the combination of interaction method and scenario was systematically varied as well. Table 1 below shows the counterbalance. Participants 17 and 18 would have completed the counterbalance, but they did not finish the scenarios. Participants 19 and 20 were given the same order as 17 and 18 in order to be able to substitute their results in the data analysis. Thus, the data analysis was performed on the fully counterbalanced data set of participants 1-16 and 19-20.

Table 1: Counterbalance

Participant pair	First scenario	Second scenario	Third scenario
1 & 2	Leak Face-to-face	Fire Separate	Evacuation Hand Images
3 & 4	Evacuation Separate	Leak Hand Images	Fire Face-to-face
5 & 6	Fire Hand Images	Evacuation Face-to-face	Leak Separate
7 & 8	Evacuation Hand Images	Leak Face-to-face	Fire Separate
9 & 10	Fire Face-to-face	Evacuation Separate	Leak Hand Images
11 & 12	Leak Separate	Fire Hand Images	Evacuation Face-to-face
13 & 14	Fire Separate	Evacuation Hand Images	Leak Face-to-face
15 & 16	Leak Hand Images	Fire Face-to-face	Evacuation Separate
17 & 18	Evacuation Face-to-face	Leak Separate	Fire Hand Images
19 & 20	Evacuation Face-to-face	Leak Separate	Fire Hand Images

5.5 Procedure

The study duration was approximately two hours. The following tasks were performed:

1. Participants were given an introduction to the study and completed the consent form.
2. Participants completed the demographic questionnaire.
3. The map interface was demonstrated to the participants and they practiced using the interface.
4. Participants completed the three scenarios, each using a different interaction method (i.e. a different interface condition).
5. Participants completed the NASA-TLX and Post-Scenario Questionnaire after each scenario.

5.6 Experimental Scenarios

The full instructions given to the participants for each of the scenarios are included in Appendix C.

5.6.1 Tanker Rollover and Fuel Leak

A fuel tanker has rolled over while inside the Westbound I-94 tunnel, blocking traffic. Only Westbound traffic is affected. The tanker is leaking, spilling liquid gasoline into the drain inside the tunnel. There are two parts to solve:

1. Redirecting traffic – Participants are each given two options (i.e. four options total) for re-routing traffic, and must choose one option that they judge to be best.
2. Removing the fuel from the sewer – The participants are given different pieces of information needed to determine how far into the sewers the fuel has leaked and which manholes to use to remove the fuel.

Two of the options for re-routing traffic are better than the others, thus it is possible to judge the quality of the participants' solution.

5.6.2 Fire on Interchange

A tanker has crashed on the I-94 / I-35W interchange, between Chicago Ave and County Road 33. The tanker jumped the barrier between Westbound and Eastbound I-94 and has started a fire, endangering I-35W as well. As a result, both directions of traffic on both freeways must be rerouted. No other locations are at risk. This scenario occurs at night, with corresponding traffic conditions. Road conditions are bare and negligible.

One participant is given two options for re-routing I-35W traffic, and the other is given two options for re-routing I-94 traffic. Participants must choose one option for each freeway. For each freeway, one option is to re-route traffic through downtown. Re-routing traffic from both freeways through downtown would not be a good idea, thus it is possible to judge the quality of the solution.

5.6.3 Downtown Evacuation Due to Bomb Threat

The IDS Center in downtown Minneapolis is subject to a bomb threat. The IDS Center must be evacuated, followed by the surrounding buildings. Vehicle traffic is already closed off, so only foot traffic is considered. For simplicity, the skyways were ignored. The bomb is suspected to be a biohazard, so wind is a concern. The wind is blowing to the Northeast, so the area Northeast of the threatened area is not a safe zone.

Each participant is given information on the current occupancy for three of the six buildings, and information on the capacity of two of the four evacuation zones. They must share their information to determine how many evacuees from each building should go to each evacuation zone. Ideally, evacuees should be distributed as evenly as possible between the major exits of each building (and as evenly as possible between streets) to avoid congestion.

5.7 Statistical Analysis

The dependent variables for this analysis were the 20 dependent variables (except for Leadership, which is a nominal variable). A 3 x 3 mixed-model analysis of variance (ANOVA)

was performed using the interface and scenario as within-subjects variables (Interface: Face-to-face, Separate, Hand Images) (scenario: Leak, Fire, Evacuation).

The questionnaire item groupings were also analyzed:

A. **Positive Interactions** – these three questions were treated as repeated measures, and a 3 (Interface) x 3 (Scenario) x 3 (Question) mixed-model ANOVA was performed.
B. **Team Behaviors** – these four questions were treated as repeated measures, and a 3 (Interface) x 3 (Scenario) x 4 (Question) mixed-model ANOVA was performed. (The Discussion Quality item was converted to a 5-point Likert scale.)
C. **Connection to Teammate** – these three questions were treated as repeated measures, and a 3 (Interface) x 3 (Scenario) x 3 (Question) mixed-model ANOVA was performed.
D. **Sources of Frustration** – since these three questions did not address the same sources of frustration, they were not treated as repeated measures. They were averaged, and a 3 (Interface) x 3 (Scenario) mixed-model ANOVA was performed on the average. (The NASA-TLX Frustration item was converted to a 5-point Likert scale.)
E. **Workload** – the six NASA-TLX questions do not address the same type of workload, thus they were not treated as repeated measures. They were averaged, and a 3 (Interface) x 3 (Scenario) mixed-model ANOVA was performed on the average.

We will report the results for the individual questions only if the corresponding group shows as significant effect. The exception to this is Workload – we will report any of the individual NASA-TLX items that are significant.

For all of the ANOVAs, a post-hoc comparison was performed on the estimated marginal means using a Bonferroni correction. Differences between means were considered significant at the $p \leq 0.05$ level.

Chapter 6. Results

First we will present the analyses for the all the significant results, followed by a summary and discussion. Unless otherwise stated, alpha = 0.05 in all analyses. The outputs of all statistical analyses, whether significant or not, are included in Appendix D, and calculations of effect size are included in Appendix E. Significant differences were found only for dependant variables:

1. Time to complete task,

NASA TLX workload aggregate measure,

4. Time pressure (a NASA TLX variable),
6. Effort (a NASA TLX variable),

Group A: Positive Interactions,

12. Encouragement,

Group B: Team Behaviors

Group C: Connection to Teammate

11. Presence,
17. Social distance.

6.1 General Observations from the Videos

Directing attention. Participants using the Separate interface appeared to have the most difficulty drawing their teammate's attention to a location on the map. This is as we expected because participant using the Separate interface could only direct attention verbally or by making electronic markings on the shared map, which are much less salient and therefore harder to notice than a pointing hand and arm. Given the size of the map interface, participants often missed seeing their partner add marks to the map if he or she was not looking at that spot.

Using drawings to remember. When using the Hand Images interface, participants frequently used gestures to communicate, but they also drew on the map to mark information they did not trust themselves to remember. For example, they usually marked the location of the crashes in the Leak and Fire scenarios, and the building locations in the Evacuation scenario. Participants who worked Face-to-face drew things less often, and often shared their paper maps. In the two virtual collaboration conditions, the Separate and Hand Images interfaces, participants would draw on the map except in very rare cases when they knew the metro area well enough to describe traffic options verbally.

Augmenting the interfaces. Participants would sometime use additional objects in their environment (external to the interfaces) for communication or as memory aids. For example, participants were given paper maps by the experimenters in order to quickly communicate the problem statement. However, in the Face-to-face condition, they sometimes communicated by

making marks on the paper map (marking buildings or drawing the sewer system) and showed it to their partners. In the Separate and Hand Images conditions, they sometimes used the paper maps as additional personal workspaces; they would study or made marks on the paper map instead of the shared electronic map. If there was a lot of information to communicate they sometimes made notes on paper, using the paper to augment their memory.

Matching communication mode to message. Participants tended to choose the communication method that was easiest for conveying particular types of information, for example:

1. *Numbers and words* were often written on paper when using the Face-to-face interface, as they were difficult to mark on the shared electronic map using the drawing interface.
2. *Temporary information* was often conveyed through gestures and words; participants avoided making a mark on the map which might clutter the map later (They could clear the map of all marks, but the interface did not allow them to erase individual marks).

Individual differences. There was much variation in how much the drawing interface was used – some drew extensively, others marked only a few things and discussed the problem verbally and recorded information on paper. This may be a reflection of individual preferences. For example, some participants preferred to think by drawing out the information. It is also possible that some needed to visualize the information because they did not know the Minneapolis metro area maps as well as other participants.

6.2 Time to Complete Task

For the Time to Complete Task, there was a significant main effect of interface, $p = 0.014$, $F(2,19.450) = 5.388$, and scenario, $p < 0.001$, $F(2,18.864) = 49.500$. There was also a significant interaction between interface and scenario, $p = 0.003$, $F(4,15.290) = 6.447$.

Figure 5 shows a graphical comparison of the interfaces. Participants competed the tasks significantly faster ($p = 0.013$) when working Face-to-face (Mean = 1230 s) than when using Hand Images (Mean = 1561 s). Comparing scenarios (see Figure 6 below), participants completed the Fire scenario (Mean = 891 s) significantly faster than the Evacuation scenario (Mean = 1675 s) or the Leak scenario (Mean = 1595 s). Figure 7 below illustrates the trends for the interaction.

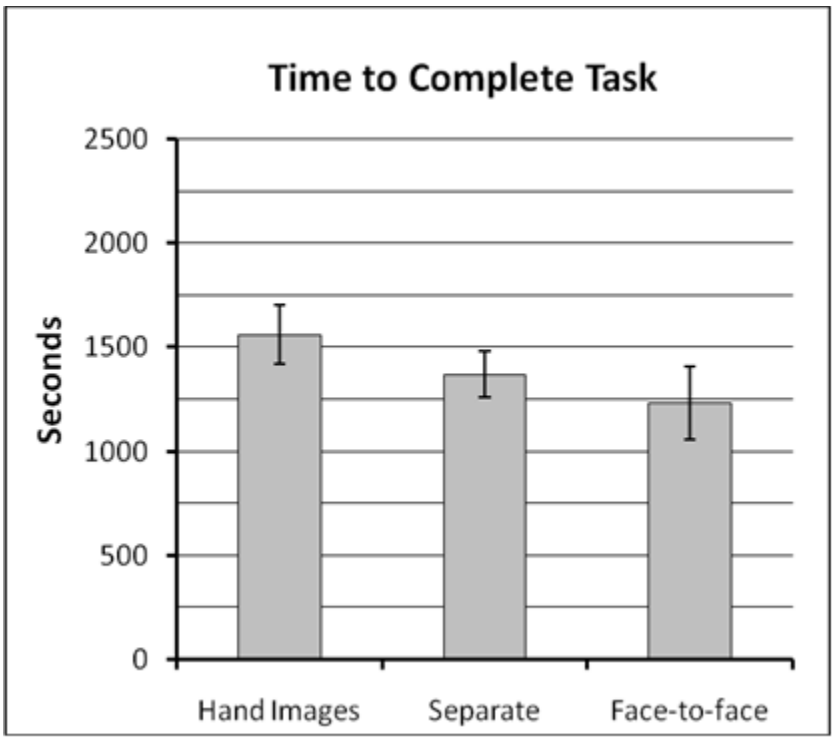

Figure 5: Time to complete task sorted by interface. Error bars show the 95% confidence interval for each mean.

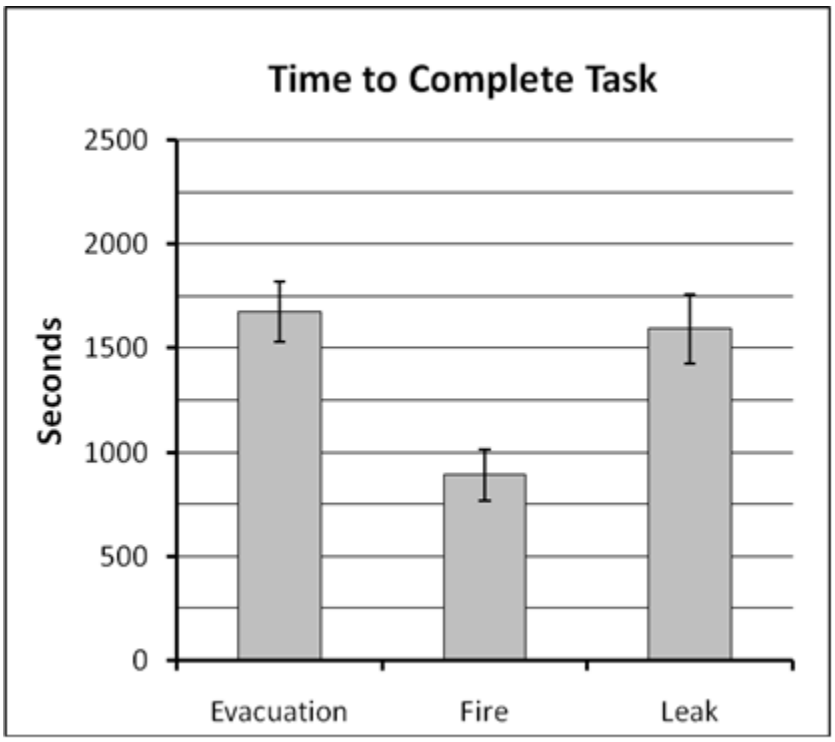

Figure 6: Time to complete task, sorted by scenario. Error bars show the 95% confidence interval for each mean.

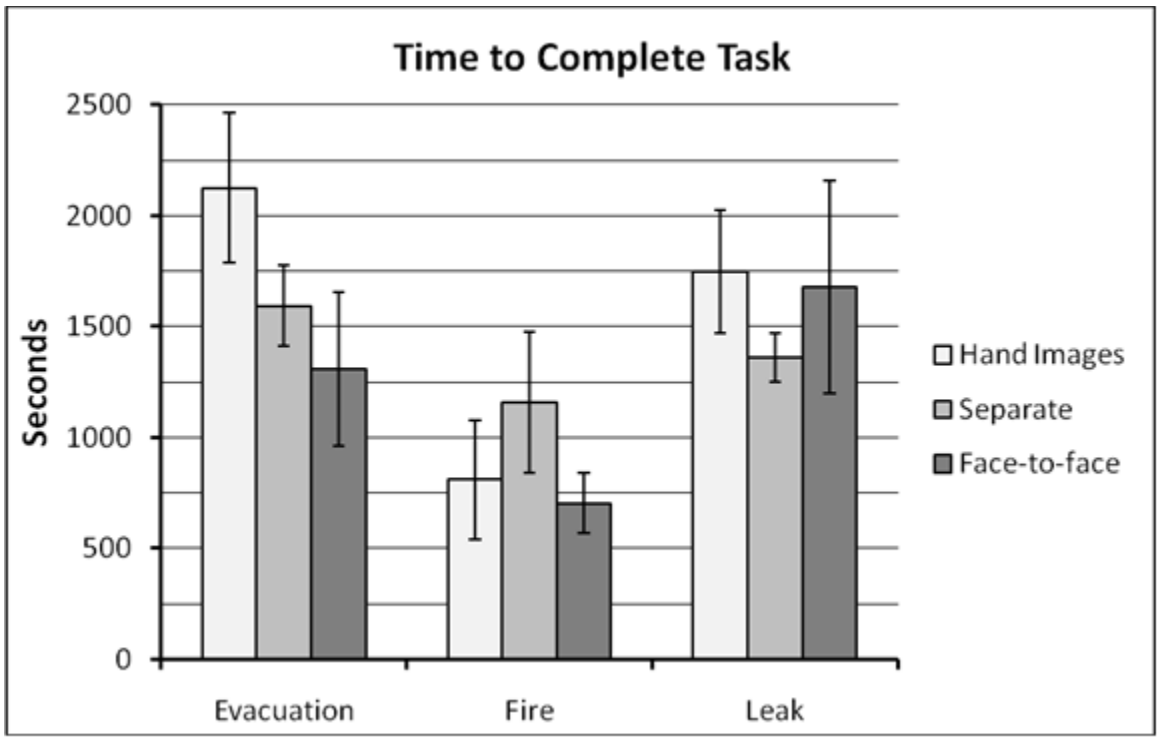

Figure 7: Illustration of interaction of scenario and interface for time to complete task. Error bars show the 95% confidence interval for each mean.

6.3 Aggregate NASA TLX Workload Measure

There was a significant main effect of interface, $p = 0.042$, $F(2, 19.488) = 3.756$. However, the pair wise comparisons revealed no significant differences between any particular pair of interfaces, so we do not interpret this to be a strong effect. However, some significant differences were revealed in some of the component measures making up the aggregate: time pressure and effort, described below.

6.4 Time Pressure

For the NASA-TLX measure of temporal demand (e.g. Time Pressure, see Figure 8 below), there was a significant main effect of interface, $p = 0.018$, $F(2,27.652) = 4.633$. Participants perceived significantly more time pressure when using Hand Images (Mean = 51) than when working Face-to-face (Mean = 28).

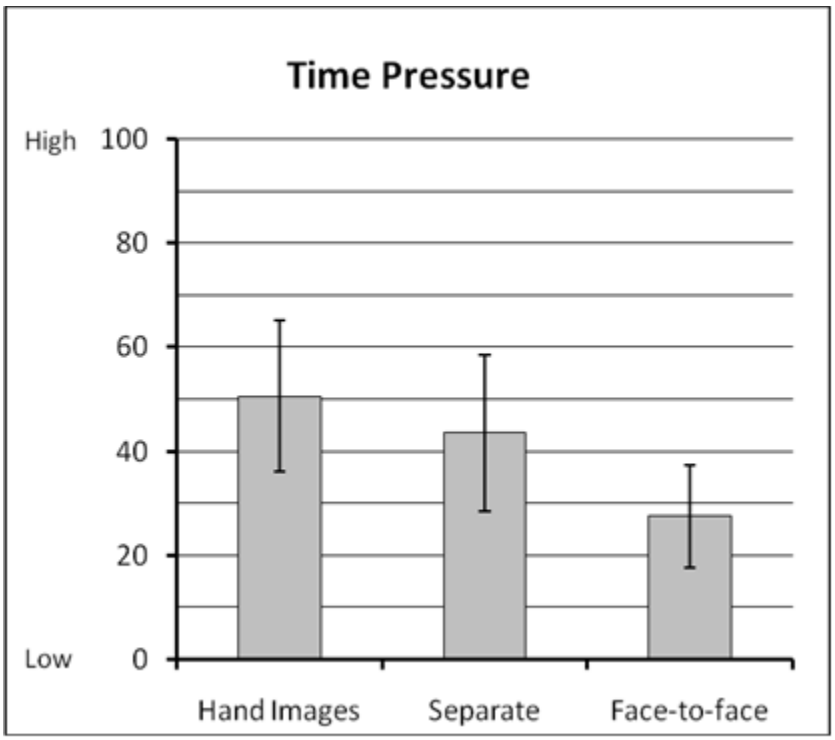

Figure 8: Time pressure sorted by interface. Error bars show the 95% confidence interval for each mean.

6.5 Effort

For the NASA-TLX measure of Effort (see Figure 9 below), there was a significant main effect of scenario, $p = 0.033$, $F(2,21.275) = 4.034$. Participants perceived that significantly more effort was required for solving the Evacuation scenario (Mean = 55) than for solving the Fire scenario (Mean = 39).

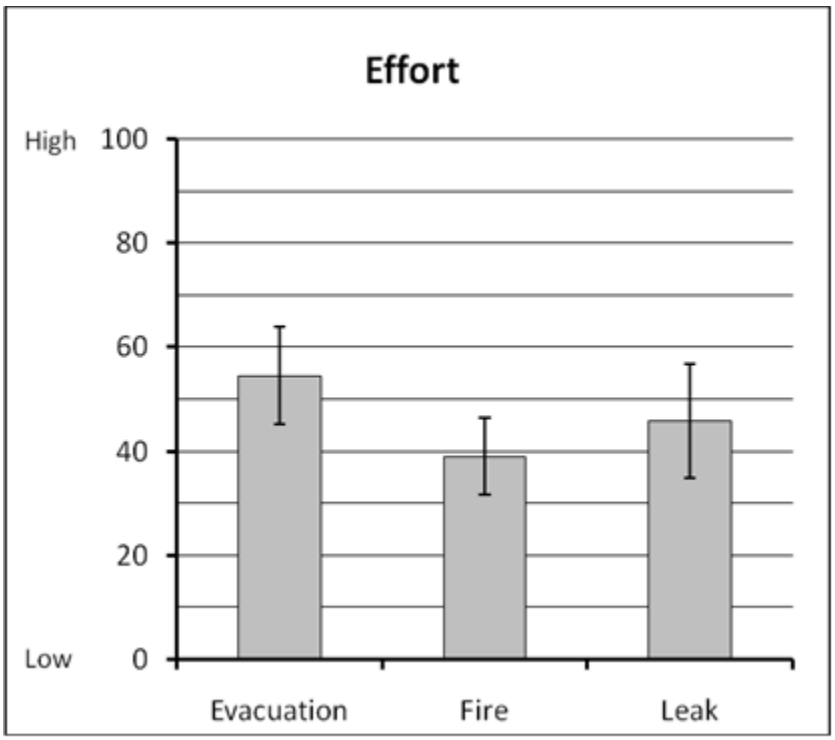

Figure 9: Effort sorted by scenario. Error bars show the 95% confidence interval for each mean.

6.6 Positive Interactions

Three questions were used in the "Positive Interactions" measure. They were questions 12 (encouragement), 14 (received positive feedback), and 18 (gave positive feedback). For the aggregate of the three Positive Interactions questions, there was a significant main effect of scenario, $p = 0.019$, $F(2,69.302) = 4.224$. There was also a significant interaction between interface and scenario, $p < 0.001$, $F(4,46.918) = 7.749$.

Figure 10 shows a graphical comparison of the scenarios. Participants perceived more positive interactions during the Evacuation scenario (Mean = 3.806) than the Leak scenario (Mean = 3.444). Figure 11 below illustrates the trends for the interaction.

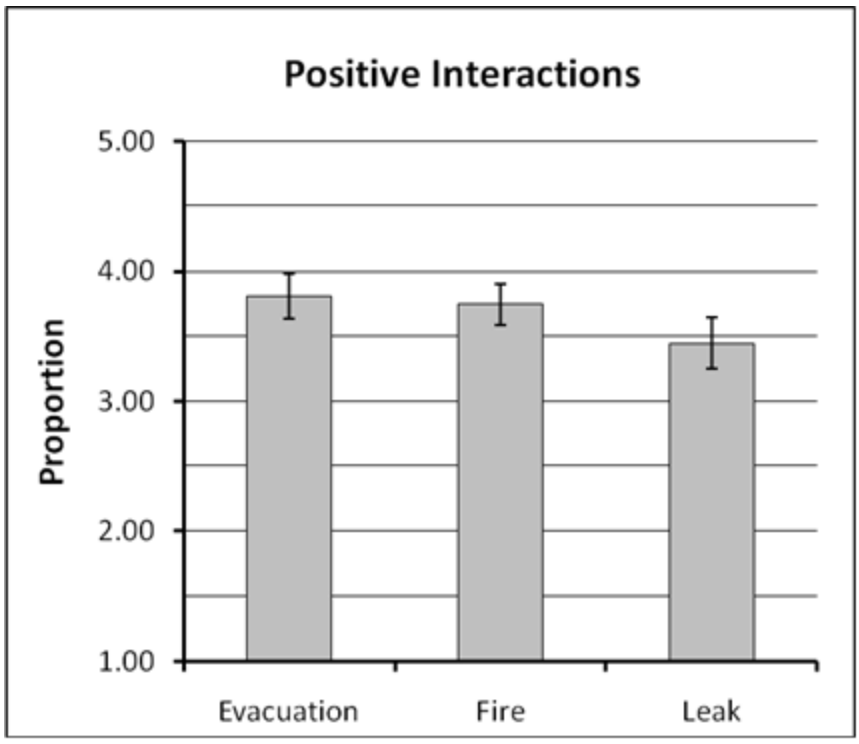

Figure 10: Positive interactions sorted by scenario. Error bars show the 95% confidence interval for each mean.

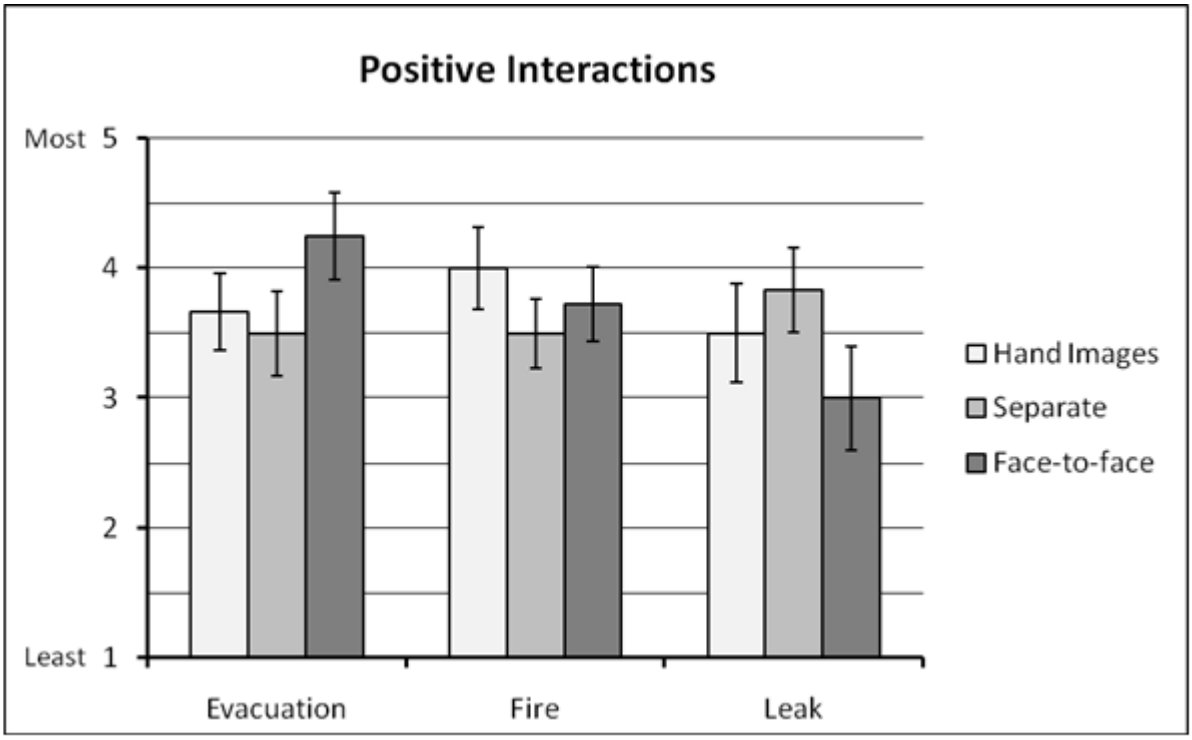

Figure 11: Illustration of interaction of scenario and interface for positive interactions. Error bars show the 95% confidence interval for each mean.

6.7 Encouragement

Encouragement was one of the component questions in the Positive Interactions measure. For Encouragement, there was a significant interaction between interface and scenario, $p = 0.006$, $F(4,19.985) = 5.021$. Figure 12 below illustrates the trends for the interaction.

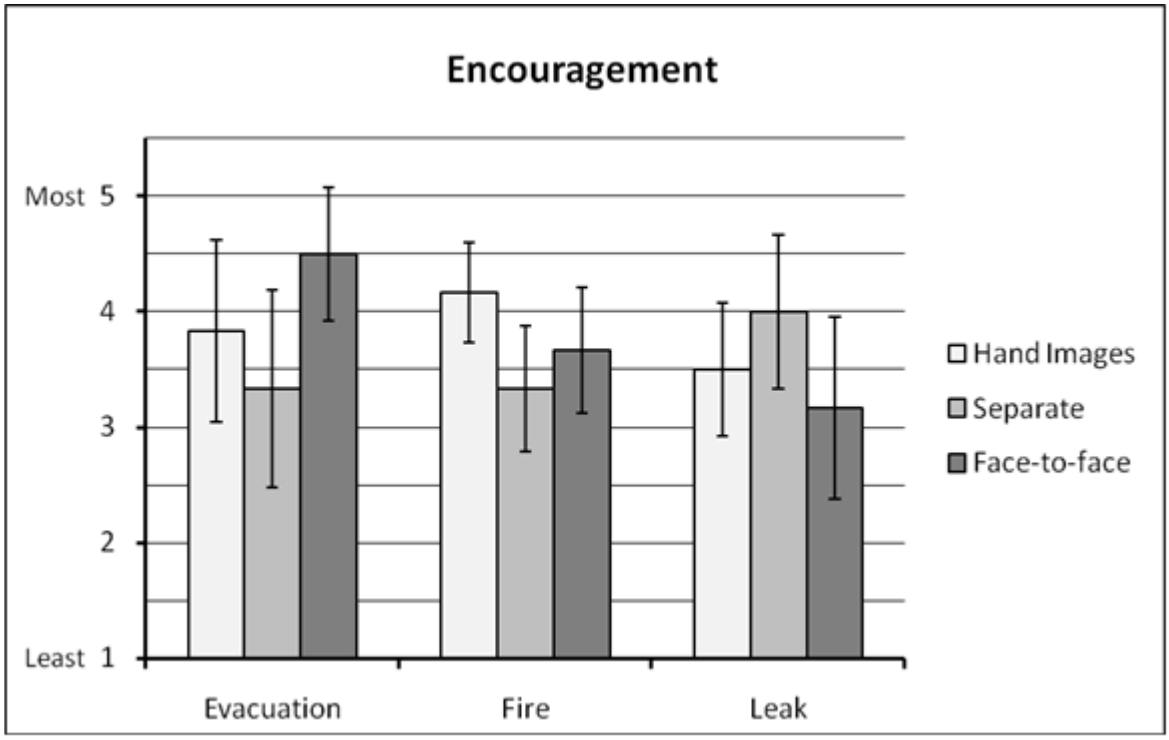

Figure 12: Illustration of interaction of scenario and interface for encouragement. Error bars show the 95% confidence interval for each mean.

6.8 Team Behaviors

Team Behaviors was measured by four questions: 8 (discussion quality), 9 (joint planning), 15 (team perception) and 16 (joint work). For the aggregate of the four Team Behaviors questions there was a significant main effect of interface, $p < 0.001$, $F(2,77.760) = 9.445$ (see Figure 13). Participants perceived significantly more teamwork when using the Hand Images interface (Mean = 4.250) than when using the Separate interface (Mean = 3.685) or the Face-to-face interface (Mean = 3.852). However, the analysis did not reveal more specifically what those team behaviors were, as we did not find significant differences in any of the individual components of this aggregate measure: discussion quality, joint planning, team perception and joint work.

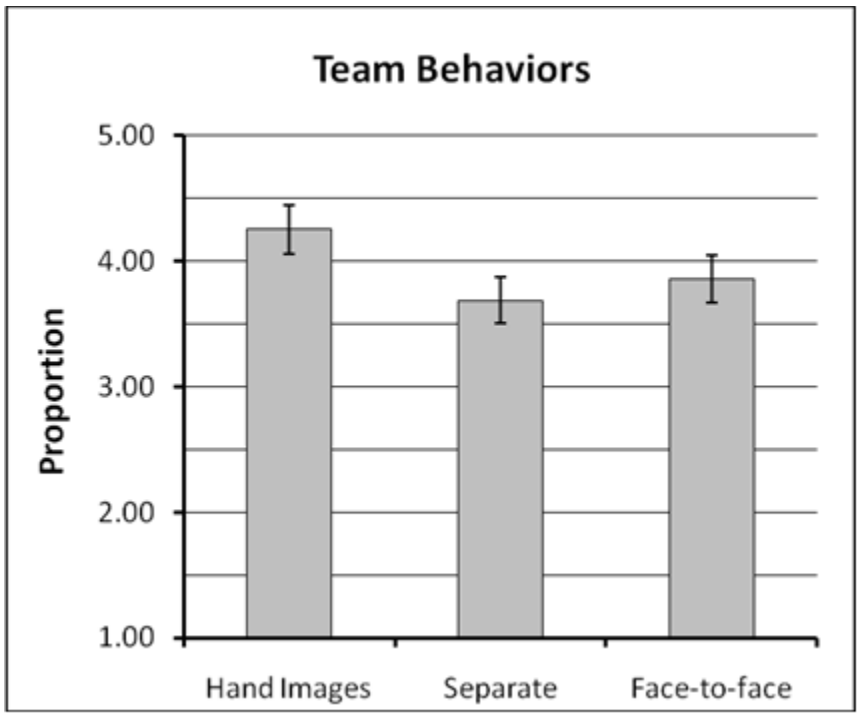

Figure 13: Team behaviors sorted by interface. Error bars show the 95% confidence interval for each mean.

6.9 Connection to Teammate

The three questions used to assess the Connection to Teammate measure: questions 11 (presence), 17 (social distance), and 19 (engagement). For the aggregate of the three questions there was a significant main effect of interface, $p < 0.001$, $F(2,67.212) = 18.444$. There was also a significant interaction between interface and scenario, $p = 0.029$, $F(4,46.568) = 2.978$.

Comparing interfaces (see Figure 14 below), participants felt significantly more connected when working Face-to-face (Mean = 4.537) than when using the Hand Images interface (Mean = 4.056) or the Separate interface (Mean = 3.722). Figure 15 illustrates the trends for the interaction.

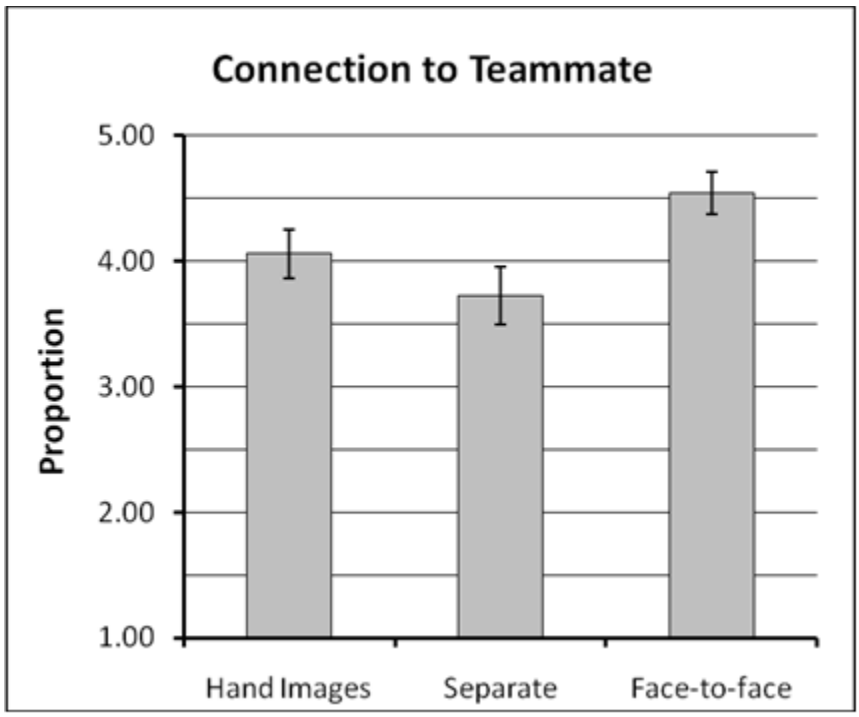

Figure 14: Connection to teammate sorted by interface. Error bars show the 95% confidence interval for each mean.

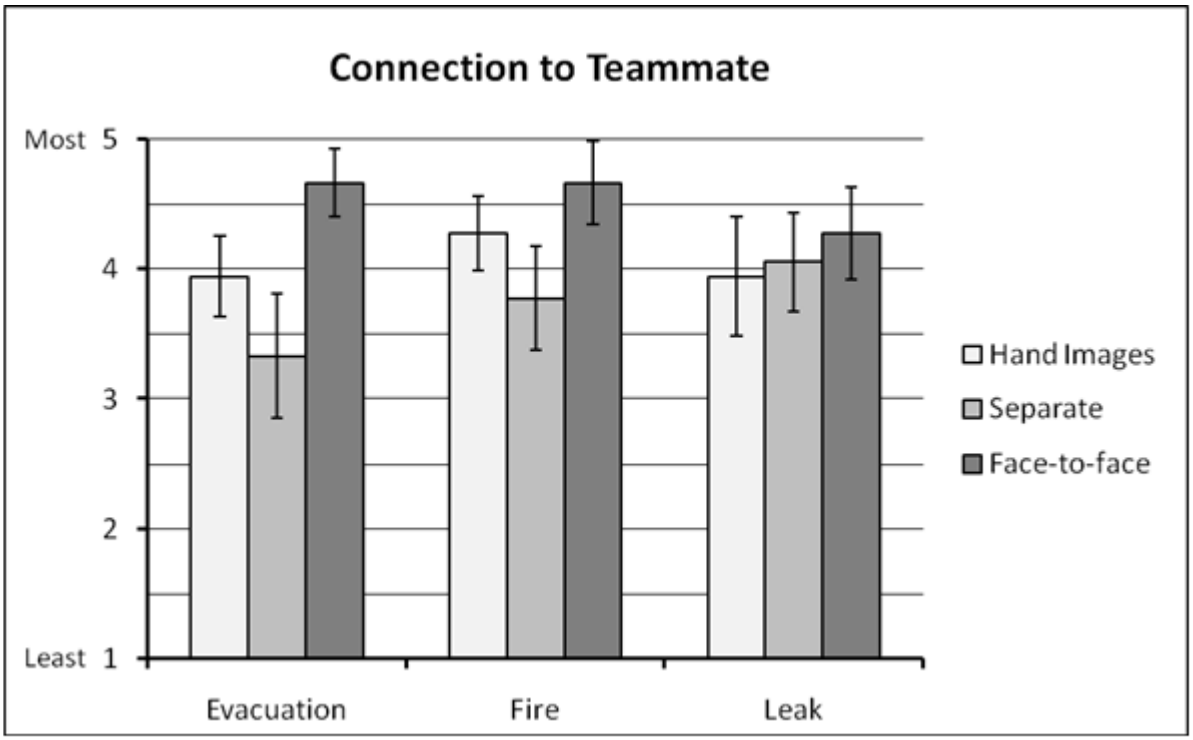

Figure 15: Illustration of interaction of scenario and interface for connection to teammate. Error bars show the 95% confidence interval for each mean.

6.10 Presence

The Presence question, question 11: "To what extent did you feel your teammate was at the same table with you?" was one of the three components in the "Connection to Teammate" measure: For the Presence question there was a significant main effect of interface, $p < 0.001$, $F(2,26.065) = 22.219$ (see Figure 16). Participants felt significantly more like their teammates were present at the same table when working Face-to-face (Mean = 4.6) than when Separate (Mean = 2.9) or when using the Hand Images (Mean = 3.4).

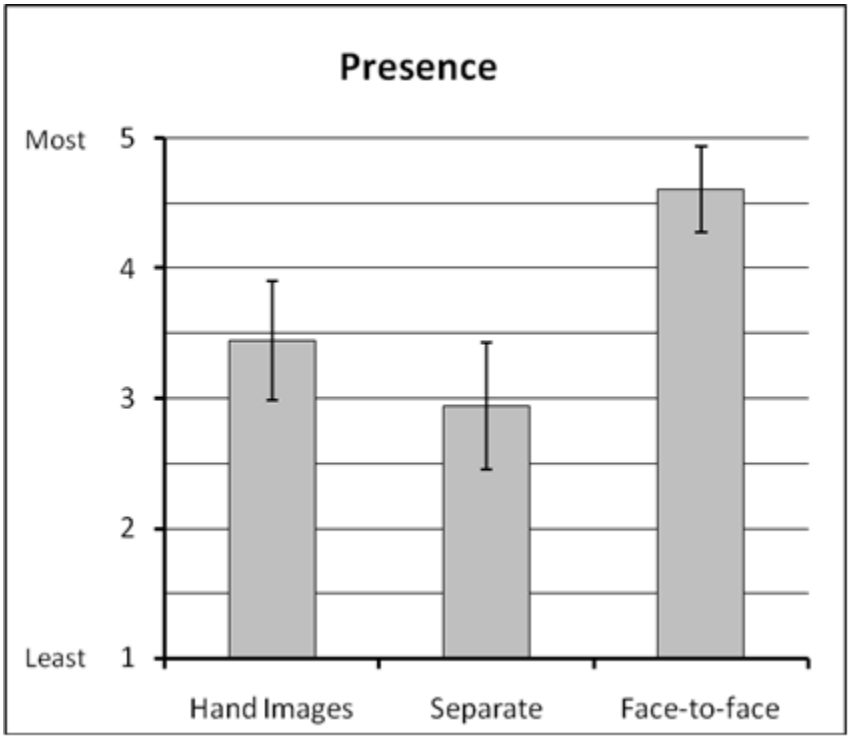

Figure 16: Presence sorted by interface. Error bars show the 95% confidence interval for each mean.

6.11 Social Distance

The Social Distance question, "I felt disconnected from my teammate," was one of the three components of the "Connection to Teammate" measure. For Social Distance (see Figure 17 below), there was a significant main effect of interface, $p = 0.001$, $F(2,25.279) = 9.289$. Participants felt significantly less socially distant from their teammates when working Face-to-face (Mean = 1.4) than when Separate (Mean = 2.4) or when using the Hand Images (Mean = 1.9).

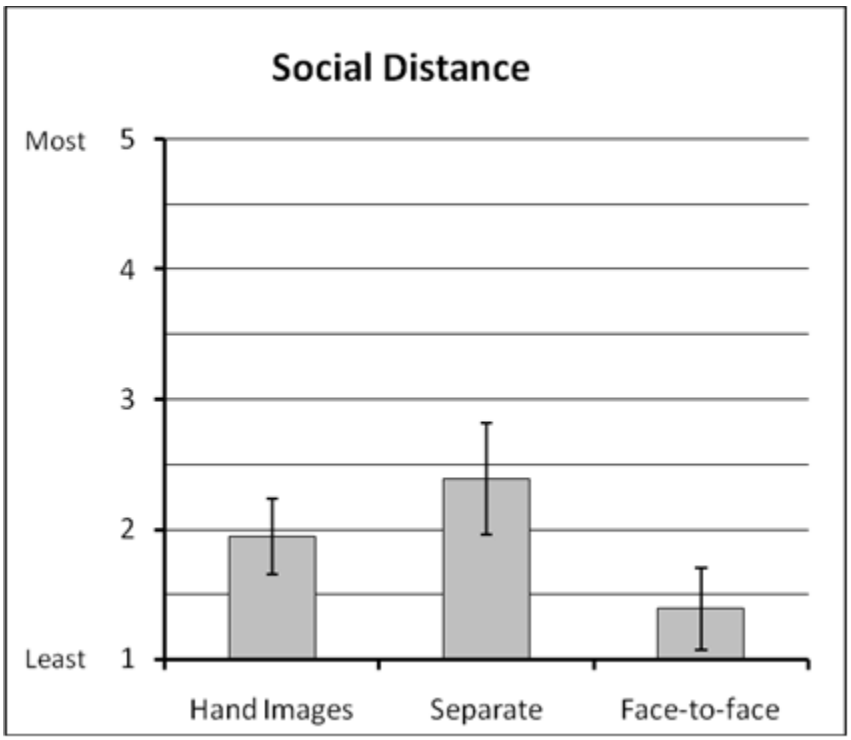

Figure 17: Social distance sorted by interface. Error bars show the 95% confidence interval for each mean.

Chapter 7. Summary and Discussion of NASA TLX and Questionnaire Data

Our primary interest was in determining which of the two virtual interfaces provided more benefits in the task of virtual management of major traffic incidents and disasters. These data suggest that the Hand Images interfaces significantly more support for team behaviors that did the Separate interface.

7.1 Comparison of the Two Virtual Collaboration Interfaces

We found that:

1. *Participants using the Hand Images interface reported significantly more team behaviors then when using the Separate interface.*

There were no other statistically significant differences between the two virtual interfaces: time required to develop a solution, the six NASA TLX measures of workload, perceptions of positive interactions, perceptions of connection to distant teammates, or sources of frustration. Thus, we conclude that the addition of hand images to the virtual interface did provide better support for virtual interactions in management of traffic incidents and disasters.

7.2 Comparison of the Virtual and Face-to-Face Interfaces

While our primary interest was in comparing the two virtual interfaces, we additionally compared both virtual interfaces to the Face-to-face interface because face-to-face interactions represents a baseline, and a type of a "gold standard." Our working hypothesis was that face-to-face interactions are better than virtual interactions in most or all respects, not only because are people used to working face-to-face, but the environment and modes of communication that people share when they really are in the same room together as so much richer than any shared virtual environment. Our objective was to better understand in what respects each of the virtual interfaces were different from face-to-face interactions, and to what degree. We found that:

2. W*hen working face-to-face, participants felt significantly more connection to their teammates* than they did when using either of the virtual interfaces, (as expected).

However, contrary to expectations, we found that:

3. *When using the Hand Images interface, participants reported a) significantly more team behaviors, and were b) significantly slower to complete tasks, and* c) *perceived significantly more time pressure than the when using face-to-face interface.*

7.3 Discussion

Some of these results were expected and others were not. For example, we anticipated that participants would feel more connected when working face-to-face than when using either of the virtual interfaces. However, we did *not* anticipate that the Hand Images interface resulted in even more team behaviors than the Face-to-face interface. We had assumed that Face-to-face

was the standard for "best" in all respects, and that it was not possible to do better. Face-to-face interactions are more familiar and provide a greater number of higher quality communication channels. For example, when seated face-to-face at the same table participants can see each other's faces and read facial expressions; the whole upper torso and more of the collaborator's environment can be seen; everything is seen in the highest perceptible resolution; there are no time delays when watching the gestures of a real person, and one can also read their facial expressions. Thus, with all the advantages of a face-to-face environment, it was not obvious why the virtual Hand Images interface should result in greater team behaviors.

We were also surprised by some of the differences which we did *not* find. For example, we were surprised to find no significant differences between the Hand Images and the Separate interfaces with respect to the 6 NASA TLX measures. These results are quite different from those found for virtual collaboration in design tasks (Cornelius et al. 2013) where virtual collaboration became significantly easier with the addition of hand images, making it indistinguishable from face-to-face collaboration in all 6 of the NASA TLX measures. However, without further analysis it was not clear *why* these two different task domains yielded such different results – particularly since we used the exact same physical test bed that was used in Cornelius' experiment, and the same software, with one addition. Cornelius used only two layers: drawing and hand images, and the current study used three layers: drawing, hand images and maps. Comparison to the face-to-face baseline made it clear that the issue was *not* that the Hand Images interface failed to improve workload, but that there was no increase in workload associated with the Separate interface like that found by Cornelius.

There are many possible explanations for why there were no differences found for any of the NASA TLX measures between the Separate and Hand Images interfaces. This might represent a difference between the domains of conceptual product design and traffic incident management. Perhaps traffic engineers who manage traffic incidents and disasters do not need gestures as much as engineering designers need them -- perhaps traffic engineers can refer to intersections and detour routes as easily by describing them verbally as they can by pointing to them. Alternatively, the difference may not be in the domains per se, but in the nature of the tasks used in each of the two experiments. The conceptual design tasks used in (Cornelius, et al. 2013) were very open ended, and required subjects to generate, discuss and compare multiple alternative solutions. In contrast, the tasks used for traffic incident management involved only the discussion and comparison of alternatives given to the participants. Although these tasks started out as open ended tasks, we simplified them after the pilot study because it was taking subjects too long to complete each task. However, the simpler tasks eliminated the brain storming aspects of the tasks; rapid brain storming may be one of the times when gestures are most useful for rapidly, if temporarily, describing many ideas.

Regardless of the reasons, more analysis and possibly further studies are needed in order to understand the underlying reasons for the different results between these two studies.

7.4 Next Analysis Steps

The next phase of analysis, video content analysis, was aimed at understanding *if* the availability of hand images to make gestures changed the way in which people communicated, and if so, *in what ways*? The examination and analysis of the videos may also provide insights into the

reasons underlying the results, expected or unexpected. We were also concerned about whether various aspects of our experimental setup may have unintentionally affected the results. For example, problem statements given to participants included paper maps with markings on them to show the location of the traffic incidents in each task. We noted that in some cases participants frequently gazed at or drew on these paper maps although we never intended for them to perform their actual work on these sheets of paper. Might this unexpected use of the paper map have reduced the time participants spent using the shared virtual/electronic interface? The next section will describe the content analysis of the video, and how we arrived at the approach used.

7.5 Additional Questions

In order to better understand how participants used the interfaces we examined the specific questions:

A. Were the participants actually using the shared electronic map interface? In other words, were they primarily working with the paper maps or other materials *outside* the interface, and communicating primarily by speaking in the virtual conditions?
B. Were there differences in the way participants spent their time when using the different interfaces?

7.6 Future Work

During the course of the study, it became clear that it would have been helpful to have one or more questionnaire items addressing frustration with the interface, not just frustration with the task and teammate. We observed that participants would sometimes struggle with the interface, for example making several attempts to draw a line or selecting the wrong drawing tool by mistake. It would be useful to have questions to measure these difficulties.

Chapter 8. Content Analysis of Participant Videos

8.1 Method

8.1.1 Videos

During the experiment, we recorded videos of each participant. For each pair of participants we recorded 5 videos; one on each side of the soft wall in the two virtual collaboration conditions (Separate and Hand Images), and one of the two participants sitting side-by-side in the Face-to-face condition. However, for coding purposes the coders coded the Face-to-face video twice; once for each participant. Thus, there were 6 coding tasks for each of the 9 pairs of participants, for a total of 54 coding tasks (though there were only 45 videos).

8.1.2 Coders

We asked three coders to code these videos. One of the coders was one of the experimenters, one was one of the software developers, and one was from outside the project.

8.1.3 Division of Labor

Coding videos can be very labor intensive. While it was necessary to divide up the coding tasks among the coders to complete this large task, there were videos which all three coders coded so as to evaluate consistency between coders. Videos for all 3 conditions for 3 participant pairs were coded by all three coders. Thus, 18 of the 54 video coding tasks were completed by all 3 coders. The remaining tasks were divided evenly among the 3 coders. Thus, each coder coded 30 video coding tasks.

8.1.4 Process

Multiple passes were made through the videos.

1. Initially, the coders each independently made a first pass through the videos to identify what actions participants actually engaged in, and to develop coding categories. We did not first divide the videos into segments, and then ask them to categorize the segments, because doing so presupposes that one has a well defined idea of what the categories (and associated video segments) should be. We wanted to let the coders determine this.
2. After the first pass through a few videos, the whole research group met to discuss what had been found so far, what the coding categories should be, what granularity of analysis made sense, and how to determine categories in ambiguous cases.
3. The coders, now armed with an updated set of coding categories, independently re-coded the videos.
4. We created a spread sheet to record the results for the 18 video coding tasks which were completed by all three coders. The spread sheet recorded the amount of total time (in seconds) dedicated to each category for a given video.
5. Once we determined that there was a high level of agreement between coders, the coders were each asked to independently code the remaining videos, which were each assigned to only one coder. During the coding process, the coders excluded time spent to resolve

technical problems with the experiment equipment. Also excluded was the time the participants spent explaining the scenario solution they had decided upon.

8.2 Coding Categories

We developed coding categories as commonly occurring combinations of activities (e.g. speaking and gesturing, speaking and marking, etc.) which could occur either inside the shared virtual interface, or outside of it. This analysis allowed us to assess to what degree the participants used the shared map interface, and whether the interface changed the way in which participants communicated information to each other by answering the questions:

- To what extent did participants use the shared collaborative interfaces to communicate to their partners?
- How was time spent? To what extent did the various interfaces change the amount of speaking, drawing, and gesturing done by each participant? For example, did they to gesture more when they knew their partner could see their hands?

Since one of our goals was to determine how often participants worked inside the shared virtual workspace (i.e. the electronic map interface, seen as the bright, projected rectangular image in the figures below in *8.2.3 Examples from the content analysis*) versus outside the shared workspace (i.e. anything outside the bright projected rectangle), we developed categorizations to reflect the types of activities that subjects performed inside and outside the shared virtual workspace. The first viewing of the videos was used to identify activities and develop categories to describe those activities, whether the activities were performed separately or in combination.

8.2.1 Activities

- **Gazing** or focusing attention at some location
  - *inside* or
  - *outside* the shared interface,
- **Speaking.** Gaze was used as in indicator of where the participant's attention was focused while speaking,
- **Gesturing**, either
  - *inside* the shared interface (these gestures can be seen by the partner in the Hand Images condition or the Face-to-face condition) or
  - *outside* the shared interface (these gestures cannot be seen by the partner except in the Face-to-face condition).
- **Marking** (drawing or writing; zooming and panning the electronic map was included in this category)
  - *inside* the shared interface (these markings can be seen by the partner), or
  - *outside* the electronic map, for example on paper. (These markings cannot be seen by the partner except in the Face-to-face condition.)

- **Manipulate.** Manipulate was used to indicate when participants used objects (inside or outside the interface) other than a pen, such as rulers or calculators.
    - *inside* the shared interface (the manipulation can be seen by the partner in the Hand Images condition or the Face-to-face condition), or
    - *outside* the interface (the manipulation cannot be seen by the partner except in the Face-to-face condition).

These 5 activities could be combined in many ways. We coded the videos according to the combinations of activities that participants performed. While the total number of possible combinations of 5 activities is the power set (e.g. the set of all subsets of the 5 activities, which is computed by $2^5 = 32$), we only used 8 of the 32 possible activity combinations for coding purposes, as described below. Additionally, these activity combinations could be divided into *inside* the shared virtual workspace and *outside*; thus, 64 total coding categories were possible, but we chose to use only 16 of them.

We did so in order to make the coding task manageable, control the detail of the analysis (keeping it at the formative level), and to focus on the categories that would inform the research questions of interest to us. Some categories provided more detail than was relevant, some did not occur, and others occurred only with very low frequency.

For example, participants were always gazing somewhere when they performed other activities; we never observed them to draw or point with their eyes shut (at least in this study). Sometimes they silently gazed at a point either inside or outside the shared virtual workspace without doing anything else, possibly for long periods of time. This typically indicated listening or thinking. Some combinations of activities were physically impossible; participants never performed all 5 activities simultaneously because they only have two hands, thus they never tried to gaze, speak, draw, point and manipulate the ruler or calculator all at the same time. That would have necessitated holding the calculator with their toes, or in their teeth which would have interfered with speaking.

8.2.2 Categories

We used the following activity combinations to code the videos:

- **Inside** the shared workspace (i.e. electronic map):
    1. **Gaze** only,
    2. **Manipulate**: Gaze and manipulate objects (i.e., objects other than the pen, such as a ruler, calculator, paper, or other objects from the room that were not part of the computer interface, and which did not involve writing or drawing),
    3. **Speak**: Gaze and speak,
    4. **Mark**: Gaze and mark (e.g. drawing, selecting interface options, moving the interface, or writing on paper),
    5. **Gesture**: Gaze and gesture,
    6. **Gesture & speak**: Gaze, speak, and gesture,
    7. **Mark & speak**: Gaze, speak, and mark,
    8. **Manipulate & speak**: Gaze, speak, and manipulate objects.

- **Outside** the shared workspace:
  9. **Gaze** only,
  10. **Manipulate**: Gaze and manipulate objects (i.e., objects other than the pen, such as a ruler, calculator, paper, or other objects from the room that were not part of the computer interface, and which did not involve writing or drawing),
  11. **Speak**: Gaze and speak,
  12. **Mark**: Gaze and mark (e.g. drawing, selecting interface options, moving the interface, or writing on paper),
  13. **Gesture**: Gaze and gesture,
  14. **Gesture & speak**: Gaze, speak, and gesture,
  15. **Mark & speak**: Gazing, speaking, and mark,
  16. **Manipulate & speak**: Gaze, speak, and manipulate objects.

8.2.3 Examples from the Content Analysis

Occasionally participants engaged in activity combinations not explicitly covered by these categories. For example, Figure 19 shows a snap shot of a participant gazing outside the shared virtual workspace, but pointing to something inside it (on the map). In categorizing such difficult-to-classify examples, we were strongly guided by the direction of the participant's gaze (indicating focus of attention) and the predominant activity requiring the most attention -- if multiple activities were carried out simultaneously. For example:

- *In Figure 18*, the participant is speaking while gazing inside the electronic workspace, but she is drawing with one hand and pointing with the other. However, her attention was primarily focused on what she was drawing; she appeared to be using the pointing gesture mainly as a "placeholder" on the map while she looked at what her other hand was drawing. This was categorized as Inside: Mark & Speak.
- *In Figure 19,* the participant silently points to something on the shared electronic map (again, as a placeholder) while gazing at the problem description on a piece of paper placed outside the shared virtual workspace. Since her attention is outside the shared virtual workspace this was categorized as: Outside: Gaze.
- *In Figure 20*, the participant is talking while gazing *inside* the shared electronic workspace, while pointing at something on paper *outside* the shared workspace. Since her attention was focused inside the shared workspace, this was categorized as Inside: Speak.
- *In Figure 21*, the participant gazes and points at *two* different locations in the shared electronic workspace, while speaking. This was categorized as Inside: Gesture & Speak.
- *In Figure 22,* the participant gives a triumphant "thumbs up" gesture to indicate success in completing the task. But he does so outside the shared virtual workspace, thus, his partner cannot see this gesture. (Perhaps he intended the gesture to be seen by the experimenter?) This was categorized as Outside: Gesture.
- *In Figure 23,* participant 6 has paused briefly from writing on paper with his right hand to point to the interface using his left hand, and participant 5 points to the interface as well. Participant 5 is also speaking. Participant 5 was categorized as Inside: Gesture and participant 6 was categorized as Inside: Gesture & Speak.

These examples illustrate not only the challenges of coding and categorizing actions, but also the complexity and richness of the many ways in which the participants used the interfaces. Participants often used the interfaces in ways that were more complex than the designers had anticipated. For example, we had expected that participants would either gesture *or* draw, but not both. However, they often drew and gestured simultaneously, as shown in Figure 18. Nor did we expect participants to make two separate gestures simultaneously, as in Figure 21 where the participant points to two different places on the map at once. As another example, we expected that participants would either work inside *or* outside the shared workspace, but not both simultaneously. However, they occasionally gestured inside while gazing outside or vice versa, as shown in Figure 19 and Figure 20. Nor did we anticipate the use of gestures as placeholders in one part of the workspace, while attention was focused elsewhere.

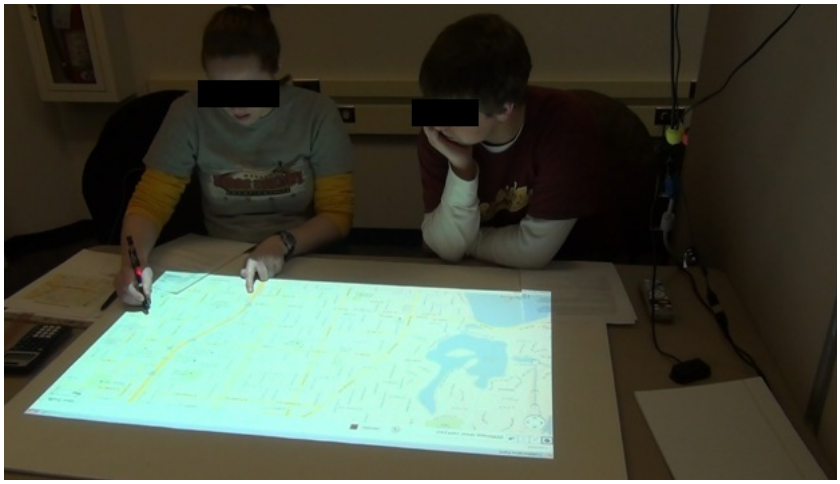

Figure 18: Participant 3 gazes and speaks while simultaneously drawing and gesturing (pointing) to a location on the electronic map. Participant 4 listens while gazing at partner's hands. (Fire scenario, Face-to-face interface).

Figure 19: Participant 3 points to a location on the shared electronic map interface while gazing outside the shared workspace at text on paper. (Leak scenario, Hand Images interface.)

Figure 20: Participant 3 speaks while gazing at the shared map and pointing to text outside the shared workspace, possibly as a placeholder in the text (leak scenario, hand images interface).

Figure 21: Participant 3 speaks and points to two different locations on the electronic map, while participant 4 gazes at the text on the paper in front of him (fire scenario, face-to-face interface).

Figure 22: Participant 4 makes a "thumbs up" gesture for the experimenter (not visible to partner) to indicate that the scenario is completed and the solution is satisfactory. This is an example of an emblematic gesture (Cassel, et al. 2000).

Figure 23: Participants 5 and 6 both simultaneously point to locations on the shared electronic map while participant 6 listens to participant 5 speak. Participant 6 has paused from writing to point at the map. This video was coded twice (once for each participant) as "Inside: Gesture," and "Inside: Gesture & Speak."

8.3 Statistical Analysis

The dependent variable for this analysis was the proportion of time the participants spent inside the shared interface when solving each scenario. A 3 x 3 mixed-model analysis of variance (ANOVA) was performed using the interface and scenario as within-subjects variables (Interface: Face-to-face, Separate, Hand Images) (scenario: Leak, Fire, Evacuation). For variables that showed a significant main effect, a post-hoc comparison was performed on the estimated marginal means using a Bonferroni correction. Differences between means were considered significant at the $p \leq 0.05$ level.

Chapter 9. Results of the Video Content Analysis

The results of the video content analysis revealed in what activities participants were engaged, for how much of the time, and to what degree the interface may have changed how they spent their time using the 16 coding categories defined in the previous chapter.

9.1 Were Participants Actually Using the Shared Electronic Interface?

Figure 24 shows for each interface the breakdown of time spent "inside versus "outside" the shared electronic interface (note: the total times in Figure 24 do not include equipment difficulties or time spent explaining the solution, and thus are different from the times in Figure 5). *Inside* means they were gazing or working inside the projected rectangle on the table. *Outside* means they were gazing or working with objects on the table outside the projected map. These objects could include the paper maps, problem statement, hand written notes, calculator, or ruler. In the Face-to-face condition, participants could also gaze at the other participant.

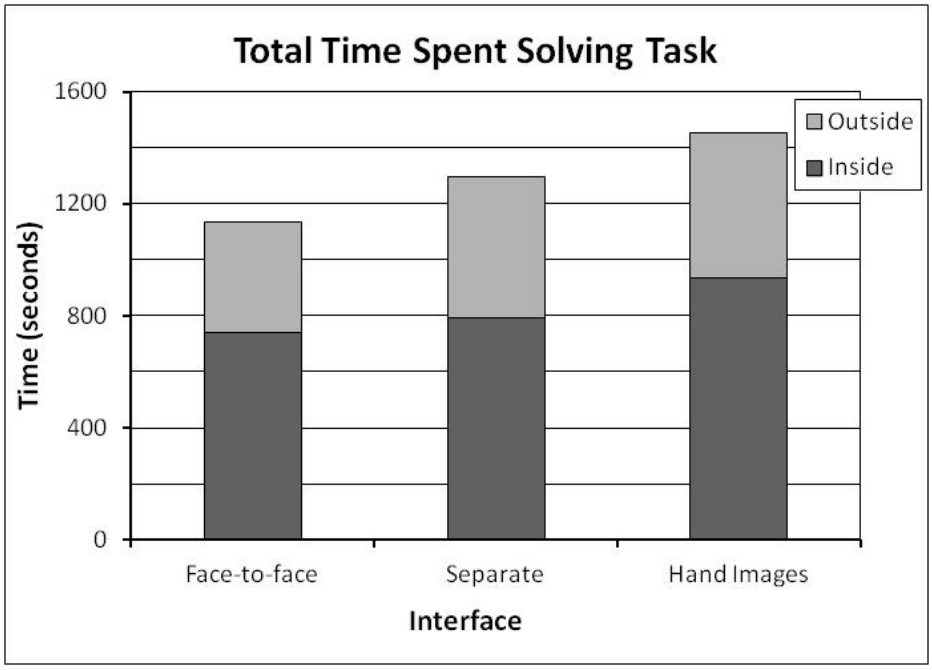

Figure 24: Time in seconds spent gazing and working inside and outside the shared electronic interface.

Figure 25 shows the average proportion of time spent gazing or working *inside* the shared electronic interface (determined by first calculating this proportion for each participant for each video, and then calculating the mean across all participants). There were no significant differences between the interfaces. In all cases, participants spent more than half their time working inside the shared electronic interface.

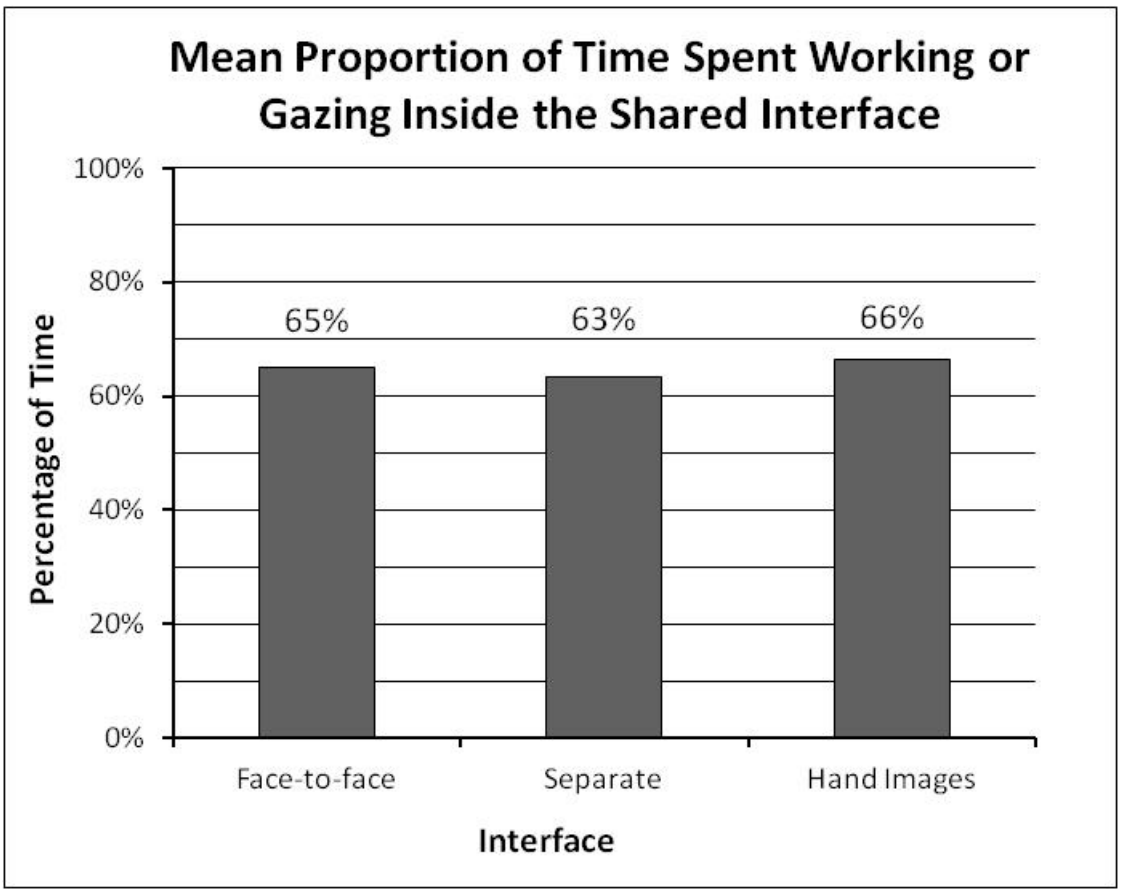

Figure 25: Mean proportion of time spent gazing and working inside the shared electronic interface.

If indeed participants in the virtual conditions (Separate and Hand Images), were communicating primarily by speech alone, and *not* frequently using the shared electronic interface, it might explain why there were no significant differences in the NASA TLX measures for these two conditions. Additionally, we wanted to understand to what extent the virtual participants worked in a "private," non-shared area which was *not* viewed by their partner (e.g. on a paper map or a sheet of notes) versus in a shared "public" area in which the partner could see everything they did. Note that in the Face-to-face condition, the concepts of "inside = public" and "outside = private" become more difficult to define because both partners could see almost everything the other did regardless of whether it was inside or outside the interface.

However, based on the data shown in Figure 24 and Figure 25, we concluded that participants *were* using the shared electronic interface in all three conditions. Furthermore, there were no significant differences between the interfaces in terms of the proportion of time they spent inside versus outside the electronic interface (Figure 25). In all conditions, participants spent between 63% and 66% of their time working inside the shared electronic interface.

We had not expected this to be true for the face-to-face condition. We had instead anticipated that participants would spend proportionately more time working outside the interface when they were on the same side of the soft wall (i.e. Face-to-face) than when they were on opposite sides

of the wall (i.e. Separate or Hand Images). We assumed this because participants working face-to-face had many ways to communicate that did not require using the shared electronic interface. They could see almost everything their partner did regardless of whether they gestured or drew on the electronic interface. They could just as easily work together on the paper map. In contrast, we assumed that participants seated on opposite sides of the wall would rely more heavily on the shared interface since they had no other means to communicate visually. However, the interface did not appear to change the proportion of time spent using the shared electronic interface.

Based on these results, we conclude that the participants were, in fact, using the shared virtual interface a substantial proportion of the time.

9.2 How was Time Spent?

Were there differences in the way participants spent their time when using the different interfaces? Figure 26 shows a break-down by interface, of how participants spent their time in seconds. The 16 coding categories defined in the previous chapter have been collapsed into 8 by combining "inside" and "outside" time for each activity combination such as "Gaze" or "Gesture and Speak," etc. We felt this bundling would make it easier for the reader to see an overview of behaviors. A star * over a bar in the graph indicates a bar that is significantly different from both bars in its grouping; a star between two bars indicates a significant difference only between those two bars.

Thus, in the face-to-face condition, participants spent significantly *less* time speaking, **and then** in the other conditions; significantly *more* time gesturing (while speaking) and *less* time marking than in the Separate condition. There are no significant differences between Face-to-face and Hand Images in the total time spent gesturing (while speaking).

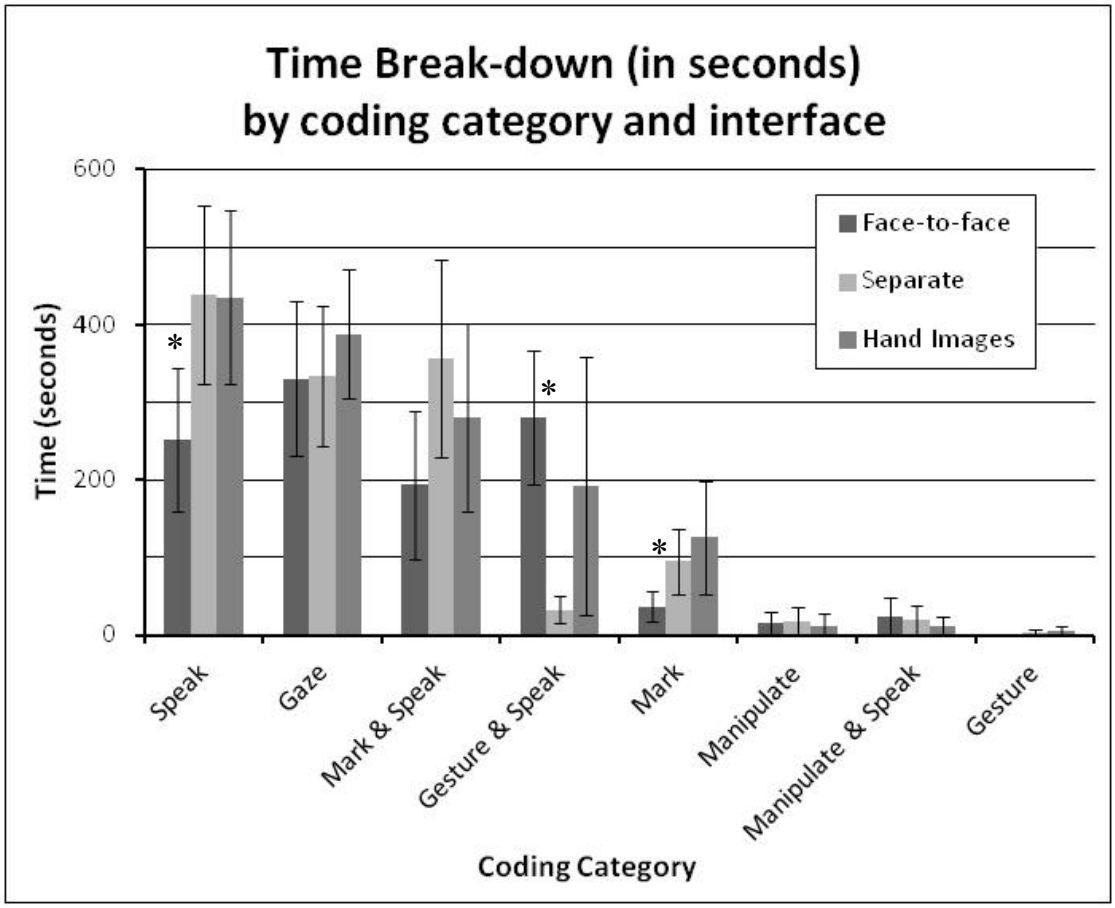

Figure 26: Time spent in each activity combination.

Participants using the Hand images interface appeared to spend less time doing everything except gesturing (while speaking). They appeared to be more efficient at communicating and working. The reason for their efficiency may be that:

- Gesturing & speaking is a more efficient form of communication in this domain than the other available forms of communication such as speaking (e.g. describing intersections and routes verbally) of marking (e.g. drawing a route on the map as one describes it), or
- The richer, higher resolution, higher bandwidth environment in which face-to-face interactions take place makes all communications more efficient, or
- Both.

Figure 27 presents the same as Figure 26, but shows it as a proportion of time spent in each activity, rather than as time in seconds. A star * over a bar in the graph indicates a bar that is significantly different (alpha =0.05) from the other two bars in its grouping. A plus + between two bars indicates a marginally significant difference between them (alpha = 0.1).

Thus, participants using the Face-to-face interface spent a marginally *smaller* proportion of their time just speaking, and marking and speaking than when using the Separate interface; and a

significantly *larger* proportion of their time gesturing (while speaking) than in the two virtual conditions.

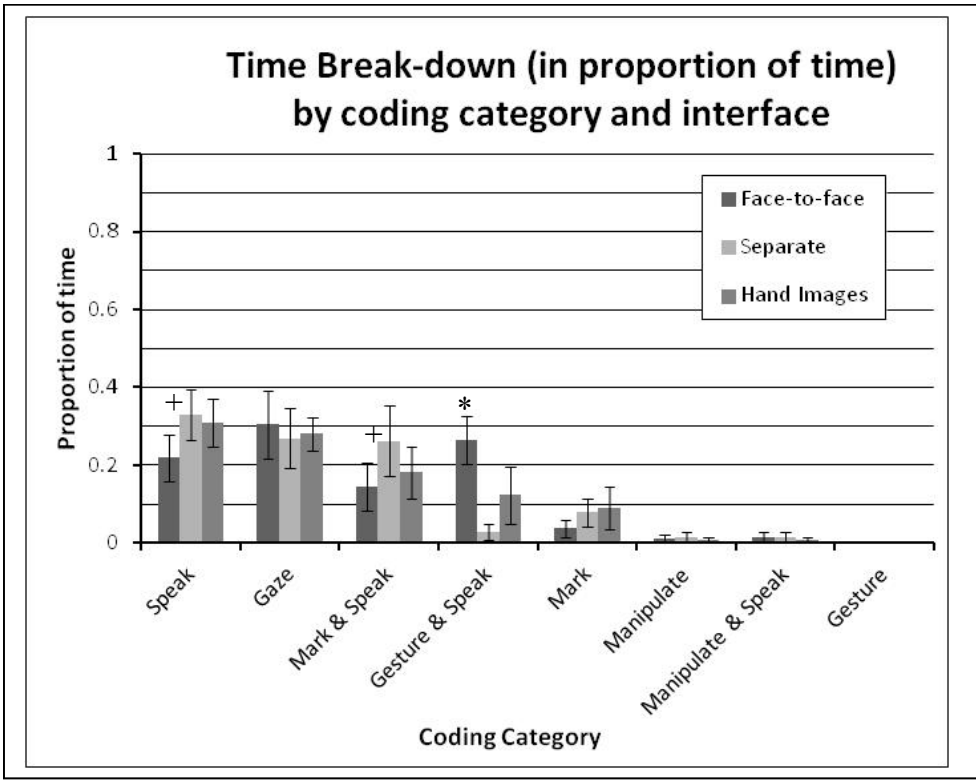

Figure 27: The proportion of time spent in each activity combination.

9.3 Discussion of Video Content Analysis

These two figures make several things clear. First of all, in all conditions participants spent much of their time speaking (only), or just gazing silently at something while thinking or listening to the other participant (like the participant in Figure 21 on the right). Much time was spent in verbal exchanges. Secondly, participants rarely did anything without also talking. They only sometimes marked (e.g. drew on the map or wrote notes) without also explaining what they were doing and they almost never gestured without also saying something.

Figure 5 in the prior chapter showed that participants using the Hand Images interface spent more total time solving problems than when they used the Face-to-face interface. Figure 26 provides some insights as to where they were spending that extra time. When using the Hand Images interface participants spent more time in most activities, except for gesturing while speaking, although not always significantly more. It could be that the additional effort required to communicate and articulate information when virtually collaborating resulted in increased team behaviors, and contributed to a greater perception of teamwork in the Hand Images interface. However, if more time spent communicating is all it takes to increase team behaviors, then it is not clear why the same perception of increased team behavior is not true for the Separate interface. Perhaps the addition of hand images to increase the perception of connection makes the difference.

Chapter 10. Summary

Gestures are important in many spatial tasks for efficiently and clearly communicating spatial concepts. Traffic incident management is an example of a 2-d spatial task in which people must coordinate emergency resources and plan out detour routes in the context of a map. When major traffic incidents or disasters occur, people from multiple agencies must work together. However, if response is to be rapid, there is rarely time for people from different agencies to get together at the same location to develop a joint plan; thus much of this work is currently done by phone. However, when two people talk by phone, they cannot sit around a shared map, point to different locations, or use gestures to indicate routes. The goal of this work is to inform the design of tools that can better assist traffic managers and emergency services when they have to virtually collaborate over distance.

We explored the question of whether gestures can 1) reduce workload in virtual collaborations or 2) better support team behaviors for traffic incident management tasks. We asked 9 pairs of participants to develop response plans for a variety of major traffic incidents and disasters, using three different interfaces: Face-to-face, Separate, and Hand Images. In all conditions an electronic map was projected on to the table and participants could electronically draw on the map. In the Face-to-face condition, both participants sat next to each other at the same table and they could draw on or manipulate a shared electronic map. In the Separate condition, they sat on opposite sides of a soft wall. They could not see each other, but they could hear each other and each could see the markings made by their partner on the shared electronic map. The Hand Images condition was identical to the Separate condition, with the addition that participants could see real-time video images of their partner's arms and hands projected on the map. We asked participants to complete the six questions in the NASA TLX workload inventory after completing each task, and answer a set of video recorded all sessions.

A statistical analysis revealed that participants reported significantly stronger team behaviors when using the Hand Images interface, but no significant differences were found in terms of the six workload measures, positive interactions, perceptions of connection to distant teammates, or sources of frustration. The results indicated that the cognitive workload was not affected by the addition of hand images. Furthermore, participants took significantly longer to finish each task when using the Hand Images interface than when using the Face-to-face interface.

Additionally, a content analysis revealed much about how they used the interfaces. When participants were not interacting face-to-face, they talked and drew more (in seconds), and when they could not see each other's hands, they spent gestured less (as a proportion of total time). On average, the largest portions of their time was spent talking (without gesturing or drawing) and listening to their partner talk (coded as gazing). Gesturing and drawing were secondary to talking and listening. Participants rarely gestured or drew without also talking. Contrary to expectations, the condition did not appear to influence how much they used the shared electronic workspace; in all conditions they used the shared electronic workspace about 65% of the time. They did not appear to rely on the interface more for communication in the virtual conditions when they had no other means of visual communication. (The other 35% of their time was spent gazing, writing or drawing outside the shared electronic interface.)

Chapter 11. Conclusions

The results of this study indicate that:

1. The ability to gesture to one's virtual teammate, by pointing or making motions over a shared electronic map, may improve team behaviors in the domain of management of traffic incidents and disasters, and
2. That the presence or absence of gestures in the interface changes the way in which people communicate. When participants interact face-to-face they spend much time gesturing. When they can no longer see each other in a virtual interaction, they compensate by talking and drawing more. When gestures are also taken away, they gesture very little (relative to face-to-face interactions).

However, unlike results found in the domain of virtual product design where gestures significantly reduced workload in all six NASA TLX measures (Cornelius, et al. 2012), no similar workload reductions were found for the domain of traffic incident management. It is not clear whether this is due to differences in the domains, or in the tasks used in the two experiments. The tasks used in conceptual product design required brainstorming on very open-ended questions, while the tasks used in this study only required comparing given alternatives. Brainstorming tasks may benefit more from gestures than more defined tasks. While we found some interesting results, we felt that there were enough unanswered questions that it was appropriate to conduct a follow-on study in which we repeated the experiment, but used more open-ended tasks. We have just completed data collection, but have not yet started the analysis.

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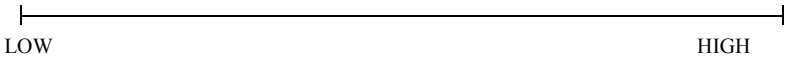
Appendix A: NASA-TLX Questionnaire

MENTAL WORKLOAD RATINGS

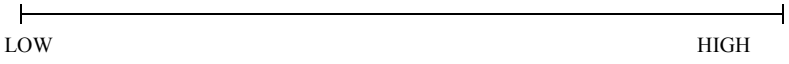
Think about the collaborative task you just completed. Please answer the following questions with that task in mind. Please place a vertical line through each scale for the six characteristics summarized below:

Example:
Happiness
How much happiness did you feel during the task?

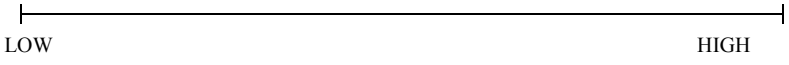
Mental Demand
How much thinking, deciding, calculating, remembering, looking, searching, etc., did you need to do?



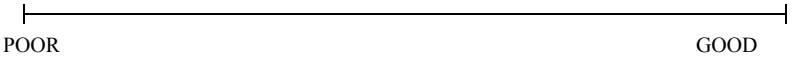
Physical Demand
How much physical activity was required?



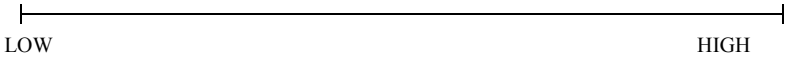
Time Pressure
Did you feel under pressure to complete the task in the time available?



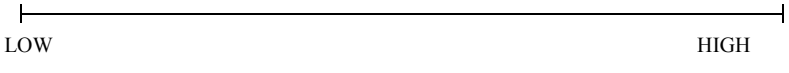
Performance
How satisfied were you with your level of performance?



Effort
How hard did you have to work?



Frustration Level
How insecure, discouraged, irritated, stressed and annoyed did you feel?



Appendix B: Post-Scenario Questionnaire

Participant ID _____

Condition _____

Post-Scenario Questionnaire

Think about the collaborative task you just completed. Please answer the following questions with that task in mind. Circle one answer for each question.

1. The overall quality of the discussion was:

1 Poor	2	3	4	5	6	7 Good

2. I made suggestions about how to do the task to my teammate.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

3. Did either of you emerge as leader?

Yes – I did	Yes – my teammate did	No

4. To what extent did you feel your teammate was at the same table with you?

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

5. I felt encouraged by my teammate's actions and ideas.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

6. I felt frustrated by the task.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

(continued on next page)

Post-Scenario Questionnaire

7. My teammate expressed positive opinions about my actions and ideas.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

8. I felt we were a team rather than two separate individuals.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

9. The solution was truly a joint effort.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

10. I felt disconnected from my teammate.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

11. I expressed positive opinions about my teammate's actions and ideas.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

12. I felt disinterested in the task.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

13. I felt frustrated by my teammate.

Not at All	To a Little Extent	To Some Extent	To a Great Extent	To a Very Great Extent

Appendix C: Scenario Instructions

Note:

The following pages include the set of instructions given to participants for each scenario. Both participants in a pair were given the "General information for use in all scenarios" page; this page was identical for both participants. However, the two participants in a pair each received different information than the other (possibly different written information, maps, or both). Thus, each member of the pair had information that his or her partner did not. This was done to encourage them to exchange information and to collaborate. Thus, some scenario descriptions and maps are included twice below; once in each participants' materials.

Summary of instructions for each Scenario:

Scenario name	**Title on participant's instructions**	**First participant has:**	**Second participant has:**
Leak	Tanker rollover + gasoline leak in Westbound I-94 tunnel	-Two pages of instructions and information -One page of maps	-Two pages of instructions and information -Two pages of maps
Fire	Tanker crash + fire on I-94 / I-35W interchange	-One page of instructions and information -Two pages of maps	-One page of instructions and information -Two pages of maps
Evacuation	Downtown evacuation due to bomb threat	-One page of instructions and information -Two pages of maps	-One page of instructions and information -Two pages of maps

General information for use in all scenarios

In these scenarios, each of you will be given different information and will need to discuss that information to complete the tasks. Share the information you have on your sheets and maps with your teammate, drawing on the collaborative interface as needed. Use the interface to facilitate discussing solutions appropriate to the scenario. Jointly decide what to do and why.

You will have approximately 20 minutes for each scenario, to reflect the time-sensitive nature of the tasks. Do your best to reach a solution within the time limit.

Using the collaborative interface:
-Go slowly. The system can't process too many changes at once.
-Try to avoid drawing at the same time as your partner. Again, this is too many changes at once.
-For the straight line tool, you only click the endpoints. The curved line tool is closer to how you would draw with a pen.
-The erase function erases everything.
-Unfortunately there is no button to undo a single action.
-Hold the infrared pen at an angle so that your hand does not obstruct the LED. The LED must face upwards.

General capacity information:
Highway: 2000 vehicles/lane/hour
City streets: 1000 vehicles/lane/hour

Definitions:

Route capacity percentage – This is the capacity the route is at *before* rerouting. A higher percentage means there are more vehicles present.

Estimated travel time before rerouting – The amount of time it takes to normally travel the route, when it is *not* used for rerouting.

Scenario 1 (Leak), Participant A. Materials given to *participant A* in each pair included:

Tanker rollover + gasoline leak in Westbound I-94 tunnel

A fuel tanker has rolled over while inside the Westbound I-94 tunnel, blocking traffic (see map L1). Only Westbound traffic is affected. The tanker is leaking, spilling liquid gasoline into the drain inside the tunnel.

In the first part of the scenario, you must decide how to reroute traffic.
In the second part of the scenario, you must decide where to remove the gasoline from the sewer.

You play the role of MnDOT in this scenario, and your teammate will play the role of the City of Minneapolis. You do not need to strictly adhere to your role – your objective is to address the incident.

Part 1 – Addressing traffic

Task:
You have two options (described below) for rerouting traffic. Your teammate also has two options. Explain your options to each other, mapping them out as needed to assist the explanation. Discuss the pros and cons and officially decide on which option to choose and why.

End Goal:
Let the experimenters know when you have
1) chosen an option and
2) justify your decision.

Option A
-Reroute I-94 through Hennepin-Lyndale exit East Lyndale Ave N entrance to I-94W
-Correspondingly close I-94W from this exit until I-394
-Route capacity: 90%
-Stoplights: 4
-Estimated travel time before rerouting: 6 minutes
Option B
-Reroute I-94 traffic through Cedar-Riverside Washington Ave NB I-394 WB I-94W
-Correspondingly close all entrances/exits to I-94W from this exit until I-394
-Route capacity: 55%
-Stoplights: 17
-Estimated travel time before rerouting: 9 minutes

(Part 2 on next page)

Part 2 – Addressing gasoline leak

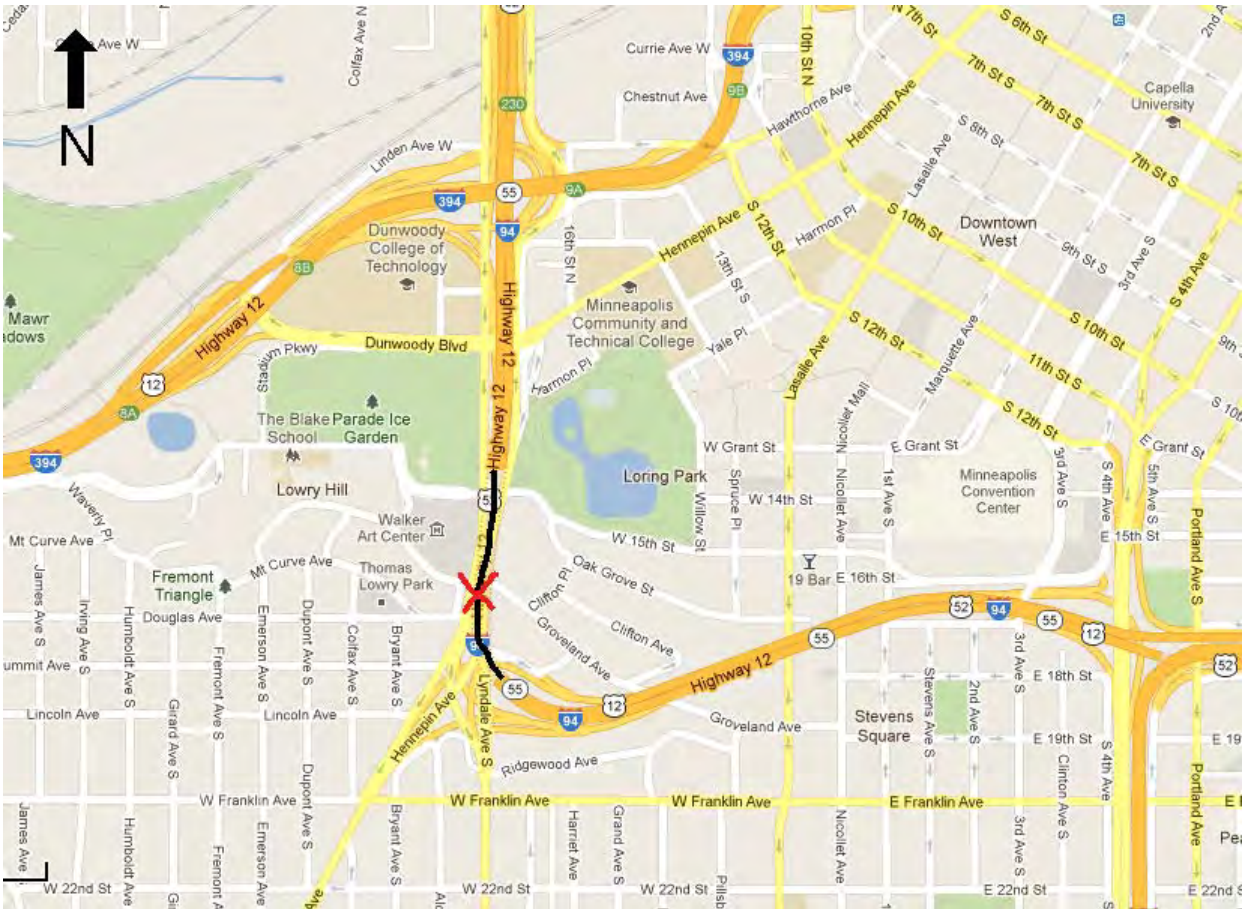
Task:
You each have some information (described below) that is relevant to containing the gasoline leak before it reaches the river. Use this to figure out how far the fuel has flowed into the sewers and choose which manholes to block to pump out the gasoline. You want to block the manholes ahead of the flowing gasoline, but no further ahead than necessary so that you don't have to pump out a lot of extra sewer water.

The tunnel drain connects to pipes under the freeway, and then to the city sewer system, which leads to the river. The crash is almost directly over the drain, so there is not much danger of fire above the road, but the fuel must be removed from the sewer for environmental reasons.

End Goal:
Let the experimenters know when you have
1) chosen which manholes to block and
2) explain your decision.

Known to MnDOT:
-2,000 gallons of gasoline leaked into the drain before the tanker's leak was contained.
-The leak began approximately 45 minutes ago (i.e. once you begin Part 2, assume the leak started 45 minutes ago).

Tanker rollover + gasoline leak in Westbound I-94 tunnel



Map L1

The black line marks the location of the I-94 tunnel.

The red X indicates the location of the rollover, inside the tunnel.

Scenario 1 (Leak), Participant B. Materials given to participant B of each pair included:

Tanker rollover + gasoline leak in Westbound I-94 tunnel

A fuel tanker has rolled over while inside the Westbound I-94 tunnel, blocking traffic (see map L1). Only Westbound traffic is affected. The tanker is leaking, spilling liquid gasoline into the drain inside the tunnel.

In the first part of the scenario, you must decide how to reroute traffic.
In the second part of the scenario, you must decide where to remove the gasoline from the sewer.

You play the role of the City of Minneapolis in this scenario, and your teammate will play the role of MnDOT. You do not need to strictly adhere to your role – your objective is to address the incident.

Part 1 – Addressing traffic

Task:
You have two options (described below) for rerouting traffic. Your teammate also has two options. Explain your options to each other, mapping them out as needed to assist the explanation. Discuss the pros and cons and officially decide on which option to choose and why.

End Goal:
Let the experimenters know when you have
1) chosen an option and
2) justify your decision.

Option 1
-Reroute I-94W and 35W NB-94W traffic through 11th St S □ Glenwood Ave (WB) □ East Lyndale Ave N □ I-94W
-Correspondingly close all entrance ramps from 11th St until I-394 for I-94W traffic, all I-94W traffic west of this exit to I-394, and ramp connecting I-35W NB to I-94W
-Route capacity: 40%
-Stoplights: 12
-Estimated travel time before rerouting: 11 minutes
Option 2
-Reroute I-94 traffic through 35W SB □ 62 WB □ 100 NB □ I-394 EB □ 1-94W
-Correspondingly close all of I-94W west of I-35W until I-394
-Route capacity: 60%
-Stoplights: 0
-Estimated travel time before rerouting: 22 minutes

(Part 2 on next page)

Part 2 – Addressing gasoline leak

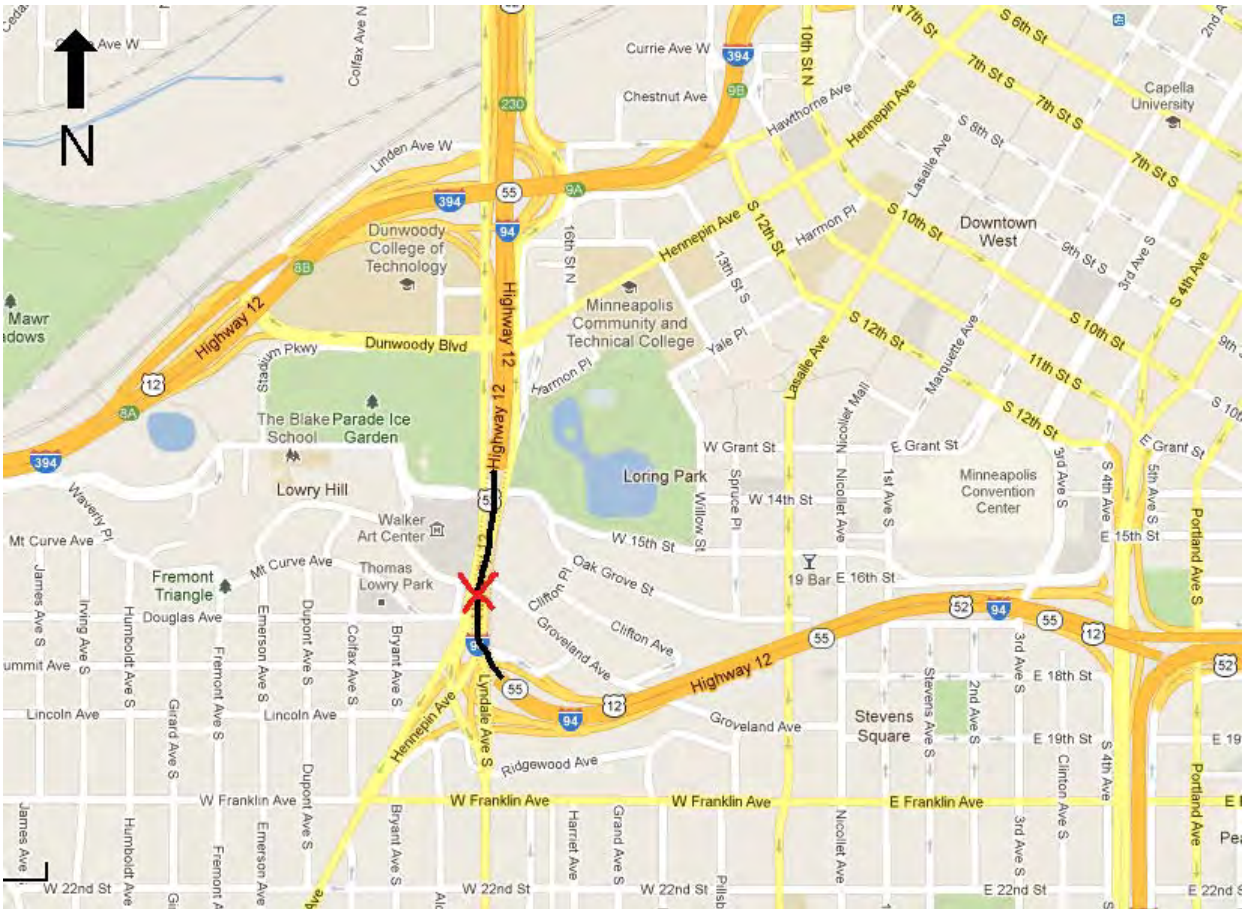
Task:
You each have some information (described below) that is relevant to containing the gasoline leak before it reaches the river. Use this to figure out how far the fuel has flowed into the sewers and choose which manholes to block to pump out the gasoline. You want to block the manholes ahead of the flowing gasoline, but no further ahead than necessary so that you don't have to pump out a lot of extra sewer water.

The tunnel drain connects to pipes under the freeway, and then to the city sewer system, which leads to the river. The crash is almost directly over the drain, so there is not much danger of fire above the road, but the fuel must be removed from the sewer for environmental reasons.

End Goal:
Let the experimenters know when you have
1) chosen which manholes to block and
2) explain your decision.

Known to City of Minneapolis:
-A map of the sewer network (see map L2).
-Water in the sewers flows at 3 ft/s, and you can assume the gasoline will be flowing on top of the water at the same speed.
-Always be conservative with pollutants. If it's almost at one manhole, go to the next one.

Tanker rollover + gasoline leak in Westbound I-94 tunnel

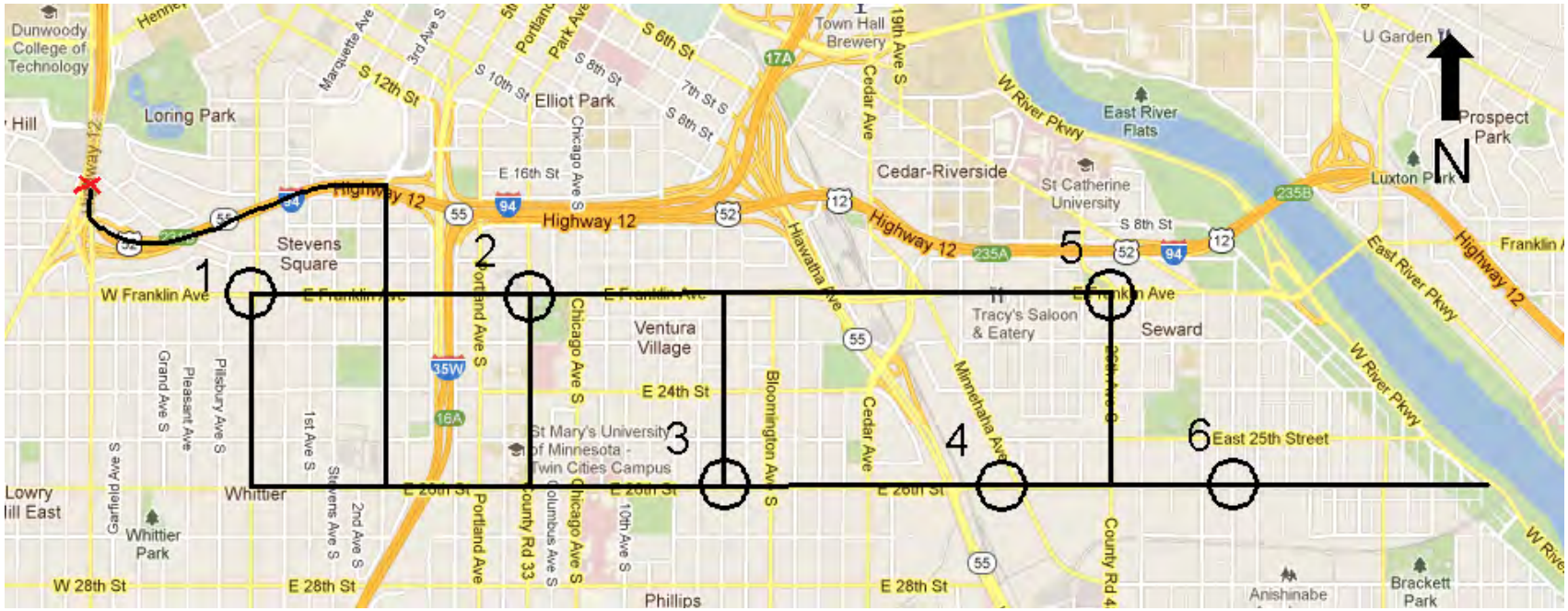


Map L1

The black line marks the location of the I-94 tunnel.

The red X indicates the location of the rollover, inside the tunnel.

Tanker rollover + gasoline leak in Westbound I-94 tunnel



Map L2

The red X indicates the location of the rollover.

The numbered circles mark the locations of manholes.

The black lines indicate the sewer pipes that are affected.

The drain runs from the tunnel under the freeway and connects to the city sewer at 3rd Ave S.

Scenario 2 (Fire), Participant A. Materials given to *participant A* in each pair included:

Tanker crash + fire on I-94 / I-35W interchange

A tanker has crashed on the I-94 / I-35W interchange, between Chicago Ave and County Road 33 (see map F1). The tanker jumped the barrier between Westbound and Eastbound I-94 and has started a fire, endangering I-35W as well (see map F2). As a result, both directions of traffic on both freeways must be rerouted. No other locations are at risk. This scenario occurs at night, with corresponding traffic conditions (Level-of-Service B). Road conditions are bare and negligible.

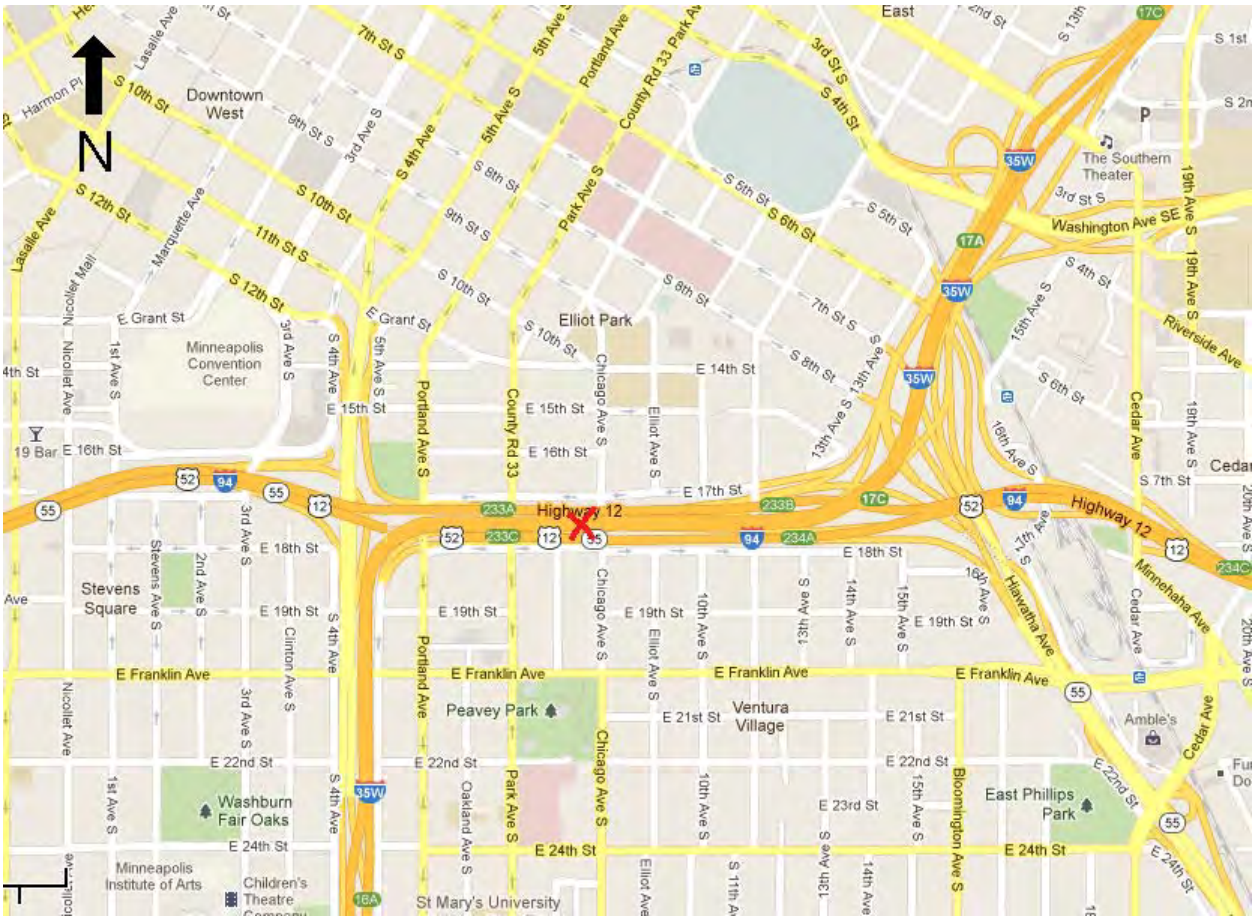
Task:
You have two options (described below) for rerouting traffic on I-35W. Your teammate has two options for rerouting traffic on I-94. Explain your options to each other, mapping them out as needed to assist the explanation. Discuss the pros and cons and officially decide on which options to choose and why. You must choose one option for I-35W and one option for I-94.

End Goal:
Let the experimenters know when you have
1) chosen an option for each freeway and
2) explain your decision.

Alternative routes:
I-35W traffic: Direct through downtown
-SB: Exit traffic on E Hennepin WB → Lyndale Ave SB → Lake Street → I-35W SB entrance
-NB: Exit traffic on 31st street → Lyndale Ave NB → Hennepin EB → I-35W NB entrance
-Stoplights: 25
-Estimated travel time before detour: 26 minutes

I-35W traffic: Direct through larger roads
-SB: Close highway continuing through to interchange; reroute traffic to Hiawatha Ave SB → 26th St WB → Portland Ave SB → Lake St WB → Merge onto I-35W SB
-NB: Close highway north of Lake St. exit; reroute traffic NB onto 2nd Ave S → Continue to E 28th St → NB to Hiawatha Ave → Merge onto I-35W NB
-Stoplights:10
-Estimated travel time before detour: 11 minutes

Tanker crash + fire on I-94 / I-35W interchange



Map F1

The red X indicates the location of the crash.

Tanker crash + fire on I-94 / I-35W interchange

Map F2

The red box indicates the location of the crash, between the Chicago Avenue bridge and the County Road 33 bridge.

Scenario 2 (Fire), Participant B. Materials given to *participant B* in each pair included:

Tanker crash + fire on I-94 / I-35W interchange

A tanker has crashed on the I-94 / I-35W interchange, between Chicago Ave and County Road 33 (see map F1). The tanker jumped the barrier between Westbound and Eastbound I-94 and has started a fire, endangering I-35W as well (see map F2). As a result, both directions of traffic on both freeways must be rerouted. No other locations are at risk. This scenario occurs at night, with corresponding traffic conditions (Level-of-Service B). Road conditions are bare and negligible.

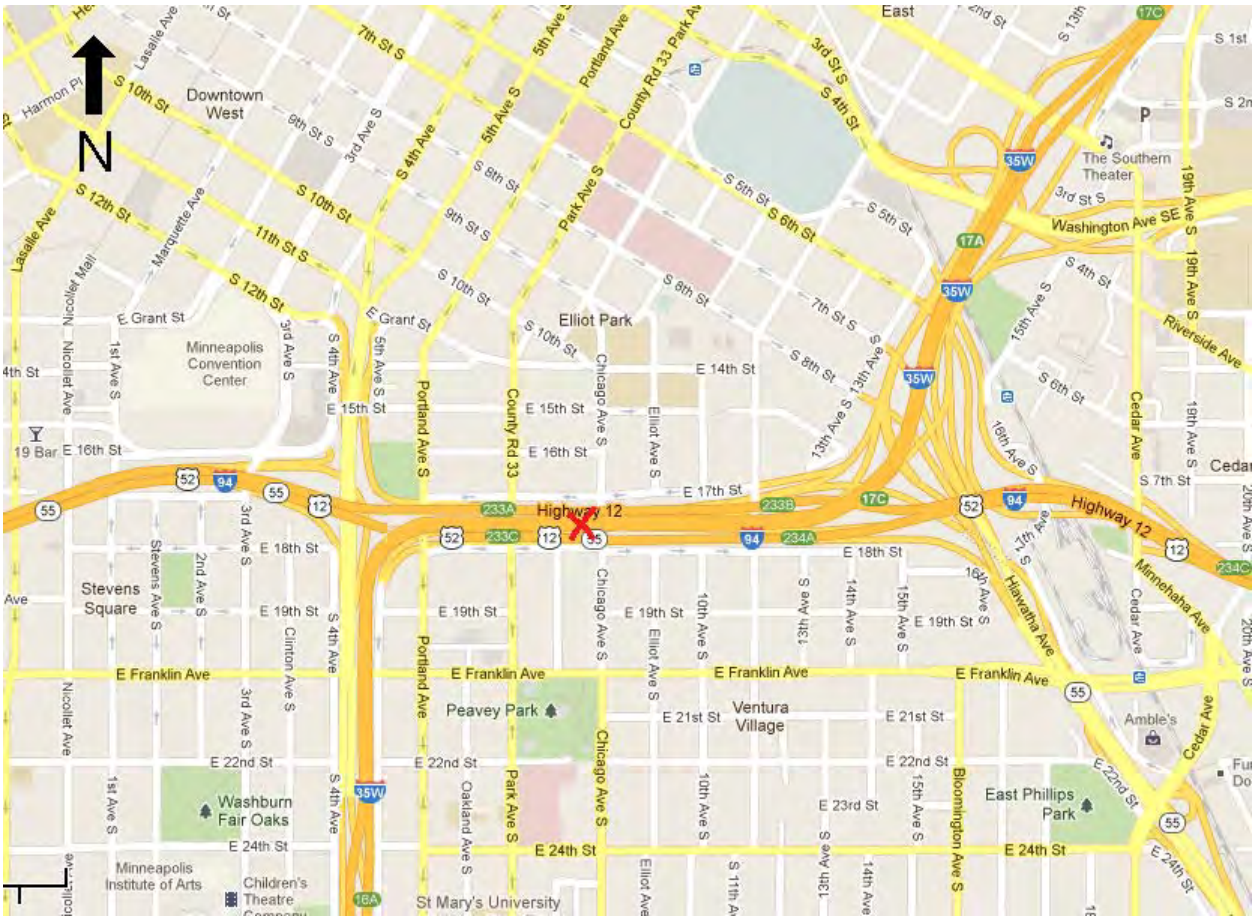
Task:
You have two options (described below) for rerouting traffic on I-94. Your teammate has two options for rerouting traffic on I-35W. Explain your options to each other, mapping them out as needed to assist the explanation. Discuss the pros and cons and officially decide on which options to choose and why. You must choose one option for I-35W and one option for I-94.

End Goal:
Let the experimenters know when you have
1) chosen an option for each freeway and
2) explain your decision.

Alternative routes:
I-94 traffic: Direct through downtown
-WB: Exit traffic through 5th St exit → N 7th St → E Lyndale Ave N → Merge onto I-94W
-EB: Exit traffic through 7th St exit → N 7th St → 10th St N → Hennepin Ave NB → S 6th St → I-94 entrance
-Stoplights: 18
-Estimated travel time before detour: 8 minutes

I-94 traffic: Direct through larger roads
-WB: Route all WB traffic to Cedar Ave SB → Highway 55 SB → 62 WB → Highway 100 NB → 55 EB
-EB: Route all EB traffic to I-35W SB →62 EB → Highway 55 NB → Cedar-Minnehaha NB entrance to I-94 EB
-Stoplights: 19
-Estimated travel time before detour: 20

Tanker crash + fire on I-94 / I-35W interchange



Map F1

The red X indicates the location of the crash.

Tanker crash + fire on I-94 / I-35W interchange

Map F2

The red box indicates the location of the crash, between the Chicago Avenue bridge and the County Road 33 bridge.

Scenario 3 (Evacuation), Participant A. Materials given to *participant A* in each pair:

Downtown evacuation due to bomb threat

The IDS Center in downtown Minneapolis is subject to a bomb threat. The IDS Center must be evacuated, followed by the surrounding buildings.
-Traffic is already closed off, so it is not a concern.
-It is 2:00pm on a workday, so there are more people in office buildings than in shopping centers
-For simplicity, ignore the skyways.
-The bomb is suspected to be a biohazard, so wind is a concern. The wind is blowing to the Northeast, so the area Northeast of the threatened area is not a safe zone.

Task:
You have information on the current occupancy of three of the six buildings that need to be evacuated. You also have information on the capacity two of the four possible evacuation zones. Your teammate has information on the other three buildings and the other two evacuation zones. Share this information with each other and discuss solutions.

You must jointly choose:
a) how many people will be directed out each building exit,
b) which evacuation center they will report to.

1) First, evacuate the IDS center.

2) Second, evacuate the surrounding buildings.

Constraints:
-Distribute evacuees as evenly as possible between exits and streets to avoid congestion
-The IDS Center is to be evacuated before the surrounding buildings, so the IDS Center evacuees will not be on the streets at the same time as the evacuees from other buildings.
-Since the IDS Center is the primary building at risk, everyone should be walking away from it as they exit each building.
-Do not exceed the capacity of each evacuation zone.

End Goal:
Let the experimenters know when you have an agreed-upon plan. You must decide:
1. How many people you have directed to each evacuation site.
2. How many people should use each exit for each building, and which evacuation zone they will walk to.

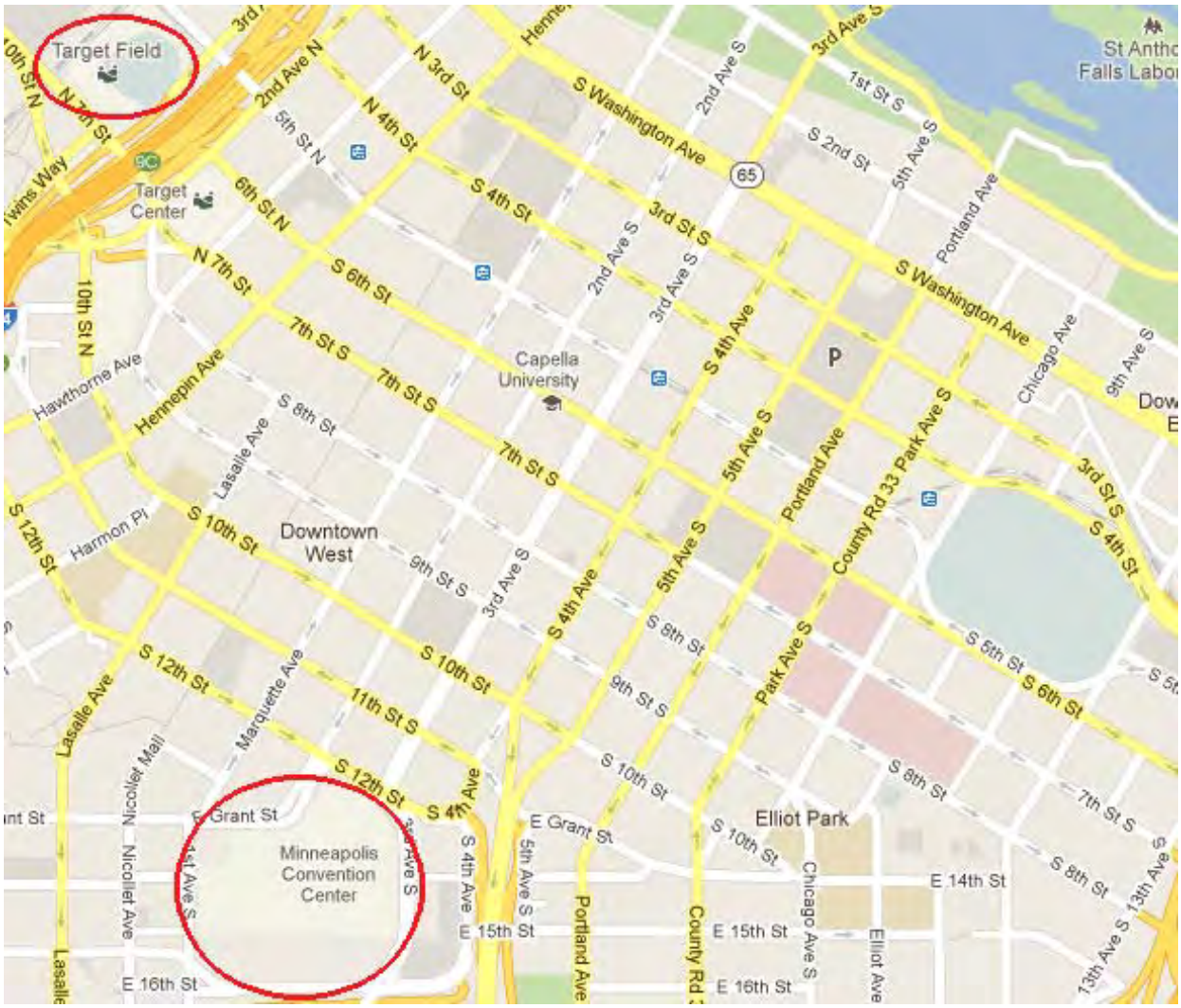
Downtown building information

Locations of the IDS Center and surrounding buildings:

Building	Major Exits (marked on map)	Current occupancy
Plaza VII	NE, SE	4,000
Shopping Center 1	All faces	2,000
Wells Fargo	NE, SW	6,000

Downtown safe zone information

Locations of safe zones:



Evacuation zone capacities:
Convention center: 8,000
Target field: 6,000

Scenario 3 (Evacuation), Participant B. Materials given to *participant B* in each pair:

Downtown evacuation due to bomb threat

The IDS Center in downtown Minneapolis is subject to a bomb threat. The IDS Center must be evacuated, followed by the surrounding buildings.
-Traffic is already closed off, so it is not a concern.
-It is 2:00pm on a workday, so there are more people in office buildings than in shopping centers
-For simplicity, ignore the skyways.
-The bomb is suspected to be a biohazard, so wind is a concern. The wind is blowing to the Northeast, so the area Northeast of the threatened area is not a safe zone.

Task:
You have information on the current occupancy of three of the six buildings that need to be evacuated. You also have information on the capacity two of the four possible evacuation zones. Your teammate has information on the other three buildings and the other two evacuation zones. Share this information with each other and discuss solutions.

You must jointly choose:
a) how many people will be directed out each building exit,
b) which evacuation center they will report to.

1) First, evacuate the IDS center.

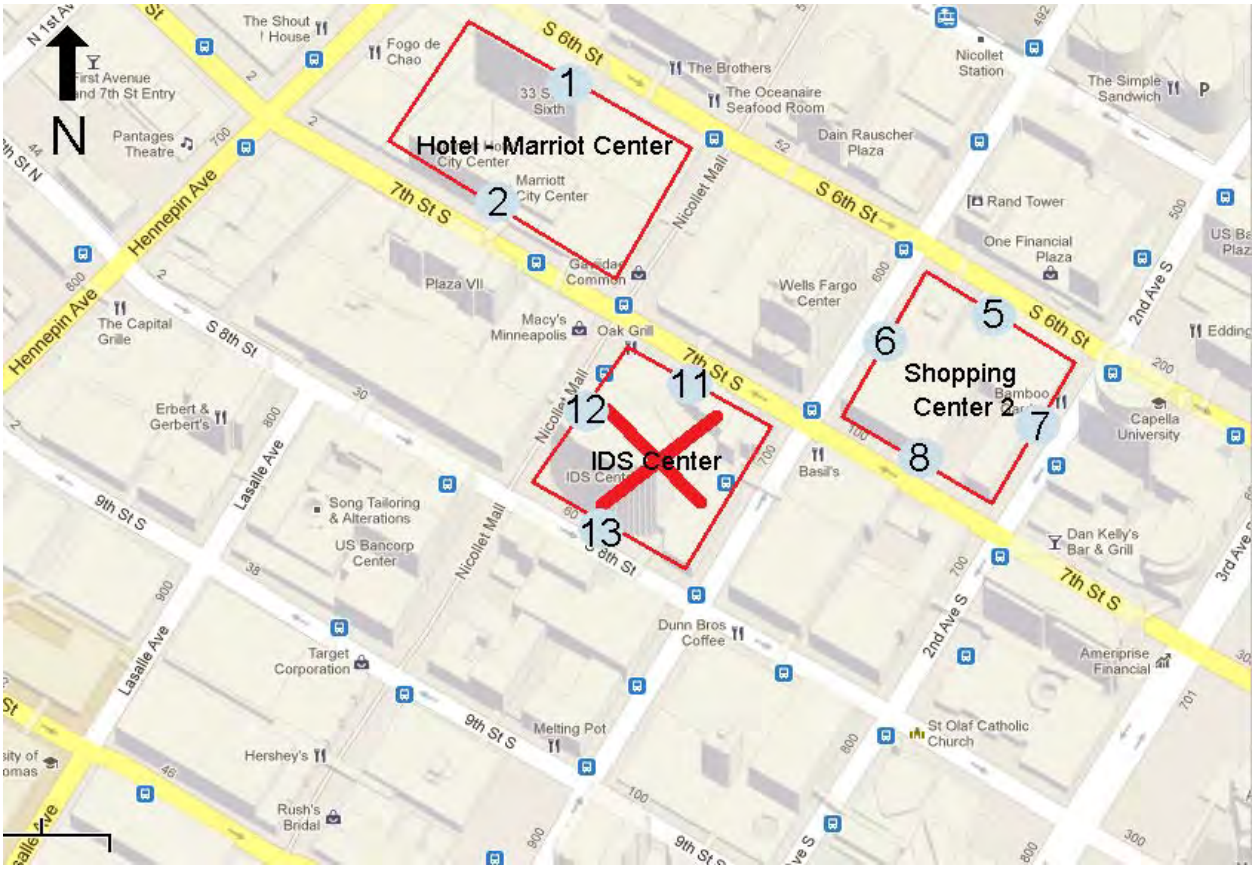
2) Second, evacuate the surrounding buildings.

Constraints:
-Distribute evacuees as evenly as possible between exits and streets to avoid congestion
-The IDS Center is to be evacuated before the surrounding buildings, so the IDS Center evacuees will not be on the streets at the same time as the evacuees from other buildings.
-Since the IDS Center is the primary building at risk, everyone should be walking away from it as they exit each building.
-Do not exceed the capacity of each evacuation zone.

End Goal:
Let the experimenters know when you have an agreed-upon plan. You must decide:
1. How many people you have directed to each evacuation site.
2. How many people should use each exit for each building, and which evacuation zone they will walk to.

Downtown building information

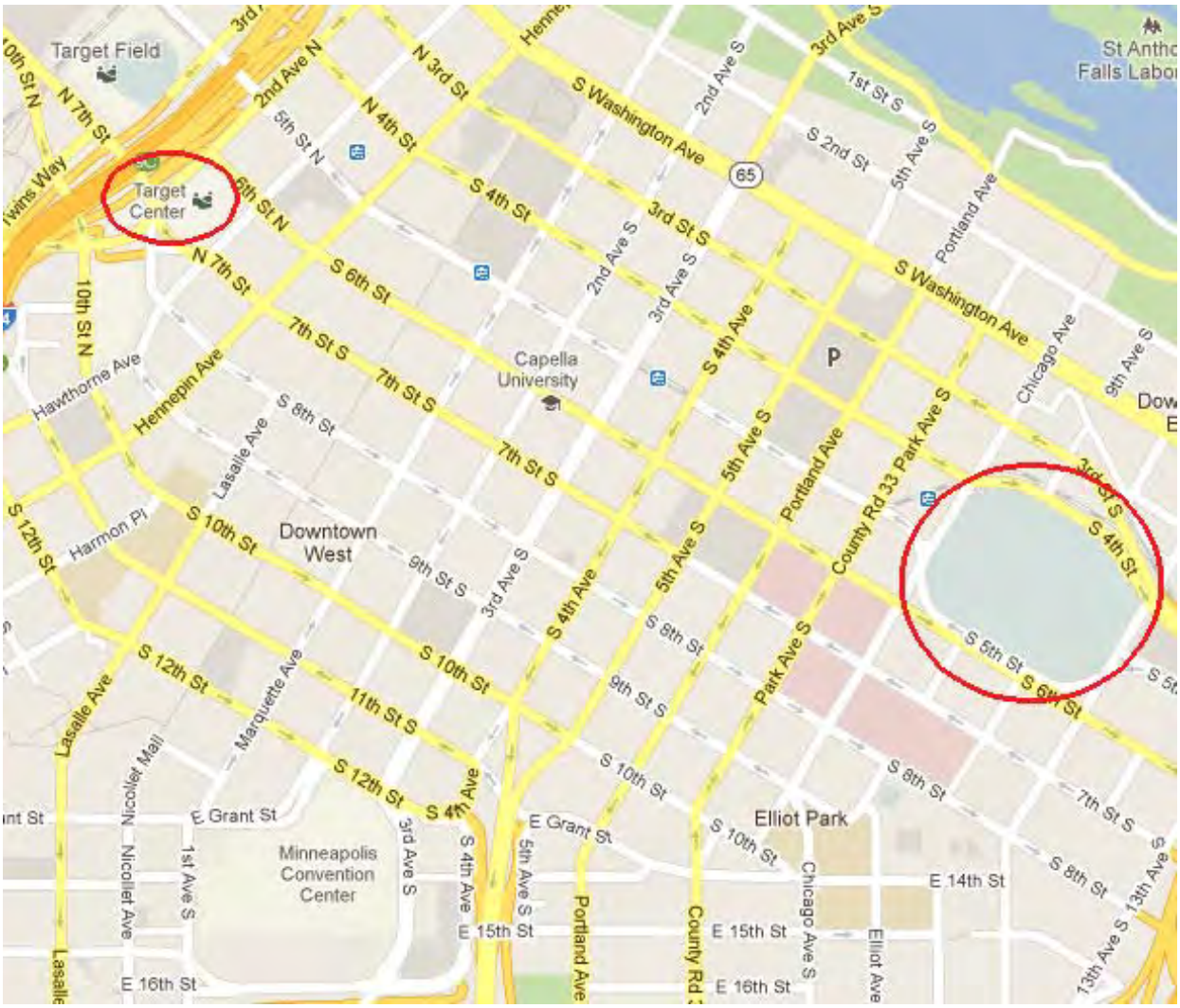
Locations of the IDS Center and surrounding buildings:



Building	Major Exits (marked on map)	Current occupancy
Hotel (Marriot Center)	NE, SW	3,000
IDS Center	NW, NE, SW	6,000
Shopping Center 2	All faces	2,000

Downtown safe zone information

Locations of safe zones:



Evacuation zone capacities:
Metrodome: 9,000
Target center: 3,000

Appendix D: ANOVA Summary Tables

Time to Complete Task

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	29.354	1,315.746	0.000
Interface	2	19.450	5.388	0.014
Scenario	2	18.864	49.500	0.000
Interface * Scenario	4	15.290	6.447	0.003

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	190.444	83.206	23.559	0.094	-23.999	404.888
	Face-to-face	330.667(*)	103.392	21.765	0.013	62.519	598.814
Separate	Hand Images	-190.444	83.206	23.559	0.094	-404.888	23.999
	Face-to-face	140.222	93.292	16.790	0.454	-107.804	388.249
Face-to-face	Hand Images	-330.667(*)	103.392	21.765	0.013	-598.814	-62.519
	Separate	-140.222	93.292	16.790	0.454	-388.249	107.804
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Time to Complete Task, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	784.667(*)	88.116	23.789	0.000	557.738	1,011.595
	Leak	80.444	99.685	19.706	1.000	-180.343	341.232
Fire	Evacuation	-784.667(*)	88.116	23.789	0.000	-1,011.595	-557.738
	Leak	-704.222(*)	92.818	17.457	0.000	-949.958	-458.486
Leak	Evacuation	-80.444	99.685	19.706	1.000	-341.232	180.343
	Fire	704.222(*)	92.818	17.457	0.000	458.486	949.958
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	2,125.333	132.201	5	1,785.501	2,465.166
	Fire	810.333	104.277	5	542.281	1,078.385
	Leak	1,746.333	108.366	5	1,467.769	2,024.898
Separate	Evacuation	1,593.667	71.360	5	1,410.229	1,777.104
	Fire	1,158.000	123.555	5	840.393	1,475.607
	Leak	1,359.000	43.101	5	1,248.204	1,469.796
Face-to-face	Evacuation	1,307.000	135.346	5	959.082	1,654.918
	Fire	703.667	53.405	5	566.386	840.947
	Leak	1,679.333	186.935	5	1,198.802	2,159.864

Mental Demand

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	38.844	228.924	0.000
Interface	2	28.856	2.715	0.083
Scenario	2	26.081	2.027	0.152
Interface * Scenario	4	23.268	1.135	0.365

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-2.167	7.901	26.797	1.000	-22.343	18.010
	Face-to-face	13.056	7.025	25.367	0.224	-4.951	31.062
Separate	Hand Images	2.167	7.901	26.797	1.000	-18.010	22.343
	Face-to-face	15.222	7.462	25.940	0.155	-3.876	34.321
Face-to-face	Hand Images	-13.056	7.025	25.367	0.224	-31.062	4.951
	Separate	-15.222	7.462	25.940	0.155	-34.321	3.876
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Mental Demand, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	15.111	7.509	26.024	0.164	-4.103	34.325
	Leak	7.444	7.535	25.945	0.997	-11.840	26.729
Fire	Evacuation	-15.111	7.509	26.024	0.164	-34.325	4.103
	Leak	-7.667	7.368	25.738	0.923	-26.534	11.201
Leak	Evacuation	-7.444	7.535	25.945	0.997	-26.729	11.840
	Fire	7.667	7.368	25.738	0.923	-11.201	26.534
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	60.333	6.576	5	43.429	77.238
	Fire	33.833	11.235	5	4.953	62.714
	Leak	55.167	9.105	5	31.762	78.571
Separate	Evacuation	55.333	11.065	5	26.889	83.778
	Fire	57.000	8.000	5	36.435	77.565
	Leak	43.500	11.090	5	14.993	72.007
Face-to-face	Evacuation	45.333	9.962	5	19.725	70.942
	Fire	24.833	7.231	5	6.244	43.422
	Leak	40.000	6.340	5	23.702	56.298

Physical Demand

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	18.931	39.842	0.000
Interface	2	12.843	0.310	0.738
Scenario	2	13.431	0.995	0.395
Interface * Scenario	4	13.569	1.134	0.382

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-2.722	3.468	13.833	1.000	-12.162	6.717
	Face-to-face	-1.167	3.899	11.448	1.000	-12.086	9.753
Separate	Hand Images	2.722	3.468	13.833	1.000	-6.717	12.162
	Face-to-face	1.556	4.374	14.013	1.000	-10.331	13.442
Face-to-face	Hand Images	1.167	3.899	11.448	1.000	-9.753	12.086
	Separate	-1.556	4.374	14.013	1.000	-13.442	10.331
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Physical Demand, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-2.778	3.067	10.583	1.000	-11.485	5.930
	Leak	-4.778	3.955	12.034	0.751	-15.766	6.210
Fire	Evacuation	2.778	3.067	10.583	1.000	-5.930	11.485
	Leak	-2.000	4.616	16.179	1.000	-14.324	10.324
Leak	Evacuation	4.778	3.955	12.034	0.751	-6.210	15.766
	Fire	2.000	4.616	16.179	1.000	-10.324	14.324
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	10.000	1.317	5	6.616	13.384
	Fire	8.667	2.216	5	2.970	14.363
	Leak	7.833	5.455	5	-6.190	21.857
Separate	Evacuation	5.667	2.348	5	-0.368	11.701
	Fire	17.500	7.518	5	-1.825	36.825
	Leak	11.500	3.128	5	3.460	19.540
Face-to-face	Evacuation	7.167	3.092	5	-0.782	15.115
	Fire	5.000	2.530	5	-1.503	11.503
	Leak	17.833	9.188	5	-5.786	41.453

Time Pressure

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	32.567	131.245	0.000
Interface	2	27.652	4.633	0.018
Scenario	2	24.910	2.193	0.133
Interface * Scenario	4	23.629	0.490	0.743

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	7.000	9.581	23.810	1.000	-17.674	31.674
	Face-to-face	23.056(*)	8.165	23.462	0.029	2.005	44.106
Separate	Hand Images	-7.000	9.581	23.810	1.000	-31.674	17.674
	Face-to-face	16.056	8.179	18.932	0.194	-5.423	37.534
Face-to-face	Hand Images	-23.056(*)	8.165	23.462	0.029	-44.106	-2.005
	Separate	-16.056	8.179	18.932	0.194	-37.534	5.423
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Time Pressure, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	18.222	8.819	21.755	0.153	-4.650	41.094
	Leak	9.500	9.275	22.280	0.950	-14.509	33.509
Fire	Evacuation	-18.222	8.819	21.755	0.153	-41.094	4.650
	Leak	-8.722	7.847	22.351	0.834	-29.030	11.585
Leak	Evacuation	-9.500	9.275	22.280	0.950	-33.509	14.509
	Fire	8.722	7.847	22.351	0.834	-11.585	29.030
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	58.333	9.489	5	33.941	82.726
	Fire	34.000	11.305	5	4.940	63.060
	Leak	59.333	13.937	5	23.507	95.160
Separate	Evacuation	55.833	16.265	5	14.022	97.645
	Fire	39.500	8.698	5	17.142	61.858
	Leak	35.333	8.597	5	13.234	57.433
Face-to-face	Evacuation	35.167	10.265	5	8.781	61.553
	Fire	21.167	6.041	5	5.638	36.696
	Leak	26.167	6.789	5	8.714	43.619

Performance

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	31.931	854.590	0.000
Interface	2	25.394	0.006	0.994
Scenario	2	25.051	0.141	0.869
Interface * Scenario	4	20.234	1.574	0.219

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-0.111	5.957	22.136	1.000	-15.539	15.316
	Face-to-face	0.444	5.039	22.843	1.000	-12.573	13.462
Separate	Hand Images	0.111	5.957	22.136	1.000	-15.316	15.539
	Face-to-face	0.556	5.790	20.646	1.000	-14.528	15.639
Face-to-face	Hand Images	-0.444	5.039	22.843	1.000	-13.462	12.573
	Separate	-0.556	5.790	20.646	1.000	-15.639	14.528
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-2.889	6.206	23.281	1.000	-18.898	13.120
	Leak	-0.111	4.956	16.986	1.000	-13.270	13.048
Fire	Evacuation	2.889	6.206	23.281	1.000	-13.120	18.898
	Leak	2.778	5.596	24.342	1.000	-11.610	17.165
Leak	Evacuation	0.111	4.956	16.986	1.000	-13.048	13.270
	Fire	-2.778	5.596	24.342	1.000	-17.165	11.610
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	75.833	4.020	5	65.499	86.167
	Fire	63.000	8.017	5	42.393	83.607
	Leak	62.333	6.530	5	45.547	79.120
Separate	Evacuation	57.667	10.298	5	31.195	84.138
	Fire	71.500	8.520	5	49.600	93.400
	Leak	72.333	4.201	5	61.536	83.131
Face-to-face	Evacuation	64.333	4.551	5	52.635	76.032
	Fire	72.000	8.177	5	50.980	93.020
	Leak	63.500	4.225	5	52.639	74.361

Effort

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	32.199	353.501	0.000
Interface	2	25.756	2.704	0.086
Scenario	2	21.275	4.034	0.033
Interface * Scenario	4	20.253	2.629	0.065

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-0.778	6.464	21.366	1.000	-17.569	16.013
	Face-to-face	10.889	5.875	20.505	0.235	-4.425	26.202
Separate	Hand Images	0.778	6.464	21.366	1.000	-16.013	17.569
	Face-to-face	11.667	5.799	23.642	0.167	-3.275	26.608
Face-to-face	Hand Images	-10.889	5.875	20.505	0.235	-26.202	4.425
	Separate	-11.667	5.799	23.642	0.167	-26.608	3.275
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Effort, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	15.556(*)	5.482	21.623	0.029	1.330	29.781
	Leak	8.722	6.572	22.420	0.594	-8.282	25.727
Fire	Evacuation	-15.556(*)	5.482	21.623	0.029	-29.781	-1.330
	Leak	-6.833	6.056	21.474	0.815	-22.557	8.890
Leak	Evacuation	-8.722	6.572	22.420	0.594	-25.727	8.282
	Fire	6.833	6.056	21.474	0.815	-8.890	22.557
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	63.833	3.781	5	54.114	73.552
	Fire	38.000	7.253	5	19.357	56.643
	Leak	47.667	11.185	5	18.914	76.419
Separate	Evacuation	50.500	9.946	5	24.934	76.066
	Fire	55.667	4.417	5	44.312	67.021
	Leak	45.667	8.102	5	24.839	66.494
Face-to-face	Evacuation	49.333	7.168	5	30.908	67.759
	Fire	23.333	5.812	5	8.393	38.273
	Leak	44.167	5.782	5	29.304	59.029

Frustration Level

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	29.962	72.271	0.000
Interface	2	26.249	0.403	0.673
Scenario	2	24.359	0.941	0.404
Interface * Scenario	4	23.348	0.613	0.657

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-5.222	8.457	20.960	1.000	-27.225	16.780
	Face-to-face	1.722	6.955	23.755	1.000	-16.191	19.636
Separate	Hand Images	5.222	8.457	20.960	1.000	-16.780	27.225
	Face-to-face	6.944	7.758	18.238	1.000	-13.503	27.392
Face-to-face	Hand Images	-1.722	6.955	23.755	1.000	-19.636	16.191
	Separate	-6.944	7.758	18.238	1.000	-27.392	13.503
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Frustration Level, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	7.444	7.791	18.238	1.000	-13.091	27.980
	Leak	-1.444	8.367	20.617	1.000	-23.246	20.357
Fire	Evacuation	-7.444	7.791	18.238	1.000	-27.980	13.091
	Leak	-8.889	7.025	24.048	0.654	-26.966	9.188
Leak	Evacuation	1.444	8.367	20.617	1.000	-20.357	23.246
	Fire	8.889	7.025	24.048	0.654	-9.188	26.966
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	23.667	5.880	5	8.551	38.782
	Fire	21.333	10.026	5	-4.438	47.105
	Leak	32.167	11.557	5	2.459	61.875
Separate	Evacuation	36.833	15.636	5	-3.361	77.028
	Fire	29.333	6.233	5	13.312	45.355
	Leak	26.667	9.573	5	2.058	51.275
Face-to-face	Evacuation	26.167	9.332	5	2.177	50.156
	Fire	13.667	6.391	5	-2.762	30.095
	Leak	32.167	6.226	5	16.163	48.171

Post-Scenario Question 1:
The overall quality of the discussion

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	32.610	1,541.399	0.000
Interface	2	22.237	0.314	0.734
Scenario	2	20.714	0.103	0.903
Interface * Scenario	4	16.796	1.334	0.298

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	0.250	0.315	26.025	1.000	-0.557	1.057
	Face-to-face	0.167	0.376	23.284	1.000	-0.803	1.137
Separate	Hand Images	-0.250	0.315	26.025	1.000	-1.057	0.557
	Face-to-face	-0.083	0.330	18.609	1.000	-0.951	0.784
Face-to-face	Hand Images	-0.167	0.376	23.284	1.000	-1.137	0.803
	Separate	0.083	0.330	18.609	1.000	-0.784	0.951
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 1, cont.:
The overall quality of the discussion

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.111	0.318	25.108	1.000	-0.705	0.927
	Leak	-0.028	0.362	22.737	1.000	-0.963	0.908
Fire	Evacuation	-0.111	0.318	25.108	1.000	-0.927	0.705
	Leak	-0.139	0.343	19.375	1.000	-1.037	0.759
Leak	Evacuation	0.028	0.362	22.737	1.000	-0.908	0.963
	Fire	0.139	0.343	19.375	1.000	-0.759	1.037
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	5.500	0.428	5	4.399	6.601
	Fire	5.500	0.500	5	4.215	6.785
	Leak	5.833	0.401	5.000	4.802	6.865
Separate	Evacuation	5.000	0.365	5	4.061	5.939
	Fire	5.167	0.307	5	4.377	5.957
	Leak	5.917	0.271	5	5.219	6.614
Face-to-face	Evacuation	6.000	0.447	5	4.850	7.150
	Fire	5.500	0.224	5.000	4.925	6.075
	Leak	4.833	0.654	5	3.152	6.515

Post-Scenario Question 2:
"I made suggestions about how to do the task to my teammate."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	29.594	1,001.739	0.000
Interface	2	19.536	0.206	0.816
Scenario	2	26.084	1.041	0.367
Interface * Scenario	4	20.608	1.917	0.146

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	0.000	0.246	24.425	1.000	-0.632	0.632
	Face-to-face	0.167	0.278	17.931	1.000	-0.567	0.900
Separate	Hand Images	0.000	0.246	24.425	1.000	-0.632	0.632
	Face-to-face	0.167	0.299	20.544	1.000	-0.613	0.946
Face-to-face	Hand Images	-0.167	0.278	17.931	1.000	-0.900	0.567
	Separate	-0.167	0.299	20.544	1.000	-0.946	0.613
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 2, cont.:
"I made suggestions about how to do the task to my teammate."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.389	0.303	21.459	0.640	-0.399	1.176
	Leak	0.111	0.283	18.670	1.000	-0.634	0.856
Fire	Evacuation	-0.389	0.303	21.459	0.640	-1.176	0.399
	Leak	-0.278	0.234	22.748	0.745	-0.883	0.328
Leak	Evacuation	-0.111	0.283	18.670	1.000	-0.856	0.634
	Fire	0.278	0.234	22.748	0.745	-0.328	0.883
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	4.167	0.307	5	3.377	4.957
	Fire	2.833	0.307	5	2.043	3.623
	Leak	3.833	0.167	5	3.405	4.262
Separate	Evacuation	3.500	0.342	5	2.622	4.378
	Fire	3.833	0.401	5	2.802	4.865
	Leak	3.500	0.224	5	2.925	4.075
Face-to-face	Evacuation	3.500	0.563	5	2.053	4.947
	Fire	3.333	0.211	5	2.791	3.875
	Leak	3.500	0.342	5	2.622	4.378

Post-Scenario Question 3:
"Did either of you emerge as leader?"

Analysis software reported an error (solution failed to converge). No results.

Post-Scenario Question 4:
"To what extent did you feel your teammate was at the same table with you?"

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	32.687	1,031.684	0.000
Interface	2	26.065	22.219	0.000
Scenario	2	20.897	1.835	0.184
Interface * Scenario	4	20.469	2.270	0.097

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	0.500	0.307	23.631	0.351	-0.292	1.292
	Face-to-face	-1.167(*)	0.255	17.892	0.001	-1.839	-0.494
Separate	Hand Images	-0.500	0.307	23.631	0.351	-1.292	0.292
	Face-to-face	-1.667(*)	0.274	24.724	0.000	-2.371	-0.962
Face-to-face	Hand Images	1.167(*)	0.255	17.892	0.001	0.494	1.839
	Separate	1.667(*)	0.274	24.724	0.000	0.962	2.371
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 4, cont.:
"To what extent did you feel your teammate was at the same table with you?"

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-0.444	0.251	24.423	0.267	-1.089	0.201
	Leak	-0.389	0.287	20.281	0.569	-1.137	0.359
Fire	Evacuation	0.444	0.251	24.423	0.267	-0.201	1.089
	Leak	0.056	0.299	23.089	1.000	-0.717	0.828
Leak	Evacuation	0.389	0.287	20.281	0.569	-0.359	1.137
	Fire	-0.056	0.299	23.089	1.000	-0.828	0.717
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	3.333	0.211	5	2.791	3.875
	Fire	4.000	0.258	5	3.336	4.664
	Leak	3.000	0.516	5	1.673	4.327
Separate	Evacuation	2.167	0.401	5	1.135	3.198
	Fire	3.000	0.365	5	2.061	3.939
	Leak	3.667	0.422	5	2.583	4.751
Face-to-face	Evacuation	4.667	0.211	5	4.125	5.209
	Fire	4.500	0.342	5	3.622	5.378
	Leak	4.667	0.211	5	4.125	5.209

Post-Scenario Question 5:
"I felt encouraged by my teammate's actions and ideas."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	38.361	1,923.857	0.000
Interface	2	26.364	0.948	0.400
Scenario	2	28.994	1.076	0.354
Interface * Scenario	4	19.985	5.021	0.006

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	3.833	0.307	5	3.043	4.623
	Fire	4.167	0.167	5	3.738	4.595
	Leak	3.500	0.224	5	2.925	4.075
Separate	Evacuation	3.333	0.333	5	2.476	4.190
	Fire	3.333	0.211	5	2.791	3.875
	Leak	4.000	0.258	5	3.336	4.664
side-by-side	Evacuation	4.500	0.224	5	3.925	5.075
	Fire	3.667	0.211	5	3.125	4.209
	Leak	3.167	0.307	5	2.377	3.957

Post-Scenario Question 5, cont.:
"I felt encouraged by my teammate's actions and ideas."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.167	0.203	24.317	1.000	-0.356	0.690
	Leak	0.333	0.228	27.477	0.464	-0.247	0.914
Fire	Evacuation	-0.167	0.203	24.317	1.000	-0.690	0.356
	Leak	0.167	0.191	26.094	1.000	-0.322	0.655
Leak	Evacuation	-0.333	0.228	27.477	0.464	-0.914	0.247
	Fire	-0.167	0.191	26.094	1.000	-0.655	0.322
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	3.833	0.307	5	3.043	4.623
	Fire	4.167	0.167	5	3.738	4.595
	Leak	3.500	0.224	5	2.925	4.075
Separate	Evacuation	3.333	0.333	5	2.476	4.190
	Fire	3.333	0.211	5	2.791	3.875
	Leak	4.000	0.258	5	3.336	4.664
Face-to-face	Evacuation	4.500	0.224	5	3.925	5.075
	Fire	3.667	0.211	5	3.125	4.209
	Leak	3.167	0.307	5	2.377	3.957

Post-Scenario Question 6:
"I felt frustrated by the task."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	37.753	227.227	0.000
Interface	2	29.494	0.243	0.786
Scenario	2	28.029	1.219	0.311
Interface * Scenario	4	23.299	0.375	0.824

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-0.222	0.324	24.286	1.000	-1.055	0.611
	Face-to-face	-0.056	0.289	29.179	1.000	-0.789	0.678
Separate	Hand Images	0.222	0.324	24.286	1.000	-0.611	1.055
	Face-to-face	0.167	0.325	24.651	1.000	-0.668	1.001
Face-to-face	Hand Images	0.056	0.289	29.179	1.000	-0.678	0.789
	Separate	-0.167	0.325	24.651	1.000	-1.001	0.668
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 6, cont.:
"I felt frustrated by the task."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.444	0.310	23.204	0.496	-0.356	1.245
	Leak	0.111	0.333	25.424	1.000	-0.743	0.965
Fire	Evacuation	-0.444	0.310	23.204	0.496	-1.245	0.356
	Leak	-0.333	0.294	28.926	0.798	-1.080	0.414
Leak	Evacuation	-0.111	0.333	25.424	1.000	-0.965	0.743
	Fire	0.333	0.294	28.926	0.798	-0.414	1.080
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	1.833	0.307	5	1.043	2.623
	Fire	1.500	0.342	5	0.622	2.378
	Leak	2.167	0.401	5	1.135	3.198
Separate	Evacuation	2.500	0.563	5	1.053	3.947
	Fire	1.833	0.307	5	1.043	2.623
	Leak	1.833	0.401	5	0.802	2.865
Face-to-face	Evacuation	2.000	0.365	5	1.061	2.939
	Fire	1.667	0.333	5	0.810	2.524
	Leak	2.000	0.365	5	1.061	2.939

Post-Scenario Question 7:
"My teammate expressed positive opinions about my actions and ideas."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	33.032	1,583.182	0.000
Interface	2	21.753	1.235	0.310
Scenario	2	21.872	2.566	0.100
Interface * Scenario	4	15.844	2.148	0.122

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	0.222	0.199	24.498	0.823	-0.289	0.733
	Face-to-face	0.361	0.239	22.507	0.432	-0.256	0.978
Separate	Hand Images	-0.222	0.199	24.498	0.823	-0.733	0.289
	Face-to-face	0.139	0.223	21.373	1.000	-0.439	0.717
Face-to-face	Hand Images	-0.361	0.239	22.507	0.432	-0.978	0.256
	Separate	-0.139	0.223	21.373	1.000	-0.717	0.439
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 7, cont.:
"My teammate expressed positive opinions about my actions and ideas."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.139	0.188	27.891	1.000	-0.340	0.618
	Leak	0.528	0.233	21.507	0.103	-0.078	1.134
Fire	Evacuation	-0.139	0.188	27.891	1.000	-0.618	0.340
	Leak	0.389	0.237	22.564	0.344	-0.224	1.002
Leak	Evacuation	-0.528	0.233	21.507	0.103	-1.134	0.078
	Fire	-0.389	0.237	22.564	0.344	-1.002	0.224
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	3.833	0.167	5.000	3.405	4.262
	Fire	4.000	0.258	5	3.336	4.664
	Leak	3.500	0.342	5	2.622	4.378
Separate	Evacuation	3.500	0.224	5	2.925	4.075
	Fire	3.500	0.224	5	2.925	4.075
	Leak	3.667	0.211	5	3.125	4.209
Face-to-face	Evacuation	4.083	0.271	5	3.386	4.781
	Fire	3.500	0.224	5	2.925	4.075
	Leak	2.667	0.422	5	1.583	3.751

Post-Scenario Question 8:
"I felt we were a team rather than two separate individuals."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	26.141	1,153.662	0.000
Interface	2	22.583	2.436	0.110
Scenario	2	26.820	0.351	0.707
Interface * Scenario	4	22.600	1.142	0.362

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	0.167	0.305	19.196	1.000	-0.634	0.967
	Face-to-face	-0.361	0.248	13.798	0.501	-1.035	0.313
Separate	Hand Images	-0.167	0.305	19.196	1.000	-0.967	0.634
	Face-to-face	-0.528	0.263	20.598	0.175	-1.214	0.158
Face-to-face	Hand Images	0.361	0.248	13.798	0.501	-0.313	1.035
	Separate	0.528	0.263	20.598	0.175	-0.158	1.214
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 8, cont.:
"I felt we were a team rather than two separate individuals."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-0.250	0.298	17.980	1.000	-1.038	0.538
	Leak	-0.194	0.306	19.608	1.000	-0.994	0.605
Fire	Evacuation	0.250	0.298	17.980	1.000	-0.538	1.038
	Leak	0.056	0.203	23.701	1.000	-0.468	0.579
Leak	Evacuation	0.194	0.306	19.608	1.000	-0.605	0.994
	Fire	-0.056	0.203	23.701	1.000	-0.579	0.468
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	3.333	0.558	5	1.900	4.767
	Fire	4.167	0.167	5.000	3.738	4.595
	Leak	3.667	0.211	5	3.125	4.209
Separate	Evacuation	3.500	0.500	5	2.215	4.785
	Fire	3.333	0.333	5	2.476	4.190
	Leak	3.833	0.307	5	3.043	4.623
Face-to-face	Evacuation	4.083	0.271	5	3.386	4.781
	Fire	4.167	0.167	5	3.738	4.595
	Leak	4.000	0.258	5	3.336	4.664

Post-Scenario Question 9:
"The solution was truly a joint effort."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	35.339	1,610.651	0.000
Interface	2	26.188	1.565	0.228
Scenario	2	22.463	0.592	0.562
Interface * Scenario	4	17.575	0.884	0.494

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	0.389	0.221	24.322	0.272	-0.179	0.957
	Face-to-face	0.139	0.220	20.457	1.000	-0.434	0.712
Separate	Hand Images	-0.389	0.221	24.322	0.272	-0.957	0.179
	Face-to-face	-0.250	0.267	26.849	1.000	-0.931	0.431
Face-to-face	Hand Images	-0.139	0.220	20.457	1.000	-0.712	0.434
	Separate	0.250	0.267	26.849	1.000	-0.431	0.931
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 9, cont.:
"The solution was truly a joint effort."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.028	0.221	25.131	1.000	-0.540	0.595
	Leak	0.250	0.248	23.937	0.968	-0.387	0.887
Fire	Evacuation	-0.028	0.221	25.131	1.000	-0.595	0.540
	Leak	0.222	0.241	22.703	1.000	-0.400	0.845
Leak	Evacuation	-0.250	0.248	23.937	0.968	-0.887	0.387
	Fire	-0.222	0.241	22.703	1.000	-0.845	0.400
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	4.333	0.211	5	3.791	4.875
	Fire	4.167	0.167	5.000	3.738	4.595
	Leak	3.667	0.211	5	3.125	4.209
Separate	Evacuation	3.500	0.342	5	2.622	4.378
	Fire	3.667	0.333	5	2.810	4.524
	Leak	3.833	0.307	5	3.043	4.623
Face-to-face	Evacuation	4.083	0.271	5	3.386	4.781
	Fire	4.000	0.258	5	3.336	4.664
	Leak	3.667	0.422	5	2.583	4.751

Post-Scenario Question 10:
"I felt disconnected from my teammate."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	28.110	431.260	0.000
Interface	2	25.279	9.289	0.001
Scenario	2	23.362	1.202	0.318
Interface * Scenario	4	17.447	0.783	0.551

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-0.444	0.236	18.392	0.226	-1.065	0.176
	Face-to-face	.556(*)	0.196	23.965	0.027	0.052	1.059
Separate	Hand Images	0.444	0.236	18.392	0.226	-0.176	1.065
	Face-to-face	1.000(*)	0.241	18.579	0.002	0.366	1.634
Face-to-face	Hand Images	-.556(*)	0.196	23.965	0.027	-1.059	-0.052
	Separate	-1.000(*)	0.241	18.579	0.002	-1.634	-0.366
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 10, cont.:
"I felt disconnected from my teammate."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.278	0.226	16.536	0.711	-0.325	0.881
	Leak	0.000	0.241	18.579	1.000	-0.634	0.634
Fire	Evacuation	-0.278	0.226	16.536	0.711	-0.881	0.325
	Leak	-0.278	0.206	25.847	0.570	-0.806	0.251
Leak	Evacuation	0.000	0.241	18.579	1.000	-0.634	0.634
	Fire	0.278	0.206	25.847	0.570	-0.251	0.806
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	1.833	0.167	5	1.405	2.262
	Fire	2.000	0.258	5	1.336	2.664
	Leak	2.000	0.258	5	1.336	2.664
Separate	Evacuation	2.833	0.477	5	1.606	4.060
	Fire	2.000	0.258	5	1.336	2.664
	Leak	2.333	0.211	5	1.791	2.875
Face-to-face	Evacuation	1.333	0.211	5	0.791	1.875
	Fire	1.167	0.167	5	0.738	1.595
	Leak	1.667	0.333	5	0.810	2.524

Post-Scenario Question 11:
"I expressed positive opinions about my teammate's actions and ideas."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	38.253	1,752.257	0.000
Interface	2	27.191	0.523	0.598
Scenario	2	24.520	1.153	0.332
Interface * Scenario	4	21.190	2.268	0.096

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-0.167	0.221	25.768	1.000	-0.732	0.399
	Face-to-face	-0.222	0.222	25.559	0.980	-0.792	0.347
Separate	Hand Images	0.167	0.221	25.768	1.000	-0.399	0.732
	Face-to-face	-0.056	0.203	25.651	1.000	-0.576	0.465
Face-to-face	Hand Images	0.222	0.222	25.559	0.980	-0.347	0.792
	Separate	0.056	0.203	25.651	1.000	-0.465	0.576
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 11, cont.:
"I expressed positive opinions about my teammate's actions and ideas."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-0.111	0.208	26.805	1.000	-0.642	0.420
	Leak	0.222	0.217	24.642	0.945	-0.334	0.779
Fire	Evacuation	0.111	0.208	26.805	1.000	-0.420	0.642
	Leak	0.333	0.222	25.559	0.438	-0.236	0.903
Leak	Evacuation	-0.222	0.217	24.642	0.945	-0.779	0.334
	Fire	-0.333	0.222	25.559	0.438	-0.903	0.236
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	3.333	0.211	5	2.791	3.875
	Fire	3.833	0.307	5	3.043	4.623
	Leak	3.500	0.342	5	2.622	4.378
Separate	Evacuation	3.667	0.211	5	3.125	4.209
	Fire	3.667	0.211	5	3.125	4.209
	Leak	3.833	0.307	5	3.043	4.623
Face-to-face	Evacuation	4.167	0.307	5	3.377	4.957
	Fire	4.000	0.258	5	3.336	4.664
	Leak	3.167	0.167	5	2.738	3.595

Post-Scenario Question 12:
"I felt disinterested in the task."

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	33.982	316.875	0.000
Interface	2	22.885	1.090	0.353
Scenario	2	23.851	0.167	0.847
Interface * Scenario	4	18.534	2.423	0.085

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	-0.056	0.197	21.134	1.000	-0.568	0.457
	Face-to-face	-0.278	0.197	22.889	0.517	-0.787	0.232
Separate	Hand Images	0.056	0.197	21.134	1.000	-0.457	0.568
	Face-to-face	-0.222	0.202	24.040	0.845	-0.742	0.297
Face-to-face	Hand Images	0.278	0.197	22.889	0.517	-0.232	0.787
	Separate	0.222	0.202	24.040	0.845	-0.297	0.742
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Post-Scenario Question 12, cont.:
"I felt disinterested in the task."

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.056	0.206	23.407	1.000	-0.477	0.588
	Leak	-0.056	0.197	22.889	1.000	-0.565	0.454
Fire	Evacuation	-0.056	0.206	23.407	1.000	-0.588	0.477
	Leak	-0.111	0.192	21.739	1.000	-0.610	0.388
Leak	Evacuation	0.056	0.197	22.889	1.000	-0.454	0.565
	Fire	0.111	0.192	21.739	1.000	-0.388	0.610
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	1.667	0.333	5	0.810	2.524
	Fire	1.167	0.167	5	0.738	1.595
	Leak	1.167	0.167	5	0.738	1.595
Separate	Evacuation	1.333	0.211	5	0.791	1.875
	Fire	1.667	0.333	5	0.810	2.524
	Leak	1.167	0.167	5	0.738	1.595
Face-to-face	Evacuation	1.333	0.211	5	0.791	1.875
	Fire	1.333	0.211	5	0.791	1.875
	Leak	2.167	0.307	5	1.377	2.957

Post-Scenario Question 13:
"I felt frustrated by my teammate."

Analysis software reported an error (solution failed to converge). No results.

Positive Interactions

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	108.246	5,237.803	0.000
Interface	2	70.382	0.422	0.658
Scenario	2	69.302	4.224	0.019
Question	2	73.218	0.664	0.518
Interface * Scenario	4	46.918	7.749	0.000
Interface * Question	4	55.088	1.109	0.362
Scenario * Question	4	50.859	0.456	0.768
Interface * Scenario * Question	8	39.530	0.411	0.907

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	0.111	0.121	75.075	1.000	-0.186	0.408
	Face-to-face	0.065	0.128	70.863	1.000	-0.248	0.378
Separate	Hand Images	-0.111	0.121	75.075	1.000	-0.408	0.186
	Face-to-face	-0.046	0.123	71.492	1.000	-0.348	0.256
Face-to-face	Hand Images	-0.065	0.128	70.863	1.000	-0.378	0.248
	Separate	0.046	0.123	71.492	1.000	-0.256	0.348
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Positive Interactions, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.065	0.115	77.814	1.000	-0.218	0.347
	Leak	.361(*)	0.130	72.222	0.022	0.041	0.681
Fire	Evacuation	-0.065	0.115	77.814	1.000	-0.347	0.218
	Leak	0.296	0.126	70.458	0.063	-0.012	0.604
Leak	Evacuation	-.361(*)	0.130	72.222	0.022	-0.681	-0.041
	Fire	-0.296	0.126	70.458	0.063	-0.604	0.012
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	3.667	0.136	11.905	3.370	3.963
	Fire	4.000	0.145	12.620	3.686	4.314
	Leak	3.500	0.177	13.505	3.118	3.882
Separate	Evacuation	3.500	0.151	12.560	3.172	3.828
	Fire	3.500	0.124	14.952	3.235	3.765
	Leak	3.833	0.151	13.773	3.509	4.158
Face-to-face	Evacuation	4.250	0.156	14.119	3.916	4.584
	Fire	3.722	0.134	14.550	3.436	4.008
	Leak	3.000	0.183	10.897	2.598	3.402

Team Behaviors

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	116.572	5,243.158	0.000
Interface	2	77.760	9.445	0.000
Scenario	2	89.394	0.101	0.904
Question	3	57.899	12.674	0.000
Interface * Scenario	4	63.645	1.006	0.411
Interface * Question	6	47.441	5.413	0.000
Scenario * Question	6	49.304	0.666	0.678
Interface * Scenario * Question	12	44.744	1.287	0.260

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	.565(*)	0.133	78.954	0.000	0.239	0.890
	Face-to-face	.398(*)	0.134	72.544	0.012	0.070	0.726
Separate	Hand Images	-.565(*)	0.133	78.954	0.000	-0.890	-0.239
	Face-to-face	-0.167	0.132	82.637	0.630	-0.489	0.156
Face-to-face	Hand Images	-.398(*)	0.134	72.544	0.012	-0.726	-0.070
	Separate	0.167	0.132	82.637	0.630	-0.156	0.489
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.060	0.137	75.748	1.000	-0.276	0.396
	Leak	0.028	0.140	81.444	1.000	-0.315	0.370
Fire	Evacuation	-0.060	0.137	75.748	1.000	-0.396	0.276
	Leak	-0.032	0.120	80.377	1.000	-0.327	0.262
Leak	Evacuation	-0.028	0.140	81.444	1.000	-0.370	0.315
	Fire	0.032	0.120	80.377	1.000	-0.262	0.327
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	4.333	0.199	14.194	3.907	4.760
	Fire	4.167	0.158	10.964	3.819	4.515
	Leak	4.250	0.132	12.575	3.964	4.536
Separate	Evacuation	3.542	0.184	15.789	3.151	3.932
	Fire	3.653	0.163	17.257	3.309	3.996
	Leak	3.861	0.130	17.228	3.587	4.136
Face-to-face	Evacuation	4.000	0.186	12.837	3.598	4.402
	Fire	3.875	0.100	16.888	3.663	4.087
	Leak	3.681	0.186	17.706	3.290	4.071

Connection to Teammate

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	87.408	5,406.174	0.000
Interface	2	67.212	18.444	0.000
Scenario	2	56.422	1.953	0.151
Question	2	70.163	21.197	0.000
Interface * Scenario	4	46.568	2.978	0.029
Interface * Question	4	55.224	10.051	0.000
Scenario * Question	4	49.237	0.628	0.644
Interface * Scenario * Question	8	38.999	1.748	0.118

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Hand Images	Separate	0.333	0.145	57.843	0.075	-0.024	0.691
	Face-to-face	-.481(*)	0.126	55.684	0.001	-0.792	-0.171
Separate	Hand Images	-0.333	0.145	57.843	0.075	-0.691	0.024
	Face-to-face	-.815(*)	0.139	63.174	0.000	-1.157	-0.473
Face-to-face	Hand Images	.481(*)	0.126	55.684	0.001	0.171	0.792
	Separate	.815(*)	0.139	63.174	0.000	0.473	1.157
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Connection to Teammate, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-0.259	0.132	61.679	0.162	-0.584	0.066
	Leak	-0.111	0.141	55.285	1.000	-0.459	0.237
Fire	Evacuation	0.259	0.132	61.679	0.162	-0.066	0.584
	Leak	0.148	0.137	59.565	0.853	-0.190	0.486
Leak	Evacuation	0.111	0.141	55.285	1.000	-0.237	0.459
	Fire	-0.148	0.137	59.565	0.853	-0.486	0.190
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Hand Images	Evacuation	3.944	0.143	11.135	3.631	4.258
	Fire	4.278	0.134	13.435	3.990	4.566
	Leak	3.944	0.200	8.542	3.488	4.401
Separate	Evacuation	3.333	0.219	11.763	2.854	3.812
	Fire	3.778	0.186	14	3.379	4.177
	Leak	4.056	0.167	9.097	3.679	4.432
Face-to-face	Evacuation	4.667	0.122	15	4.407	4.926
	Fire	4.667	0.145	10.906	4.347	4.986
	Leak	4.278	0.167	13.446	3.919	4.637

Workload (NASA-TLX Aggregate)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	27.454	392.571	0.000
Interface	2	19.488	3.756	0.042
Scenario	2	19.964	2.874	0.080
Interface * Scenario	4	18.208	1.634	0.209

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-7.852	3.571	17.477	0.125	-17.305	1.601
	Separate	-8.481	4.089	16.443	0.162	-19.377	2.414
Hand Images	Face-to-face	7.852	3.571	17.477	0.125	-1.601	17.305
	Separate	-0.630	4.810	22.211	1.000	-13.083	11.823
Separate	Face-to-face	8.481	4.089	16.443	0.162	-2.414	19.377
	Hand Images	0.630	4.810	22.211	1.000	-11.823	13.083
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Workload (NASA-TLX Aggregate), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	9.407	4.119	17.039	0.106	-1.525	20.340
	Leak	3.259	4.473	18.636	1.000	-8.504	15.023
Fire	Evacuation	-9.407	4.119	17.039	0.106	-20.340	1.525
	Leak	-6.148	3.954	20.318	0.406	-16.463	4.166
Leak	Evacuation	-3.259	4.473	18.636	1.000	-15.023	8.504
	Fire	6.148	3.954	20.318	0.406	-4.166	16.463
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	33.139	4.495	5	21.585	44.692
	Fire	19.333	2.375	5	13.227	25.440
	Leak	32.806	1.634	5	28.604	37.007
Hand Images	Evacuation	40.056	2.427	5	33.818	46.293
	Fire	28.806	5.901	5	13.636	43.975
	Leak	39.972	6.748	5	22.625	57.319
Separate	Evacuation	41.083	8.363	5	19.586	62.581
	Fire	37.917	4.023	5	27.575	48.259
	Leak	31.722	5.984	5	16.339	47.105

Frustration Aggregate

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	28.973	361.971	0.000
Interface	2	18.967	0.355	0.706
Scenario	2	28.410	1.516	0.237
Interface * Scenario	4	21.067	1.059	0.401

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	0.033	0.206	27.885	1.000	-0.492	0.557
	Separate	-0.167	0.236	17.225	1.000	-0.792	0.459
Hand Images	Face-to-face	-0.033	0.206	27.885	1.000	-0.557	0.492
	Separate	-0.199	0.248	19.362	1.000	-0.848	0.450
Separate	Face-to-face	0.167	0.236	17.225	1.000	-0.459	0.792
	Hand Images	0.199	0.248	19.362	1.000	-0.450	0.848
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Frustration Aggregate, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.266	0.230	16.384	0.794	-0.348	0.880
	Leak	-0.038	0.261	22.343	1.000	-0.714	0.638
Fire	Evacuation	-0.266	0.230	16.384	0.794	-0.880	0.348
	Leak	-0.304	0.195	24.873	0.398	-0.805	0.198
Leak	Evacuation	0.038	0.261	22.343	1.000	-0.638	0.714
	Fire	0.304	0.195	24.873	0.398	-0.198	0.805
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	1.738	0.251	5	1.093	2.383
	Fire	1.404	0.173	5	0.961	1.848
	Leak	2.096	0.270	5	1.403	2.789
Hand Images	Evacuation	1.704	0.275	5	0.997	2.412
	Fire	1.507	0.238	5	0.894	2.119
	Leak	1.929	0.290	5	1.183	2.675
Separate	Evacuation	2.158	0.485	5	0.910	3.405
	Fire	1.891	0.129	5	1.560	2.222
	Leak	1.689	0.289	5	0.947	2.431

Proportion of time spent working inside the electronic interface

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	29.360	531.429	0.000
Interface	2	21.487	0.094	0.911
Scenario	2	26.352	6.742	0.004
Interface * Scenario	4	24.215	0.933	0.462

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-0.013	0.070	19.039	1.000	-0.198	0.171
	Separate	0.017	0.066	23.312	1.000	-0.153	0.187
Hand Images	Face-to-face	0.013	0.070	19.039	1.000	-0.171	0.198
	Separate	0.030	0.071	18.102	1.000	-0.156	0.217
Separate	Face-to-face	-0.017	0.066	23.312	1.000	-0.187	0.153
	Hand Images	-0.030	0.071	18.102	1.000	-0.217	0.156
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Proportion of time spent working inside the electronic interface, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-.281(*)	0.076	21.057	0.004	-0.479	-0.082
	Leak	-.207(*)	0.074	20.240	0.033	-0.400	-0.014
Fire	Evacuation	.281(*)	0.076	21.057	0.004	0.082	0.479
	Leak	0.074	0.055	23.162	0.575	-0.068	0.215
Leak	Evacuation	.207(*)	0.074	20.240	0.033	0.014	0.400
	Fire	-0.074	0.055	23.162	0.575	-0.215	0.068
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	0.571	0.078	5	0.371	0.772
	Fire	0.682	0.098	5	0.430	0.935
	Leak	0.699	0.059	5	0.548	0.851
Hand Images	Evacuation	0.511	0.138	5	0.157	0.864
	Fire	0.794	0.057	5	0.648	0.940
	Leak	0.689	0.057	5	0.543	0.834
Separate	Evacuation	0.380	0.111	5	0.094	0.666
	Fire	0.827	0.049	5	0.702	0.952
	Leak	0.695	0.071	5	0.511	0.878

Total time: Speaking (without gesturing or marking)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	33.583	207.815	0.000
Interface	2	21.365	6.102	0.008
Scenario	2	24.011	11.252	0.000
Interface * Scenario	4	16.768	1.148	0.368

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-183.722(*)	56.997	21.796	0.012	-331.526	-35.918
	Separate	-186.463(*)	68.586	24.144	0.036	-362.901	-10.025
Hand Images	Face-to-face	183.722(*)	56.997	21.796	0.012	35.918	331.526
	Separate	-2.741	65.051	22.119	1.000	-171.227	165.746
Separate	Face-to-face	186.463(*)	68.586	24.144	0.036	10.025	362.901
	Hand Images	2.741	65.051	22.119	1.000	-165.746	171.227
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Total time: Speaking (without gesturing or marking), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	212.315(*)	56.230	18.825	0.004	64.574	360.056
	Leak	-15.222	72.464	26.302	1.000	-200.508	170.063
Fire	Evacuation	-212.315(*)	56.230	18.825	0.004	-360.056	-64.574
	Leak	-227.537(*)	61.412	22.545	0.004	-386.355	-68.719
Leak	Evacuation	15.222	72.464	26.302	1.000	-170.063	200.508
	Fire	227.537(*)	61.412	22.545	0.004	68.719	386.355
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	293.278	77.801	5	93.285	493.271
	Fire	158.111	41.792	5	50.682	265.540
	Leak	303.611	94.581	5	60.483	546.739
Hand Images	Evacuation	519.111	51.493	5	386.745	651.477
	Fire	208.889	41.053	5	103.358	314.420
	Leak	578.167	90.310	5	346.017	810.317
Separate	Evacuation	509.889	110.371	5	226.172	793.606
	Fire	318.333	64.329	5	152.971	483.695
	Leak	486.167	96.290	5	238.646	733.688

Total time: Gazing (without speaking, marking, gesturing, or manipulating)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	40.037	219.344	0.000
Interface	2	27.008	0.752	0.481
Scenario	2	27.927	3.626	0.040
Interface * Scenario	4	19.287	1.120	0.376

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-57.648	54.560	25.692	0.902	-197.378	82.082
	Separate	-3.574	62.817	28.506	1.000	-163.357	156.209
Hand Images	Face-to-face	57.648	54.560	25.692	0.902	-82.082	197.378
	Separate	54.074	56.306	26.376	1.000	-89.869	198.017
Separate	Face-to-face	3.574	62.817	28.506	1.000	-156.209	163.357
	Hand Images	-54.074	56.306	26.376	1.000	-198.017	89.869
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Total time: Gazing (without speaking, marking, gesturing, or manipulating), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	77.333	59.241	27.964	0.607	-73.534	228.200
	Leak	-70.056	59.864	26.204	0.757	-223.163	83.052
Fire	Evacuation	-77.333	59.241	27.964	0.607	-228.200	73.534
	Leak	-147.389(*)	54.772	26.342	0.037	-287.422	-7.356
Leak	Evacuation	70.056	59.864	26.204	0.757	-83.052	223.163
	Fire	147.389(*)	54.772	26.342	0.037	7.356	287.422
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	289.111	89.227	5	59.747	518.475
	Fire	237.944	65.280	5	70.138	405.751
	Leak	463.833	68.287	5	288.295	639.372
Hand Images	Evacuation	432.444	66.776	5	260.791	604.098
	Fire	251.889	60.330	5	96.806	406.972
	Leak	479.500	42.499	5	370.253	588.747
Separate	Evacuation	337.833	77.454	5	138.731	536.936
	Fire	337.556	72.557	5	151.042	524.069
	Leak	326.222	85.817	5	105.622	546.823

Total time: Marking while Speaking

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	193.648	36.160	6.098	105.511
Interface	280.796	42.715	8.617	183.510
Scenario	356.556	62.294	14.008	222.955
Interface * Scenario	193.648	36.160	6.098	105.511

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-87.148	55.965	14.714	0.422	-238.267	63.971
	Separate	-162.907	72.029	19.859	0.105	-351.209	25.394
Hand Images	Face-to-face	87.148	55.965	14.714	0.422	-63.971	238.267
	Separate	-75.759	75.532	22.273	0.980	-271.283	119.764
Separate	Face-to-face	162.907	72.029	19.859	0.105	-25.394	351.209
	Hand Images	75.759	75.532	22.273	0.980	-119.764	271.283
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Total time: Marking while Speaking, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	264.315(*)	68.081	16.493	0.004	82.957	445.672
	Leak	124.685	73.004	22.574	0.304	-64.091	313.461
Fire	Evacuation	-264.315(*)	68.081	16.493	0.004	-445.672	-82.957
	Leak	-139.630	63.724	17.875	0.126	-307.925	28.666
Leak	Evacuation	-124.685	73.004	22.574	0.304	-313.461	64.091
	Fire	139.630	63.724	17.875	0.126	-28.666	307.925
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	268.389	29.963	5	191.366	345.412
	Fire	18.389	15.973	5	-22.672	59.449
	Leak	294.167	103.029	5	29.322	559.011
Hand Images	Evacuation	505.611	109.393	5	224.407	786.815
	Fire	96.667	30.562	5	18.104	175.229
	Leak	240.111	59.328	5	87.603	392.620
Separate	Evacuation	446.000	117.059	5	145.089	746.911
	Fire	312.000	118.146	5	8.296	615.704
	Leak	311.667	85.228	5	92.581	530.752

Total time: Gesturing while Speaking

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	8.875	32.134	0.000
Interface	2	7.116	19.228	0.001
Scenario	2	12.016	1.552	0.251
Interface * Scenario	4	7.727	1.365	0.330

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	88.759	88.968	8.729	1.000	-174.003	351.522
	Separate	248.630(*)	42.122	10.118	0.000	128.011	369.248
Hand Images	Face-to-face	-88.759	88.968	8.729	1.000	-351.522	174.003
	Separate	159.870	79.207	5.731	0.277	-104.902	424.643
Separate	Face-to-face	-248.630(*)	42.122	10.118	0.000	-369.248	-128.011
	Hand Images	-159.870	79.207	5.731	0.277	-424.643	104.902
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Total time: Gesturing while Speaking, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	95.852	80.581	6.124	0.835	-167.162	358.866
	Leak	38.815	88.062	8.383	1.000	-223.732	301.362
Fire	Evacuation	-95.852	80.581	6.124	0.835	-358.866	167.162
	Leak	-57.037	41.413	9.877	0.597	-176.186	62.112
Leak	Evacuation	-38.815	88.062	8.383	1.000	-301.362	223.732
	Fire	57.037	41.413	9.877	0.597	-62.112	176.186
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	258.389	60.515	5	102.831	413.947
	Fire	231.278	34.252	5	143.230	319.326
	Leak	354.167	102.642	5	90.318	618.015
Hand Images	Evacuation	348.222	229.478	5	-241.670	938.115
	Fire	77.333	20.038	5	25.825	128.842
	Leak	152.000	52.963	5	15.855	288.145
Separate	Evacuation	34.500	8.774	5	11.946	57.054
	Fire	44.944	21.567	5	-10.494	100.383
	Leak	18.500	7.442	5	-0.630	37.630

Total time: Marking (without speaking)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	20.662	37.961	0.000
Interface	2	26.601	6.296	0.006
Scenario	2	18.036	0.813	0.459
Interface * Scenario	4	21.721	0.869	0.498

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-88.981	37.825	14.468	0.100	-191.337	13.374
	Separate	-58.519(*)	20.185	20.820	0.026	-111.065	-5.972
Hand Images	Face-to-face	88.981	37.825	14.468	0.100	-13.374	191.337
	Separate	30.463	40.870	18.798	1.000	-76.937	137.863
Separate	Face-to-face	58.519(*)	20.185	20.820	0.026	5.972	111.065
	Hand Images	-30.463	40.870	18.798	1.000	-137.863	76.937
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Total time: Marking (without speaking), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	48.130	37.797	14.662	0.668	-53.976	150.235
	Leak	28.037	33.331	14.180	1.000	-62.396	118.470
Fire	Evacuation	-48.130	37.797	14.662	0.668	-150.235	53.976
	Leak	-20.093	31.128	13.106	1.000	-105.469	65.284
Leak	Evacuation	-28.037	33.331	14.180	1.000	-118.470	62.396
	Fire	20.093	31.128	13.106	1.000	-65.284	105.469
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	49.611	18.374	5	2.378	96.844
	Fire	19.111	12.515	5	-13.061	51.283
	Leak	41.833	16.139	5	0.346	83.321
Hand Images	Evacuation	126.944	73.703	5	-62.514	316.403
	Fire	99.389	70.418	5	-81.626	280.404
	Leak	151.167	41.603	5	44.224	258.109
Separate	Evacuation	157.667	36.026	5	65.060	250.273
	Fire	71.333	25.968	5	4.581	138.085
	Leak	57.111	30.657	5	-21.696	135.919

Total time: Manipulating (without speaking)

Analysis software reported an error. No results.

Total time: Manipulating while Speaking

Analysis software reported an error. No results.

Total time: Gesturing (without speaking)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	15.371	12.270	0.003
Interface	2	16.565	2.625	0.102
Scenario	2	12.042	1.614	0.239
Interface * Scenario	4	14.300	1.159	0.370

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-4.278	2.290	6.421	0.323	-11.634	3.079
	Separate	-3.000	2.031	17.288	0.473	-8.384	2.384
Hand Images	Face-to-face	4.278	2.290	6.421	0.323	-3.079	11.634
	Separate	1.278	2.933	14.122	1.000	-6.683	9.239
Separate	Face-to-face	3.000	2.031	17.288	0.473	-2.384	8.384
	Hand Images	-1.278	2.933	14.122	1.000	-9.239	6.683
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Total time: Gesturing (without speaking), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-0.241	1.664	15.461	1.000	-4.705	4.224
	Leak	-4.815	2.733	11.263	0.316	-12.491	2.862
Fire	Evacuation	0.241	1.664	15.461	1.000	-4.224	4.705
	Leak	-4.574	2.781	11.830	0.379	-12.321	3.172
Leak	Evacuation	4.815	2.733	11.263	0.316	-2.862	12.491
	Fire	4.574	2.781	11.830	0.379	-3.172	12.321
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	1.000	1.000	5	-1.571	3.571
	Fire	1.556	1.490	5	-2.274	5.385
	Leak	0.667	0.494	5	-0.604	1.938
Hand Images	Evacuation	1.222	1.222	5	-1.920	4.364
	Fire	0.833	0.833	5	-1.309	2.975
	Leak	14.000	6.445	5	-2.568	30.568
Separate	Evacuation	3.222	2.964	5	-4.396	10.840
	Fire	3.778	3.274	5	-4.637	12.193
	Leak	5.222	3.765	5	-4.456	14.900

Proportion of time: Speaking (without gesturing or marking)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	39.196	256.655	0.000
Interface	2	25.697	3.680	0.039
Scenario	2	26.710	0.070	0.933
Interface * Scenario	4	19.485	0.699	0.602

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-0.089	0.043	25.601	0.142	-0.199	0.020
	Separate	-0.111	0.044	27.357	0.053	-0.223	0.001
Hand Images	Face-to-face	0.089	0.043	25.601	0.142	-0.020	0.199
	Separate	-0.022	0.044	25.546	1.000	-0.135	0.092
Separate	Face-to-face	0.111	0.044	27.357	0.053	-0.001	0.223
	Hand Images	0.022	0.044	25.546	1.000	-0.092	0.135
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Proportion of time: Speaking (without gesturing or marking), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.001	0.044	26.638	1.000	-0.111	0.114
	Leak	-0.013	0.042	26.054	1.000	-0.121	0.095
Fire	Evacuation	-0.001	0.044	26.638	1.000	-0.114	0.111
	Leak	-0.015	0.045	25.888	1.000	-0.129	0.100
Leak	Evacuation	0.013	0.042	26.054	1.000	-0.095	0.121
	Fire	0.015	0.045	25.888	1.000	-0.100	0.129
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	0.239	0.060	5	0.086	0.392
	Fire	0.239	0.053	5	0.102	0.375
	Leak	0.179	0.041	5	0.073	0.285
Hand Images	Evacuation	0.279	0.039	5	0.178	0.379
	Fire	0.308	0.069	5	0.130	0.485
	Leak	0.338	0.046	5	0.221	0.455
Separate	Evacuation	0.327	0.052	5	0.193	0.461
	Fire	0.294	0.046	5	0.176	0.413
	Leak	0.368	0.067	5	0.196	0.539

Proportion of time: Gazing (without speaking, marking, gesturing, or manipulating)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	33.206	203.672	0.000
Interface	2	28.742	0.207	0.814
Scenario	2	24.492	2.377	0.114
Interface * Scenario	4	21.085	0.047	0.995

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	0.025	0.046	18.917	1.000	-0.096	0.146
	Separate	0.035	0.057	27.693	1.000	-0.109	0.180
Hand Images	Face-to-face	-0.025	0.046	18.917	1.000	-0.146	0.096
	Separate	0.010	0.043	20.746	1.000	-0.101	0.122
Separate	Face-to-face	-0.035	0.057	27.693	1.000	-0.180	0.109
	Hand Images	-0.010	0.043	20.746	1.000	-0.122	0.101
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Proportion of time: Gazing (without speaking, marking, gesturing, or manipulating), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-0.105	0.050	22.632	0.137	-0.233	0.023
	Leak	-0.059	0.045	22.104	0.605	-0.175	0.057
Fire	Evacuation	0.105	0.050	22.632	0.137	-0.023	0.233
	Leak	0.046	0.052	22.529	1.000	-0.089	0.181
Leak	Evacuation	0.059	0.045	22.104	0.605	-0.057	0.175
	Fire	-0.046	0.052	22.529	1.000	-0.181	0.089
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	0.242	0.061	5	0.085	0.398
	Fire	0.348	0.087	5	0.124	0.571
	Leak	0.326	0.068	5	0.150	0.502
Hand Images	Evacuation	0.223	0.032	5	0.140	0.306
	Fire	0.333	0.044	5	0.220	0.446
	Leak	0.285	0.018	5	0.240	0.330
Separate	Evacuation	0.227	0.056	5	0.083	0.370
	Fire	0.325	0.069	5	0.148	0.502
	Leak	0.258	0.072	5	0.072	0.444

Proportion of time: Marking while Speaking

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	28.165	108.452	0.000
Interface	2	19.476	2.927	0.077
Scenario	2	21.282	4.227	0.028
Interface * Scenario	4	17.656	1.116	0.380

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-0.036	0.035	19.217	0.929	-0.127	0.055
	Separate	-0.117	0.049	19.208	0.085	-0.246	0.013
Hand Images	Face-to-face	0.036	0.035	19.217	0.929	-0.055	0.127
	Separate	-0.081	0.053	22.340	0.427	-0.218	0.057
Separate	Face-to-face	0.117	0.049	19.208	0.085	-0.013	0.246
	Hand Images	0.081	0.053	22.340	0.427	-0.057	0.218
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Proportion of time: Marking while Speaking, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	.142(*)	0.049	18.493	0.029	0.013	0.271
	Leak	0.091	0.046	22.686	0.185	-0.029	0.211
Fire	Evacuation	-.142(*)	0.049	18.493	0.029	-0.271	-0.013
	Leak	-0.051	0.043	16.172	0.769	-0.166	0.064
Leak	Evacuation	-0.091	0.046	22.686	0.185	-0.211	0.029
	Fire	0.051	0.043	16.172	0.769	-0.064	0.166
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	0.246	0.037	5	0.152	0.340
	Fire	0.026	0.021	5	-0.028	0.080
	Leak	0.166	0.043	5	0.055	0.277
Hand Images	Evacuation	0.280	0.068	5	0.105	0.455
	Fire	0.120	0.033	5	0.036	0.205
	Leak	0.146	0.037	5	0.050	0.242
Separate	Evacuation	0.298	0.079	5	0.095	0.500
	Fire	0.252	0.090	5	0.022	0.482
	Leak	0.238	0.063	5	0.077	0.400

Proportion of time: Gesturing while Speaking

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	16.307	82.265	0.000
Interface	2	11.601	38.516	0.000
Scenario	2	15.867	3.281	0.064
Interface * Scenario	4	11.030	0.796	0.552

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	.142(*)	0.045	15.115	0.020	0.020	0.263
	Separate	.236(*)	0.028	17.582	0.000	0.163	0.309
Hand Images	Face-to-face	-.142(*)	0.045	15.115	0.020	-0.263	-0.020
	Separate	0.095	0.038	8.544	0.106	-0.018	0.207
Separate	Face-to-face	-.236(*)	0.028	17.582	0.000	-0.309	-0.163
	Hand Images	-0.095	0.038	8.544	0.106	-0.207	0.018
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Proportion of time: Gesturing while Speaking, cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	-0.042	0.043	13.003	1.000	-0.160	0.077
	Leak	0.029	0.040	10.163	1.000	-0.086	0.143
Fire	Evacuation	0.042	0.043	13.003	1.000	-0.077	0.160
	Leak	0.070	0.027	21.432	0.054	-0.001	0.142
Leak	Evacuation	-0.029	0.040	10.163	1.000	-0.143	0.086
	Fire	-0.070	0.027	21.432	0.054	-0.142	0.001
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	0.225	0.050	5	0.097	0.353
	Fire	0.352	0.046	5	0.235	0.469
	Leak	0.217	0.039	5	0.117	0.317
Hand Images	Evacuation	0.155	0.098	5	-0.098	0.408
	Fire	0.129	0.043	5	0.020	0.238
	Leak	0.086	0.026	5	0.018	0.154
Separate	Evacuation	0.024	0.006	5.000	0.008	0.039
	Fire	0.048	0.026	5	-0.019	0.115
	Leak	0.014	0.006	5.000	-0.001	0.030

Proportion of time: Marking (without speaking)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	20.483	36.496	0.000
Interface	2	26.569	2.895	0.073
Scenario	2	22.036	0.262	0.772
Interface * Scenario	4	23.983	0.747	0.570

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-0.052	0.030	12.818	0.314	-0.133	0.030
	Separate	-0.041	0.020	25.347	0.167	-0.093	0.011
Hand Images	Face-to-face	0.052	0.030	12.818	0.314	-0.030	0.133
	Separate	0.011	0.032	16.296	1.000	-0.075	0.096
Separate	Face-to-face	0.041	0.020	25.347	0.167	-0.011	0.093
	Hand Images	-0.011	0.032	16.296	1.000	-0.096	0.075
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Proportion of time: Marking (without speaking), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.000	0.031	14.800	1.000	-0.084	0.083
	Leak	0.014	0.021	25.299	1.000	-0.041	0.069
Fire	Evacuation	0.000	0.031	14.800	1.000	-0.083	0.084
	Leak	0.015	0.030	13.296	1.000	-0.068	0.097
Leak	Evacuation	-0.014	0.021	25.299	1.000	-0.069	0.041
	Fire	-0.015	0.030	13.296	1.000	-0.097	0.068
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	0.047	0.022	5	-0.009	0.103
	Fire	0.034	0.024	5	-0.028	0.096
	Leak	0.033	0.013	5	-0.001	0.066
Hand Images	Evacuation	0.062	0.033	5	-0.022	0.146
	Fire	0.109	0.068	5	-0.066	0.285
	Leak	0.097	0.031	5	0.018	0.176
Separate	Evacuation	0.111	0.029	5	0.038	0.184
	Fire	0.078	0.032	5	-0.005	0.160
	Leak	0.048	0.026	5	-0.020	0.115

Proportion of time: Manipulating (without speaking)

Analysis software reported an error. No results.

Proportion of time: Manipulating while Speaking

Analysis software reported an error. No results.

Proportion of time: Gesturing (without speaking)

Type III Tests of Fixed Effects				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	22.465	12.766	0.002
Interface	2	16.034	1.094	0.359
Scenario	2	16.017	1.127	0.348
Interface * Scenario	4	15.134	1.153	0.370

Pairwise Comparisons							
(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Face-to-face	Hand Images	-0.002	0.002	9.992	0.769	-0.006	0.003
	Separate	-0.002	0.002	19.599	0.818	-0.006	0.003
Hand Images	Face-to-face	0.002	0.002	9.992	0.769	-0.003	0.006
	Separate	0.000	0.002	17.468	1.000	-0.005	0.005
Separate	Face-to-face	0.002	0.002	19.599	0.818	-0.003	0.006
	Hand Images	0.000	0.002	17.468	1.000	-0.005	0.005
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Proportion of time: Gesturing (without speaking), cont.

Pairwise Comparisons							
(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	df	Sig.(a)	95% Confidence Interval for Difference(a)	
						Lower Bound	Upper Bound
Evacuation	Fire	0.000	0.001	20.631	1.000	-0.004	0.003
	Leak	-0.003	0.002	14.974	0.469	-0.008	0.002
Fire	Evacuation	0.000	0.001	20.631	1.000	-0.003	0.004
	Leak	-0.002	0.002	16.536	0.707	-0.008	0.003
Leak	Evacuation	0.003	0.002	14.974	0.469	-0.002	0.008
	Fire	0.002	0.002	16.536	0.707	-0.003	0.008
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
a. Adjustment for multiple comparisons: Bonferroni.							

Interface * Scenario						
Interface	Scenario	Mean	Std. Error	df	95% Confidence Interval	
					Upper Bound	Lower Bound
Face-to-face	Evacuation	0.001	0.001	5	-0.002	0.005
	Fire	0.002	0.002	5	-0.003	0.007
	Leak	0.001	0.000	5	0.000	0.002
Hand Images	Evacuation	0.001	0.001	5	-0.001	0.003
	Fire	0.001	0.001	5	-0.001	0.003
	Leak	0.008	0.004	5	-0.002	0.018
Separate	Evacuation	0.002	0.002	5	-0.003	0.008
	Fire	0.003	0.002	5	-0.003	0.009
	Leak	0.004	0.003	5	-0.004	0.013

Appendix E: Effect Sizes

EFFECT SIZES				
		Variable – NASA-TLX items		
		Mental Demand	Physical Demand	Time Pressure
Hand Images	Mean	49.7778	8.83333	50.5556
	Standard Dev.	24.1796	8.06773	29.5381
Separate	Mean	51.9444	11.5556	43.5556
	Standard Dev.	24.1721	12.306	28.525
Face-to-face	Mean	36.7222	10	27.5
	Standard Dev.	20.4502	14.5076	19.1626
(I) Interface	(J) Interface	Variable Effect Size (I-J)		
Hand Images	Separate	-0.0896	-0.2616	0.24108
	Face-to-face	0.58303	-0.0994	0.92604
Separate	Hand Images	0.08962	0.26163	-0.2411
	Face-to-face	0.67991	0.11564	0.66075
Face-to-face	Hand Images	-0.583	0.09939	-0.926
	Separate	-0.6799	-0.1156	-0.6608
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2				

EFFECT SIZES				
		Variable – NASA-TLX items		
		Performance	Effort	Frustration Level
Hand Images	Mean	67.0556	49.8333	25.7222
	Standard Dev.	16.0641	21.4263	22.2943
Separate	Mean	67.1667	50.6111	30.9444
	Standard Dev.	19.8561	18.5064	26.1027
Face-to-face	Mean	66.6111	38.9444	24
	Standard Dev.	14.1967	18.5202	18.896
(I) Interface	(J) Interface	Variable Effect Size (I-J)		
Hand Images	Separate	-0.0062	-0.0389	-0.2151
	Face-to-face	0.02932	0.54374	0.08334
Separate	Hand Images	0.00615	0.03885	0.21514
	Face-to-face	0.03219	0.63018	0.30477
Face-to-face	Hand Images	-0.0293	-0.5437	-0.0833
	Separate	-0.0322	-0.6302	-0.3048
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2				

EFFECT SIZES				
		Variable – Post-Questionnaire items		
		Discussion quality	Joint planning	Leadership
Hand Images	Mean	5.61111	3.61111	2.77778
	Standard Dev.	1.0369	0.84984	0.80845
Separate	Mean	5.36111	3.61111	2.61111
	Standard Dev.	0.83676	0.77754	0.77754
Face-to-face	Mean	5.44444	3.44444	2.88889
	Standard Dev.	1.19913	0.92178	0.58298
(I) Interface	(J) Interface	Variable Effect Size (I-J)		
Hand Images	Separate	0.26535	0	0.21013
	Face-to-face	0.14868	0.188	-0.1577
Separate	Hand Images	-0.2653	0	-0.2101
	Face-to-face	-0.0806	0.19545	-0.4042
Face-to-face	Hand Images	-0.1487	-0.188	0.15765
	Separate	0.0806	-0.1955	0.40423
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2				

EFFECT SIZES				
		Variable – Post-Questionnaire items		
		Presence	Encouragement	Task frustration
Hand Images	Mean	3.44444	3.83333	1.83333
	Standard Dev.	0.92178	0.61835	0.85749
Separate	Mean	2.94444	3.55556	2.05556
	Standard Dev.	1.10997	0.70479	1.05564
Face-to-face	Mean	4.61111	3.77778	1.88889
	Standard Dev.	0.60768	0.80845	0.83235
(I) Interface	(J) Interface	Variable Effect Size (I-J)		
Hand Images	Separate	0.49009	0.41898	-0.2311
	Face-to-face	-1.4944	0.07719	-0.0657
Separate	Hand Images	-0.4901	-0.419	0.23108
	Face-to-face	-1.8626	-0.293	0.17533
Face-to-face	Hand Images	1.4944	-0.0772	0.06574
	Separate	1.86263	0.29302	-0.1753
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2				

EFFECT SIZES				
		Variable – Post-Questionnaire items		
		Received positive feedback	Team perception	Joint work
Hand Images	Mean	3.77778	3.72222	4.05556
	Standard Dev.	0.64676	0.89479	0.5393
Separate	Mean	3.55556	3.55556	3.66667
	Standard Dev.	0.51131	0.92178	0.76696
Face-to-face	Mean	3.41667	4.08333	3.91667
	Standard Dev.	0.94324	0.54906	0.77174
(I) Interface	(J) Interface	Variable Effect Size (I-J)		
Hand Images	Separate	0.38118	0.18348	0.58658
	Face-to-face	0.44653	-0.4865	0.20862
Separate	Hand Images	-0.3812	-0.1835	-0.5866
	Face-to-face	0.18307	-0.6957	-0.3249
Face-to-face	Hand Images	-0.4465	0.48645	-0.2086
	Separate	-0.1831	0.69567	0.32495
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2				

EFFECT SIZES					
		Variable – Post-Questionnaire items			
		Social distance	Gave positive feedback	Engagement	Frustration with teammate
Hand Images	Mean	1.94444	3.55556	1.33333	1.27778
	Standard Dev.	0.5393	0.70479	0.59409	0.57451
Separate	Mean	2.38889	3.72222	1.38889	1.44444
	Standard Dev.	0.84984	0.57451	0.60768	0.6157
Face-to-face	Mean	1.38889	3.77778	1.61111	1.38889
	Standard Dev.	0.60768	0.73208	0.6978	0.77754
(I) Interface	(J) Interface	Variable Effect Size (I-J)			
Hand Images	Separate	-0.6245	-0.2592	-0.0925	-0.2799
	Face-to-face	0.967	-0.3093	-0.4287	-0.1625
Separate	Hand Images	0.62447	0.25922	0.09245	0.27989
	Face-to-face	1.35364	-0.0844	-0.3396	0.07922
Face-to-face	Hand Images	-0.967	0.30926	0.42865	0.16254
	Separate	-1.3536	0.08443	0.33964	-0.0792

Effect size formula is Cohen' d:
d = (Mean_I – Mean_J) / s_p
Where s_p is the pooled standard deviation:
s_p^2 = (s_I^2 + s_J^2) / 2

EFFECT SIZES			
		Variable	
		Workload (NASA-TLX Aggregate)	Frustration Aggregate
Hand Images	Mean	36.2778	1.71333
	Standard Dev.	13.4823	0.64343
Separate	Mean	36.9074	1.91259
	Standard Dev.	15.2048	0.79423
Face-to-face	Mean	28.4259	1.74593
	Standard Dev.	9.70096	0.61338
(I) Interface	(J) Interface	Variable Effect Size (I-J)	
Hand Images	Separate	-0.0438	-0.2757
	Face-to-face	0.66854	-0.0519
Separate	Hand Images	0.04382	0.27569
	Face-to-face	0.66504	0.23488
Face-to-face	Hand Images	-0.6685	0.05185
	Separate	-0.665	-0.2349
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2			

EFFECT SIZES			
		Variable	
		Time to complete task (seconds)	Proportion of time spent inside the interface
Hand Images	Mean	1560.67	0.66449
	Standard Dev.	627.823	0.2433
Separate	Mean	1370.22	0.63406
	Standard Dev.	269.752	0.26872
Face-to-face	Mean	1230	0.65099
	Standard Dev.	519.762	0.19316
(I) Interface	(J) Interface	Variable Effect Size (I-J)	
Hand Images	Separate	0.39415	0.11871
	Face-to-face	0.57374	0.06142
Separate	Hand Images	-0.3941	-0.1187
	Face-to-face	0.33864	-0.0724
Face-to-face	Hand Images	-0.5737	-0.0614
	Separate	-0.3386	0.07237
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2			

EFFECT SIZES					
		Variable – Time spent on each action (in seconds)			
		Mark-Speak	Gesture-Speak	Mark	Gesture
Hand Images	Mean	280.796	192.519	125.833	5.35185
	Standard Dev.	243.652	335.272	147.867	10.807
Separate	Mean	356.556	32.6481	95.3704	4.07407
	Standard Dev.	256.648	34.3453	85.0244	7.7574
Face-to-face	Mean	193.648	281.278	36.8519	1.07407
	Standard Dev.	192.732	173.398	38.8482	2.50113
(I) Interface	(J) Interface	Variable Effect Size (I-J)			
Hand Images	Separate	-0.3028	0.67084	0.25257	0.13584
	Face-to-face	0.39672	-0.3326	0.82309	0.54538
Separate	Hand Images	0.30275	-0.6708	-0.2526	-0.1358
	Face-to-face	0.71781	-1.9892	0.88531	0.52053
Face-to-face	Hand Images	-0.3967	0.33255	-0.8231	-0.5454
	Separate	-0.7178	1.98915	-0.8853	-0.5205
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2					

EFFECT SIZES					
		Variable – Time spent on each action (in seconds)			
		Speak	Gaze	Manipulate	Manipulate-Speak
Hand Images	Mean	435.389	387.944	12.5741	11.1481
	Standard Dev.	223.207	166.343	30.5592	26.6775
Separate	Mean	438.13	333.87	17.3889	19.3889
	Standard Dev.	229.91	181.396	36.2073	39.5729
Face-to-face	Mean	251.667	330.296	16.2593	23.0556
	Standard Dev.	184.94	199.252	28.1361	52.1485
(I) Interface	(J) Interface	Variable Effect Size (I-J)			
Hand Images	Separate	-0.0121	0.31071	-0.1437	-0.2442
	Face-to-face	0.89634	0.3141	-0.1255	-0.2875
Separate	Hand Images	0.0121	-0.3107	0.14372	0.24419
	Face-to-face	0.89371	0.01876	0.03484	-0.0792
Face-to-face	Hand Images	-0.8963	-0.3141	0.12546	0.28748
	Separate	-0.8937	-0.0188	-0.0348	0.07921
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2					

EFFECT SIZES					
		Variable – Proportion of time spent on each action			
		Mark-Speak	Gesture-Speak	Mark	Gesture
Hand Images	Mean	0.18203	0.12329	0.08946	0.00317
	Standard Dev.	0.13327	0.14958	0.11052	0.00634
Separate	Mean	0.26265	0.02866	0.07871	0.00321
	Standard Dev.	0.18109	0.03908	0.07194	0.006
Face-to-face	Mean	0.14597	0.26483	0.03766	0.0013
	Standard Dev.	0.12338	0.12133	0.04712	0.00326
(I) Interface	(J) Interface	Variable Effect Size (I-J)			
Hand Images	Separate	-0.5071	0.86563	0.11527	-0.0071
	Face-to-face	0.28083	-1.0393	0.60975	0.37014
Separate	Hand Images	0.50708	-0.8656	-0.1153	0.00709
	Face-to-face	0.75306	-2.6201	0.67507	0.39529
Face-to-face	Hand Images	-0.2808	1.03926	-0.6098	-0.3701
	Separate	-0.7531	2.62013	-0.6751	-0.3953

Effect size formula is Cohen' d:
d = (Mean_I – Mean_J) / s_p
Where s_p is the pooled standard deviation:
s_p^2 = (s_I^2 + s_J^2) / 2

EFFECT SIZES					
		Variable – Proportion of time spent on each action			
		Speak	Gaze	Manipulate	Manipulate-Speak
Hand Images	Mean	0.308	0.28033	0.00706	0.00665
	Standard Dev.	0.12413	0.08894	0.01598	0.01599
Separate	Mean	0.32969	0.26992	0.01343	0.01373
	Standard Dev.	0.13153	0.15796	0.02759	0.0285
Face-to-face	Mean	0.21892	0.30527	0.01202	0.01402
	Standard Dev.	0.1229	0.17426	0.02156	0.03048
(I) Interface	(J) Interface	Variable Effect Size (I-J)			
Hand Images	Separate	-0.1696	0.08122	-0.2823	-0.3063
	Face-to-face	0.72127	-0.1803	-0.2615	-0.3031
Separate	Hand Images	0.16956	-0.0812	0.28227	0.30628
	Face-to-face	0.87026	-0.2126	0.05667	-0.0101
Face-to-face	Hand Images	-0.7213	0.18031	0.26148	0.30306
	Separate	-0.8703	0.21258	-0.0567	0.01011
Effect size formula is Cohen' d: d = (Mean_I – Mean_J) / s_p Where s_p is the pooled standard deviation: s_p^2 = (s_I^2 + s_J^2) / 2					