The Effect of Communication Channel and Visual Awareness Display on Coordination in Online Tasks

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ABSTRACT
Geographically distributed workgroups are increasingly collaborating on time-sensitive, highly interdependent tasks that require detailed coordination to achieve success; although success under these conditions is often difficult. Improving these collaborations requires both better support from communication and information tools and a better understanding of how people use modes of coordination, such as explicit communication using audio and text, and the use of visual awareness displays of others' activities. To examine these issues, we conducted an experiment in which groups completed two tasks in the multiplayer online role-playing game Neverwinter Nights. Task performance results showed that the effects of communication channel were mixed and that the availability of the awareness display did not have a direct effect. However, transcripts revealed differences in the processes of collaboration such that in the absence of the awareness display, participants adapted their communication behavior to explicitly share information with group members.

Categories and Subject Descriptors
H.5.3. Synchronous Interaction

General Terms
Human Factors

Keywords
Awareness, Collaboration, Communication

1. INTRODUCTION
Collaboration in online environments increasingly involves time-sensitive, highly interdependent tasks that require detailed coordination if they are to be completed successfully [6]. Military groups use online simulators to practice teamwork for real world exercises [12], scientific instruments and models can be manipulated online [20], and millions play online games requiring group effort to achieve higher status or gain points [16].

Consider the example of a group of soldiers practicing teamwork for an enemy raid using an online simulator. To successfully collaborate on this task, the group must: 1) assess the situation, in this case by observing the simulated environment and explicitly discussing its current state; 2) discuss a strategy for accomplishing their goal that details task elements and each team members' role, and 3) determine when everybody is ready to begin. As their task unfolds, team members must maintain awareness of their collaborators' status, activity or location. Based on this awareness, the team can make on-the-fly adjustments to strategy in response to uncertainty or unexpected events [22]. Providing support for the communication processes that lead to effective coordination, however, can be a difficult problem.

It is well known from years of CSCW research that success in geographically dispersed groups can be elusive, especially when the task is non-routine, tightly coupled [18], and requires substantial coordination of activities. Improving these collaborations requires better support from communication and information tools. Improving these tools, however, requires a better understanding of how people use modes of coordination, such as explicit communication via different media and referring to visual displays of others' activities.

This paper reports on an experimental study of how communication media and visual awareness displays affect participant performance and coordination behavior in a fast-paced, tightly-coupled task in a multiplayer online role-playing game environment. We chose this task because it shares coordination processes with other collaborative tasks, in that these tasks require collaborators to repeatedly assess the situation, develop and maintain a strategy, and keep aware of the location, status, and activities of others [12].

Results showed that audio communication improved performance of non-routine task elements, while text communication was better for the better defined and more routine task of killing enemies. Transcripts of participant dialogue revealed that audio better facilitated group coordination, and that groups without an awareness display compensated for this by explicitly communicating relevant information.

2. BACKGROUND
As the example scenario above indicates, coordinated efforts require awareness of group members and their actions. There are three key ways to discern others' location, status and activities: 1) verbal language, via explicit communication of information (e.g., [3]); 2) visual awareness displays, such as radar views (e.g., [10]); and 3) direct observation of the environment [15]. We focus primarily on explicit communication and visual awareness displays, as observation has been studied by others (e.g., [15]).

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2.1 Explicit Communication

Clark [3] discusses the role and importance of language in the coordination of joint actions, which are executed in concert by multiple individuals. Language can range from complex discussion (e.g., of a detailed military strategy), to short utterances that all parties are likely to understand. For example, a team member saying "found it" may be sufficient to indicate that a target has been located.

Another key element in coordination is the amount and frequency of communication required to effectively complete a task. Van de Ven et al. [22] found that tasks with higher levels of uncertainty about process and outcomes tend to require more unscheduled, informal communication as the task progresses. Malone and Crowston [14] build on this, noting that different task types and structures have different dependencies, which affect the ways in which information is shared among the actors involved in the task.

Uncertain tasks are characterized by unfamiliar environments or obstacles that may arise unexpectedly during the task, in contrast to better defined tasks that are frequently executed and routine in nature. Given these circumstances, it should be expected based on [22] that groups completing this type of task would use frequent explicit communication to coordinate. Examples include developing a strategy prior to the task, and updating the plan over the course of the task as the situation changes, which would be difficult to do without explicit communication about the updates. Communication can also be used to notify group members of changes in status or activity.

When interacting with others in online environments, people typically communicate either via audio or text. While both of these media can be used for interactions that are informal and unscheduled and therefore appropriate for uncertain tasks [22], these media differ on particular properties relevant to the coordination process. For example, typing to communicate with others via text can interfere with time-sensitive online tasks, as people need to use their hands both to communicate and work on the task. As typing is slower than speech, one benefit of audio is that when, for example, informing collaborators about being ready to begin a task, speaking "I'm ready" is more natural and expedient.

Some previous research has examined how audio can be used to maintain awareness for coordination in distributed workgroups (e.g., [11], [24]). However, in these studies, audio was the only form of information available; no comparisons were made to other media or displays.

Given that audio is a more expedient and less effortful method for communication, using it may have multiple effects. First, as typing may interfere with performing online tasks, communicating via audio should help improve performance. Furthermore, using audio may better facilitate discussing elements of the coordination process where rapid communication is essential. For example, to notify others about a change in status during a time-sensitive task, speaking this information is faster, easier, and more timely than typing. Another advantage of the timeliness of audio is that the ease of interacting means that conversation is not only easier, but that conversations about coordination occur that would not take place in another medium. Understanding the differences in the ways that audio and text are used to communicate about coordination in routine and non-routine tasks is one focus of this study, which will serve to extend existing work on awareness.

2.2 Visual Awareness Displays

Much research on awareness is rooted in work by Neisser [17] and Endsley [7]. Neisser's [17] perception-action cycle shows the cyclical relationship between an environment, one's knowledge of that environment, and gathering additional information about it.

Endsley [7] provides a three-part model for situation awareness, in which each part builds on the previous one. First, one must perceive the characteristics of significant elements in the environment. In the military task, this could be the team members monitoring the location and activities of each other using a visual awareness display (similar to a "heads up display" used in a real world mission), and noticing that one member has stopped and is searching part of an enemy camp. Second, one must comprehend those elements by synthesizing the elements perceived in step one, such as synthesizing the location and activity information from the awareness display and concluding that the team member has located a bomb to defuse. Third, one must anticipate how those elements may change in the future, which is intended to help with decision making. For example, by anticipating that enemy fighters will appear in the future, and directing nearby team members who have not located a bomb (based on their location and activity as determined by the awareness display) to assist in the defusing.

Gutwin and Greenberg introduce "workspace awareness" as a specific type of situation awareness in which the goal is an understanding of one's collaborators' interactions with a common workspace. Workspace awareness is different from situation awareness in that users must be aware of the actions of others within the workspace, where Endsley focused primarily on individuals. In the military task, for example, team members could use a visual awareness display which provides a summary of other members' activities, allowing team members to make better informed decisions. Furthermore, the presence or absence of a visual awareness display may affect the ways in which collaborators discuss certain elements of the coordination process.

Visual awareness displays often contain relevant information about location, status, and activity [10], so when these displays are present, people are able to obtain and display this information quickly without having to explicitly communicate it, which makes better use of scarce communication time. When these displays are absent, however, people may need to engage in more frequent and detailed communication in order to adequately obtain and display this information, which may lead to redundancy when information has remained static over time (e.g., one's location has not changed). In the military task, if group members were unable to use a visual awareness display to view a summary of others' actions, they would have to explicitly ask others about their current activities before developing or adjusting strategy.

Visual awareness displays can help performance, but past studies have explored this using tasks that are time-sensitive but less interdependent [5], or tasks that are interdependent, but less time-sensitive [9]. However, there are many tasks, such as simulated military operations, which are both time-sensitive and interdependent, so understanding the role of visual awareness displays in these environments is helpful.

3. CURRENT STUDY

In this study, we examine the ways in which communication channel and the availability of a visual awareness display affect group performance in a multiplayer online role-playing game, as well as the ways in which these variables affect the groups' communication and coordination processes.

We have discussed the different properties of uncertain, time-sensitive coordination tasks in online environments. Specifically, these tasks are characterized by unfamiliar environments, sudden and unexpected obstacles, and unpredictable events. Multiplayer online role-playing games are environments that have these properties, as illustrated in the following example from the game Neverwinter Nights. Three players are travelling together on a path through a forest. Two of the players have weapons, and the third can cast magical healing spells to restore the health of the others. At any moment they may encounter enemy goblins that appear unexpectedly and are a threat because each one is much stronger than the individual players, so could easily kill them. To avoid this fate, players must repeatedly assess the present situation, so they can respond to an attack together. They do this by staying aware of the location of others, remaining together, and coordinating their response.

To prepare for a goblin attack, players first must consider their current health status, as well as the health status of others, which they could obtain from a visual awareness display if available, or by asking their teammates. More health points means greater ability to withstand damage from the enemy, so players must ensure that their health status is full or nearly so.

Before attacking the goblin, the players must develop a strategy and ensure that all group members are ready to begin. In this scenario, after discussing the number of health points each player has, they decide that the one with the most health points will run in first, attract the attention of the goblin, and then hit the goblin with his axe. In practice, this reduces the goblin's health, but also causes him to hit back and reduce the health of the attacker. At this point, the player with the second-most health points joins the battle and hits the goblin with his sword. By moving around in the game space, those two players can then alternate who is receiving the majority of the goblin's damage. During all of this, the player with magic spells monitors the health status of the others by observing a visual awareness display, if available, or asking the others about their health status, and uses his spells to restore the others' health as needed. This helps allow the fighting players to continue fighting the goblin.

Finally, all three players stop briefly to rest, which will help restore the health and abilities of all players. Players cannot rest while any member of their group is in battle with a goblin, so it is crucial that they rest at the same time, which they can coordinate by observing the environment to see who has stopped to rest or by explicitly discussing when to stop.

In our experiment, triads completed two tasks in the multiplayer online role-playing game Neverwinter Nights in which they moved along a designated path with the goal of killing as many enemy goblins as possible in ten minutes. Goblins could attack the players as well, so players were also instructed to avoid death. Each player had a unique role and capabilities and while collaboration was not strictly required, it was engineered to be a significantly preferred strategy.

3.1 Game Environment and Task

Three-person groups performed two structurally equivalent tasks within Neverwinter Nights (NWN). The tasks, described above, differed only in terms of the environmental setting (forest vs. city) and the direction of the path that participants travelled. We selected multiplayer online role-playing games as an experimental task because, as highlighted in an earlier example, these games require complex and interdependent coordination on a time-sensitive task. This game was chosen because it is easy to modify and control and players can form groups to collaborate on tasks.

Importantly for our experiment, NWN also allows for the custom creation of unique game modules, in which many aspects of game play (e.g., layout, enemy presence, character traits) can be configured. These modules can be stored on a local server and played by a closed group of individuals. In contrast to other multi-player online role playing games which place strict limits on user controls and modifications [2], this allowed us to maintain experimental control and limit potential threats to the internal validity of our experiment such as the presence of others, changes in content, or participants' prior experience with the task. We created modules that were locally stored and accessible only to our participants.

To reduce the possibility of a ceiling effect on performance, the task was designed so that it could not be completed in the allotted time. The enemy goblins were designed to be so difficult to kill that no single player could successfully kill a goblin without dying first. Dying was not permanent – a player was presented with the ability to "respawn" after dying and return to the game – but it did come at some cost to players in terms of time and points. This was because the incentive structure of the task was such that ten points were awarded for each goblin killed, but three points were deducted each time a player died.

Each player was assigned a unique role, with assigned capabilities that were designed to be interdependent in that there would be a division of labor among the participants. Roles were as follows:

Fighter (Damage Dealer): The fighter was provided with a short sword to use to kill goblins, and began the game with 14 health points. Initial health point level is a measure of how much damage a player can withstand before dying or having their health restored. Fighters were instructed to focus on killing goblins.

Barbarian (Damage Taker): The barbarian could also use weapons to kill goblins and was instructed to focus on killing goblins. Unlike the fighter, the barbarian began with 17 health points, meaning they could withstand more damage.

Cleric (Healer): The cleric was much weaker at killing goblins, as she had only 10 health points and did not have a weapon, but was able to use spells to restore the health of any player, including herself. Clerics were instructed to focus on preventing members of the group from dying.

3.2 Hypotheses

We were first interested in the effects of communication channel and availability of an awareness display on group performance. One measure of group performance is the number of goblins killed by the group during the ten-minute period. Another measure of performance is the prevention of player deaths, as preventing death requires the coordination of all group members.

These elements differ in the degree of uncertainty and the amount of coordination needed to succeed, however. Killing enemies was less uncertain overall because all goblins in the maze had the

same number of health points, which meant that players could begin to predict what they needed to do to defeat the goblin. In contrast, goblins inflicted critical attacks on the players at seemingly random intervals, meaning that the healer could not predict when players would lose health points. It was therefore difficult to establish a routine.

Additionally, killing enemies required less coordination. While the goblins were designed so that a player acting alone could not kill them without dying, players were able to "respawn" after dying, which allowed them to rejoin the battle. Therefore, it was possible for a player to kill goblins alone if they died and respawned several times during a fight. Healing, on the other hand, required more coordination, as the cleric was the only player who possessed skills to restore health to players during a battle. Thus, to prevent the fighter or barbarian from dying, the players must work together.

Therefore, preventing player deaths through healing is an uncertain activity that requires more coordination, and killing goblins is a less uncertain activity that requires less coordination.

Audio provides some advantages over text for communication in time-sensitive online tasks. For example, since audio is faster, timelier and less effortful than text, it should allow for more and easier coordination-related communication, which is important for success in the more uncertain activity of healing to preventing player deaths. Therefore, we predicted that:

H1: Groups using audio to communicate will have fewer participant deaths than groups using text to communicate.

Additionally, in fast paced online tasks, communicating via text can interfere with performing the task, as both actions require people to use the keyboard. Audio, on the other hand, allows people to communicate and work on the task simultaneously, which may improve performance. As a result, we hypothesized:

H2: Groups using audio to communicate will kill more goblins than groups using text to communicate.

Next, given that visual awareness displays concisely provide relevant information about the environment (e.g., location and health levels of others) throughout the task, players that have access to the visual display should be able to quickly reference this display to determine these important attributes about their teammates (i.e., step 1 in Endsley's [7] theory). Because they can get this information more quickly, they should be able to more quickly coordinate and respond to sudden changes in the environment or situation, which is important in a time-sensitive task. As a result, we predicted that:

H3: Groups using the visual awareness display will have fewer participant deaths than groups not using this display.

H4: Groups using the visual awareness display will kill more goblins than groups not using this display.

In situations where groups both use audio communication and have an awareness display, they have access to both concise visual information about the environment and a quicker form of communication. These should be complementary such that:

H5: There will be an interaction effect such that groups using audio to communicate and the visual awareness display will have fewer deaths than other groups.

H6: There will be an interaction effect such that groups using audio to communicate and the visual awareness display will kill more goblins than other groups.

In addition to performance, we explored the ways in which the availability of the awareness display would affect group communication and coordination processes. For example, when participants need to obtain relevant information about their group members (e.g., their status or activities), we believed they will get this using the most efficient available method. When groups have access to the visual awareness display, we believed that participants will look at the display to gather this information. When they do not have access to the display, however, they may need to modify their communication to explicitly obtain this information. On the other hand, even in the absence of an awareness display, participants may be able to discern some information by observing others in the environment, in which case they may not need to explicitly communicate this information.

RQ1: How do groups that do not have access to the visual awareness display communicate differently than groups that do have access to the display?

Furthermore, we explored the ways in which communication channel may affect group discussion. Given that audio is a more expedient medium, we believed this would facilitate communication about coordination processes that required rapid communication. One area in which it may be beneficial is in developing and maintaining a strategy, as it would be easier to discuss a strategy during a battle using audio since they can speak and play simultaneously. Additionally, audio communication may occur more during uncertain elements of the tasks, such as coordinating the beginning of battles through resting and ready check statements, as well as coordinating healing. On the other hand, there may be topics so essential to the coordination process, such as healing, they are discussed regardless of the media used.

RQ2: How do groups that communicate via audio coordinate differently than groups who coordinate via text?

4. METHOD

We used a mixed-model 2x2 experimental design. Communication channel (audio versus text) was a between-subjects manipulation and availability of the awareness display (available or not) was manipulated within subjects.

4.1 Participants

There were 84 participants in the study, of whom 29 were male and 55 were female. All were students at a large US university. Students were recruited via an on-campus web-based recruitment system, signed up for the study individually but participated as three-person groups, and received either $10 cash or course credit for their participation. Participants' ages ranged from 18 to 31. In the week prior to participating in the study, 19% (SD=0.40%) of participants had played console video games for an average of 0.73 hours (SD= 0.40), and 21% (SD=0.41%) had played PC-based video games for an average of 0.28 hours (SD=0.71). Only one participant had played Neverwinter Nights prior to the study.

4.2 Procedure

After filling out a consent form, participants read an introduction to the task, which explained their role, which was randomly assigned. They then watched an instructional video which introduced them to game concepts and how to perform their role. Following the video, participants were given a reference sheet with this information.

Participants then completed an individual practice session to acquaint them with the activities they would do during the group tasks. Following the individual practice, they completed two group practices and two group tasks, with one practice and task with the awareness display and one practice and task without the display. Additionally, participants completed a demographic questionnaire prior to the first task which asked about their experience with various types of video games.

4.3 Experimental Conditions

Participants were located in the same room for the duration of the experiment. To prevent players from interacting with each other, they each sat facing different walls and had dividers between them so that they were unable to see the other participants, and wore headsets which helped prevent the text group from overhearing noises made by their group members.

In the audio condition, participants communicated with their group members using audio headsets over the VoIP system Ventrilo (www.ventrilo.com), which provided participants with full duplex voice communication.

Figure 1. The text chat box (lower left corner) used in the text communication condition.

In the text condition, participants communicated with their group members by typing into a text box that was integrated into the game and appeared above the players' hotkeys bar (Figure 1). The text box could display four lines of text before being bumped out of view, although past messages could be reviewed. There was no decay, so messages would persist in the text box until they were bumped out of view. The text group wore headsets that allowed them to hear game sounds which ensured that both groups were provided with game sounds, which help to provide context and support for gameplay [13]. The text box could not be removed from the audio group, but its use was not explained to participants and no audio group communicated via text.

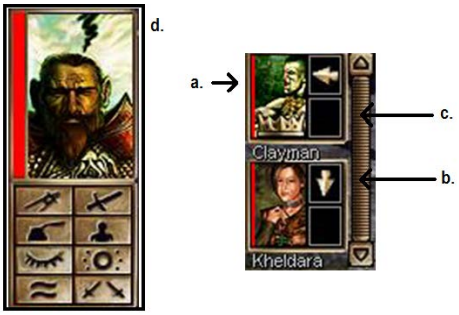

Figure 2. The Awareness Display. Components displayed side-by-side here but were arranged vertically in the game (see Figure 1).

The awareness display was integrated into the game space and displayed in the upper right hand corner of participants' screens. In the awareness display condition (see Figure 2), this showed:

(a.) group members' health status, shown on the red bar on the left

(b.) location relative to the user (as indicated by the arrow)

(c.) current activity (e.g., if a player was resting, an icon appears)

In the no awareness display condition, participants were not given this information about their group members, and were only given access to their own information (d.). However, in the no awareness display condition, participants could gather information about the activities of other group members by looking around the game environment and observing the actions of their avatars (e.g., avatars sit when they are resting).

4.4 Data Collection and Analysis

Performance Task performance was measured by collecting game-generated logs of start time, goblin kills and player deaths, and any text-based communication.

Transcripts Text and audio communication were recorded, and audio was fully transcribed. Transcripts were coded for three main categories: Task related, socio-emotional, and tangential communication [1]. The coding scheme is in Table 1.

Two independent coders performed the coding task. They rated a sample of utterances until they reached 75% agreement, then each coded different transcripts. They coded 1/4 of the same transcripts to ensure the categories they used did not change during coding. Their agreement ranged from 63% to 87% throughout the process.

Task	
Task Strategy	Tactics for playing the game and completing tasks
Ready Check	Expressions of preparedness to begin the next battle
Resting	Related to the resting function in the game, which restored players' health and refreshed the cleric's healing spells.
Location	Related to the whereabouts of self or others
Healing	Related to the healing function, which restored health to players during battle
Positive Learning Curve	Indications of correct understanding of game mechanics
Negative Learning Curve	Indications of incorrect understanding of game mechanics
Positive Role	Indications of correct understanding of player role in game
Negative Role	Indications of incorrect understanding of player role in game
Socio-emotional	
Acknowledgement	Related to conversational acknowledgements
Positive expression	Indicators of positive emotion
Negative expression	Indicators of negative emotion
Tangential	

Tangential	Conversation unrelated to the experimental task assigned

Table 1. Description of the coding categories.

5. RESULTS

Linear Mixed Model Analysis was performed on data gathered from game logs, questionnaires, and transcripts. In all models, awareness display availability, communication channel, task, the order of the awareness conditions, and the interaction between awareness display availability and communication channel were fixed variables, and group was set as a random variable. Note that the denominator degrees of freedom in these models are estimated using a Satterthwaite's approximation, which can yield non-integer degrees of freedom [21].

5.1 Performance

Two indicators of performance were used: the number of group member deaths and number of goblin kills. Our first two hypotheses predicted that groups communicating via audio would have fewer player deaths and more goblin kills than groups communicating via text. Consistent with Hypothesis 1, groups that used audio had fewer player deaths (M=12.58, SD=7.15) than did groups that used text to communicate (M=21.23, SD=12.44), F[1, 25.289]= 6.78, p<.05 (the mean of the bars on the left and the mean of the bars on the right in Figure 3). This suggests that audio communication better facilitated sharing relevant coordination information than did text communication.

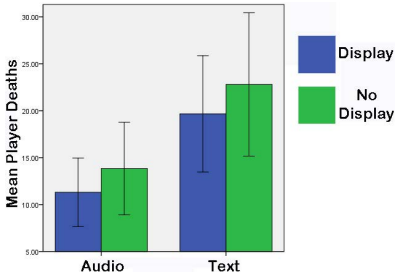

Figure 3. Mean Player Deaths.

Hypothesis 2, on the other hand, was not supported. Surprisingly, groups that used text to communicate killed more goblins (M=12.50, SD=2.78) than groups that used audio (M=10.65, SD=1.90), F[1, 25.283]=4.39, p<.05 (the mean of the bars on the left and on the right in Figure 4). There are several possible ways to interpret this finding. One is that quick and less effortful communication was not as essential to success in this task as we had initially believed. It is also possible that text communication is not as effortful as had been expected, or that killing goblins was a task that did not require much explicit communication.

Hypotheses 3 and 4 posited that groups with the awareness display would have fewer player deaths and more goblin kills than groups without it. These hypotheses were not supported, as there was no significant difference in the number of player deaths whether groups had access to the awareness display (M=15.79, SD=9.95) or not (M=18.64, SD= 12.21), F[1, 24.921]=.64, *n.s.* (the mean of the blue bars and the mean of the green bars in Figure 3). Groups also did not kill more goblins when they had the awareness display (M= 11.57, SD= 2.69) than when they did not (M= 11.71, SD=2.48), F[1, 24.602]= .01, *n.s.* (the mean of the blue bars and the mean of the green bars in Figure 4). This suggests that even without the information shown on the visual display, players could still obtain the knowledge needed to coordinate in game play. This result raises the question of the types of information players explicitly shared in the absence of the awareness display, which will be explored below.

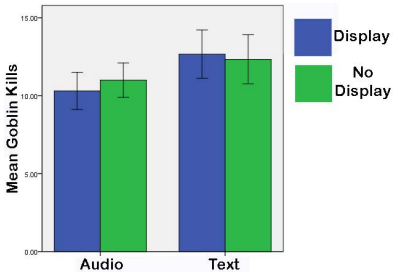

Figure 4. Mean number of goblin kills.

Hypotheses 5 and 6 predicted an interaction between communication channel and availability of the awareness display on the number of player deaths and the number of goblin kills. There was no such interaction for player deaths F[1, 24.980]=.03, *n.s,*(Figure 3) so Hypothesis 5 was not supported. There was also no interaction for goblin kills, F[1, 24.642]=1.96, *n.s.*, so Hypothesis 6 was not supported (Figure 4).

There was no effect of the tasks themselves, the order in which awareness conditions were presented, or the order in which the tasks were presented on performance in any condition.

5.2 Discussions among Group Members

We believed that the presence or absence of the visual awareness display would affect the coordination process among group members, as in the absence of the awareness display they would explicitly share relevant awareness information.

One type of awareness maintenance is "ready check" statements. These allowed participants to ensure that all team members were ready and had full health prior to attacking a goblin. Participants made significantly more ready check statements when they did not have the awareness display (M=1.21, SD=1.81) than when they did (M=0.61, SD=1.62), F[1, 24.487]=12.93, p=.001. This suggests that awareness information may have reduced the perceived need for explicit readiness checks.

Resting was another category that indicated that group members were acting in coordination. Resting statements referred to the arrangement of a rest following a fight. There was no overall significant difference of visual display on resting statements ($M_{Display}$= 4.0, SD= 4.50; $M_{No\ Display}$=4.5, SD= 5.13), F[1. 24.692]=.74. *n.s.* However, there was a marginally significant interaction between channel and awareness, F[1, 24.739]=3.78, p<.1. When participants communicated via audio, they used more resting statements than when they did not have access to the visual display. However, when they communicated via text, the effect was reversed such that more resting statements were made when participants had access to this display. This suggests that audio communication may have replaced the need for the visual awareness display for this type of information. A possible interpretation of the text results is that since communicating via text was difficult during battle, players may have done most of their communicating during the period between fights, and when they were able to see information about the group members' health statuses using the visual display it may have prompted additional discussion about the need to rest before the next fight.

Healing statements referred to coordinating the cleric's restoration of player health. There were no overall categorical differences for

healing statements. There were, however, two marginally significant differences in that there were more offers for healing made when participants did not have access to the awareness display (M=0.46, SD=1.10) than when they did have access to this display (M=0.07, SD=0.03), F[1, 25.162]=3.31, p<.1. Additionally, there were more responses to these offers when participants did not have access to the awareness display (M=0.5, SD=1.29) than when they did have access to this display (M=0.04, SD=0.19) F[1, 25.063]=3.46, p<.1. This suggests that when clerics did not have the awareness display, which would have allowed them to see when their group members needed to be healed, they compensated by explicitly offering to heal. In one example of such an offer during a period in which the group did not have access to the awareness display, the cleric asks "anyone need a heal? I'm all rested up," to which the barbarian responds "no, I'm good" and the fighter adds "not yet."

Location statements deal with the location of other group members or asked other players to change their location. There was no significant difference in the statements when groups had the display (M= .64, SD=1.28) and when they did not have the display (M=.57, SD=1.35), F[1, 24.635]=.04, *n.s.* One explanation for this difference is that in both conditions, players were able to observe the environment. If participants were close together, they would be able to locate others in the environment without explicitly discussing this information.

Communication Channel Effects We believed that using audio would lead to more statements about a variety of topics, given its more efficient and less effortful nature.

Task strategy statements related to establishing and maintaining a strategy during the task. There were no overall categorical differences for strategy statements by communication channel. However, when comparing the specific codes within the strategy category, there were more explicit statements of action, which are descriptive statements about the actions of the players, in the audio condition (M=2.92, SD=2.67) than in the text condition (M=0.75, SD=1.34), F[1, 25.164]=9.10, p<.01.

Notifications of upcoming goblins were more prevalent in the audio condition (M=2.27, SD=2.99) than in the text condition (M=0.30, SD=0.53), F[1, 25.206]=7.88, p=.01. Not only did notifications vary in quantity, they varied in quality as well. For instance, in the audio condition, notifications tended to be more detailed, such as "there's another goblin up ahead" or "there's one over here, over to the left," while in the text condition, statements tended to be more brief, such as "goblin" or "one up there." This suggests that although groups in both conditions developed strategies through suggestions and questions about strategies, audio helped facilitate additional conversations about these strategies and better adapt to changes in the environment, such as the location of the next goblin.

Participants using audio made significantly more ready check statements (M=4.0, SD=5.12) than did those using text (M=0.83, SD=2.12), F[1, 25.170]=5.39, p<.05. This finding suggests that audio allowed participants to easily verify the readiness of their teammates prior to killing goblins, which resulted in fewer player deaths. There were also more resting statements made in the audio condition (M=6.58, SD=5.46), than in the text condition (M=2.23, SD=2.96), F[1, 25.197]=8.95, p<.01. This indicates that audio enabled participants to easily give group members a chance to restore their health and the cleric's healing spells before the next battle, which helped prevent player deaths.

Ready check and resting statements were often interwoven, and exchanges were often more detailed when participants communicated using audio. For example, using audio, an exchange occurred in which the fighter asked the group members "are we all okay?" The cleric responded by stating "I need to rest" and the barbarian added "me too." After the rest, the barbarian asked "ready?" to which the cleric said "yeah let's go" and the fighter said "yup." This exchange ensured that all players were ready to begin and had a chance to rest, which restored their avatar to full health, and refreshed the cleric's healing spells. When using text, players often were briefer, and not all group members participated in the discussion. In one example, the barbarian typed "rdy?" to which the fighter responded "need to rest." After the rest, the fighter announced "k go." In this example, the cleric never participated in the discussion, so it is not clear if her health was restored.

The difference in the number of healing statements between audio (M=2.81, SD=4.94) and text (M=1.57, SD=3.20) was not significant F[1, 25.179]=.81, *n.s.* This indicates that although healing was an uncertain and time-sensitive task, the act of healing was so essential that healing statements occurred regardless of communication channel.

6. Discussion

6.1 Theoretical Implications

We were interested in the effects of explicit communication and visual awareness information on performance in a time-sensitive, interdependent task, as well as the ways in which people use these two types of awareness information when communicating in order to coordinate.

One key finding was that the presence or absence of the awareness display impacted the way in which participants communicated about the coordination process. When the awareness display was present, participants explicitly communicated fewer statements related to position or status (e.g., ready checks and offers to heal), because players were able to discern this information by observing the display. When the display was not present, they used language to communicate this information. This indicates that participants adapted their use of language to get the information needed for coordination. It appears this adaption was successful, as groups without the visual display performed as well as groups that did have it. Similar adaptation has been seen in prior studies of less time-sensitive tasks [8, 19], but these studies did not account for adapting style across different communication channels.

We also found that communication about coordination processes was affected by communication medium. When participants communicated via audio, they made more statements related to notifications of changes in the environment and status (such as ready checks or the coordination of resting), which were some of the most time-sensitive components of the task. Thus, the ease of communication via audio not only simplified coordination, but meant that more communication about coordination took place. Taken together with past research examining the role of explicit communication in coordination, an implication of our results is that audio can help to better facilitate coordination on uncertain tasks in online environments.

Performance results suggest that teams not only adapted their communication styles to the constraints of the media they were using, but that these adaptations affected the quality of their performance as well. Those using audio were better able to

coordinate on preventing player deaths than those using text, but the same was not true for killing goblins. One possible interpretation is that, unlike preventing deaths, goblins could be killed whether coordination was effective or not. The implication is that selection of medium has consequences not only for how people communicate and coordinate, but how well they perform critical elements of a task. In time-sensitive, critical situations such as the ones discussed above, this can be very important.

6.2 Practical and Design Implications

We noted earlier that teams are increasingly being asked to perform time-sensitive, uncertain tasks in online environments. Examples of such scenarios include simulation exercises, manipulation of remote instruments and the millions who play online games such as World of Warcraft. Our results have several implications that should be considered in designing communication features for these environments.

First, we found that the presence or absence of an awareness display did not affect performance, but it did affect the information that was exchanged verbally by participants. In cases where information in the environment is complex or changing more rapidly than it did in our task, such exchanges could be impractical or even detrimental to the group if they are distracting. Designers should realize that an awareness display not only provides information that is useful in coordination; it can serve to reduce the amount of conversation that is necessary, thus potentially reducing distraction.

Second, the medium of communication affected both the amount of information that was exchanged in coordination, and team performance on the task. In situations where coordination is particularly important to success, designers may wish to provide for audio conversation. There is a tradeoff that must be considered here, however, in that this improved coordination is the result of more communication. Those in less egalitarian scenarios may actually benefit from text – because there may be less discussion if all that is needed is to give instructions. The key is that the medium of communication can affect how much communication takes place, which in turn can have varying effects on task performance, depending on how much coordination is required. This should be considered in selecting media.

6.3 Limitations and Future Work

One limitation of this study is that our participants were typically inexperienced at playing multiplayer online role-playing games, and therefore may have used the awareness display or explicit communication differently than experienced players, which could affect the generalizability of these findings to other environments in which collaborators are experienced.

Another limitation of this study is that participants used audio communication tools as part of a small group. Therefore, the benefits of multi-tasking that audio afforded outweighed potential consequences such as its inability to support simultaneous conversation [4] or difficulties interpreting who is speaking [11].

Future work can examine the how experienced collaborators use awareness displays and communication in uncertain tasks, as well as how audio tools are used by larger groups in these situations. Additionally, differences in information presented in visual awareness displays, such as whether all group members receive the same information or are given role-specific information may impact the collaborative process.

7. Conclusion

The results from this study advance our understanding of the effects of explicit communication and visual awareness displays on coordination and performance on a highly time-sensitive and interdependent task. We found that audio communication afforded participants benefits for collaboration and performance during uncertain elements of the task, and participants changed their communication behavior to reflect whether they had access to a visual awareness display. These findings help us better understand awareness management in such collaborations and the ways in which people use awareness tools.

8. REFERENCES

1. Bales, R. *Interaction Process Analysis: A Method for the Study of Small Groups.* Addison Wesley, Reading, Mass. 1950.
2. Blizzard World of Warcraft End User License Agreement. http://www.worldofwarcraft.com/legal/eula.html
3. Clark, H. *Using Language*. Cambridge University Press, New York, NY, 1996
4. Clark, H. and Brennan, S. Grounding in Communication. In *Perspectives in Socially Shared Cognition*, L. B. Resnick, J. M. Levine, & S. D. Teasley Eds., APA, Washington, DC, 1991, 127-149.
5. Dabbish, L. and Kraut, R. E. Controlling interruptions: awareness displays and social motivation for coordination. In *Proc. CSCW 2004*, (2004), 182-191.
6. DeSanctis, G., Staudenmayer, N, Wong, S.S. Interdependence in Virtual Organizations. In *The Virtual Organization Vol. 6*, C. Cooper and D. Rousseau Eds. Wiley and Sons, New York, NY, 1999, 81-104.
7. Endsley, M. Toward a theory of situation awareness in dynamic systems. *Human Factors*, 37 (1995), 32--64.
8. Gergle, D., Kraut, R., & Fussell, S.R. Language efficiency and visual technology: Minimizing collaborative effort with visual information. *Journal of Language and Social Psych.*, 23, 4 (2004), 491-517.
9. Gutwin, C. and Greenberg, S. Effects of awareness support on groupware usability. In *Proc. CHI 1998,* (1998), 511-518.
10. Gutwin, C. and Greenberg, S. A Descriptive Framework of Workspace Awareness for Real-Time Groupware. *J. CSCW 11, 3* (2002), 411-446.
11. Hindus, D., Ackerman, M. S., Mainwaring, S., and Starr, B. Thunderwire: a field study of an audio-only media space. In *Proc. CSCW,* (1996), 238-247.
12. Hussain, T.S. and Ferguson, W. Efficient development of large-scale military training environments using a multi-player game. 2005 Fall Simulation Interoperability Workshop (2005), 421-431.
13. Jørgensen, K. Audio and Gameplay: An analysis of PvP battlegrounds in World of Warcraft. *Game Studies, 8, 2* (2008).
14. Malone, T. W. and Crowston, K. The interdisciplinary study of coordination. *ACM Computing Surveys, 26, 1* (1994), 87-119.
15. Moore, R. J., Gathman, E. C., Ducheneaut, N., and Nickell, E. Coordinating joint activity in avatar-mediated interaction. In *Proc CHI,* 2007, 21-30.
16. Nardi, B. and Harris, J. Strangers and Friends: Collaborative Play in World of Warcraft. In *Proc. CSCW*, (2006), 149-158.
17. Neisser, U. *Cognition and Reality*. W.H. Freeman, San Francisco, 1974.
18. Olson, G. M., & Olson, J. S. Distance Matters. *Human-Computer Interaction*, 15, 2/3 (2000), 139-178.
19. Schober, M.F. Spatial perspective-taking in conversation. *Cognition*, 47, 1 (1993), 1-24.
20. Sonnenwald, D.H, Maglaughlin, K.L., and Whitton, M.C. Designing to support situation awareness across distances: an example from a scientific collaboratory. *Information Processing*

and Management: an International Journal, 40, 6 (2004), 989-1011.
21. SPSS Technical Report- Linear Effects Mixed Modeling. http://www.spss.ch/upload/1107355943_LinearMixedEffectsModelling.pdf
22. Van de Ven, A. H., Delbecq, A. L., & Koenig, R., jr. Determinants of coordination modes within organizations. *Am. Soc. Review*, *41* (1976), 322- 338.
23. Wadley, G., Gibbs, M., and Benda, P. Speaking in character: using voice-over-IP to communicate within MMORPGs. In *Proc. Australasian Conference on Interactive Entertainment 2007,* (2007), 1-8.
24. Watts, J. C., Woods, D. D., Corban, J. M., Patterson, E. S., Kerr, R. L., and Hicks, L. C. Voice loops as cooperative aids in space shuttle mission control. In *Proc. CSCW*, (1996), 48-56.