Improving Recognition and Characterization in Groupware with Rich Embodiments

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ABSTRACT
Embodiments are visual representations of people in a groupware system. Embodiments convey awareness information such as presence, location, and movement – but they provide far less information than what is available from a real body in a face-to-face setting. As a result, it is often difficult to recognize and characterize other people in a groupware system without extensive communication. To address this problem, *information-rich embodiments* use ideas from multivariate information visualization to maximize the amount of information that is represented about a person. To investigate the feasibility of rich embodiment and their effects on group interaction, we carried out three studies. The first shows that users are able to recall and interpret a large set of variables that are graphically encoded on an embodiment. The second and third studies demonstrated rich embodiments in two groupware systems – a multiplayer game and a drawing application – and showed that the enhanced representations do improve recognition and characterization, and that they can enrich interaction in a variety of ways.

Author Keywords
Embodiment, rich embodiment, telepointers, avatars.

ACM Classification Keywords
H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – *CSCW*.

INTRODUCTION
Embodiments are visual representations of people in a distributed groupware system – representations that can range from a telepointer in a shared whiteboard, to a vehicle in a networked racing game, to a human avatar in a collaborative virtual environment. Regardless of their form, embodiments are valuable in groupware because they convey awareness information about presence, location, and movement. However, these basic pieces of information are far less than what is available in the real world, where people use hundreds of different visual indicators to determine a person's identity, status, role, occupation, current activity, expertise, and availability. The comparative lack of information in groupware embodiments reduces the richness and subtlety that is possible in distributed interactions: it is difficult to determine who people are, and it is difficult to quickly gather information about people that could be useful to the collaboration.

Groupware embodiments are much smaller than their real-world counterparts; however, they could still display considerably more information than what is seen in current systems. By using visual effects such as shape, orientation, texture, or secondary icons, embodiments could represent more pieces of information about other participants. These *information-rich embodiments* provide awareness of many different factors that could be valuable in a collaborative task – experiential variables about a person's familiarity with the current tool, session variables such as the amount of time that they have been present, personal variables such as age or city, or system variables such as network delay. With this extra visual information, rich embodiments can help people identify, recognize, and characterize others in groupware systems – and with less effort than for other mechanisms such as participant lists or user profiles. Some online games are beginning to add more information to player representations, and some researchers have looked at overloading telepointers with other information [10]. These examples, however, encode only a handful of additional variables, and they have not been studied in detail in order to determine if they actually work.

To investigate these issues, we carried out three studies: the first looked at the number of variables that people would be able to remember and interpret on an embodiment; the second explored the way that rich embodiments were used over an eight-week period in a multiplayer game; and the third tested rich embodiments in a shared drawing tool. These studies showed that people are able to remember and interpret a large amount of extra information (fifteen different variables), and that the rich embodiments did improve people's ability to recognize and characterize other participants. The rich embodiments changed the way people worked, and enhanced the interactions that occurred.

EMBODIMENT IN GROUPWARE

Graphical representations of people have been part of groupware since the very first multi-user systems – for example, spaceships in Spacewar (1961) or racquets in Pong (1972). Both in these early systems and in current groupware, the purpose of an embodiment remains the same – to act as a placeholder for the participant that provides information to the rest of the group. Embodiments can be categorized as symbolic (telepointers and avatars) or literal (video images).

Telepointers are representations of each person's local mouse cursor. Although extremely simple, telepointers can convey presence, work location, and activity. Telepointers are widely used in shared-workspace groupware (e.g., [10]), and are drawn as 2D objects in the space.

Avatars are usually human or animal representations of people, although they can also take the form of vehicles (where the metaphor assumes that the person is inside the vehicle). Avatars require more space than telepointers, but as a result can also convey more information about gesture, facial expression, and movement. This form of embodiment is used in multiplayer games and virtual environments [2,5].

Video provides a high-fidelity and literal representation of a groupware user. Video can convey considerably more than other embodiments – identity, activity, gestures, eye contact, and facial expressions – and can do so with a representation that is nearly identical to the real world [15,20]. However, video embodiments do not scale well to multiple users, and are only possible when people can use direct input (i.e., they use their hands and arms to interact with the computational workspace, rather than a mouse).

As awareness mechanisms, embodiments can convey information about presence, identity, location, and activity [12]. Aside from video representations, most embodiments provide only the most basic indications of who is who, and of what characteristics people have. Some projects and systems, however, have begun to add extra information.

Richer Forms of Embodiment

Groupware researchers have discussed the need to add richer information to embodiments [2,12], and some systems and games have added more information to people's representations – although these efforts generally only add a one or two extra variables. Much of this work follows the idea of edit wear and read wear [14], and focuses on identity: for example, Benford et al. [2] suggest that embodiments should represent one's unique self in the same way that physical appearance does; and Gutwin and Greenberg [12] suggest the use of colour, nametags, images, or unique icons to aid identification. The importance of identity can also be seen in videogame avatars [8], many of which allow people to choose and customize their embodiments (e.g., *City of Heroes*). Note that *identity* here refers to information that indicates who a person is, rather than their personal identity or sense of self.

Displaying a person's current state on an embodiment has also been considered. Game avatars (e.g., *Star Wars Galaxies* or *EverQuest*) often depict certain aspects of a character's identity (such as name, guild, rank, race, or gender) either on the avatar itself of in a floating display (see Figure 1). State and activity information has also been explored in more traditional groupware embodiments: semantic telepointers [10] add visual cues that show when actions such as mouse clicks and menu selections occur; buddy icons in messaging applications often use overlays and colour to show availability; and Vaghi et al. [21] suggested displaying information about network delay above the avatars in a collaborative virtual environment.

Although this information can be used by other players and participants, the extra displays generally do not change the capabilities of the embodiment. One exception is the 'Fatboy' mod in *Unreal Tournament*. With this mod, the width of an avatar represents the player's kill-to-death ratio: better players are recognizable by their wide avatars (and thus easier to hit), and poor players become thinner.

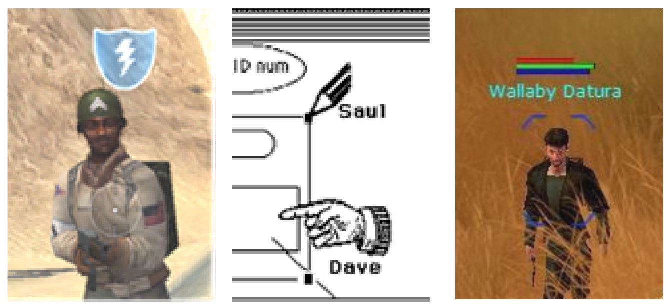

Figure 1: Examples of information added to embodiments. *Enemy Territory* (left): avatar type shows role; icon shows status. *GroupDraw* (centre): pointer shape indicates tool, text shows name. *Star Wars Galaxies* (right): avatar type shows gender; floating display shows health, name, and profession.

Multivariate Information Visualization

The idea of representing multiple variables on a single graphical object has also been explored by researchers in information visualization. In this field, an embodiment would be a *glyph* – an iconic entity that represents several data dimensions on one graphical unit. Data can be scalar, ordinal or nominal, and dimensions can be represented using geometric attributes of the glyph (shape, orientation, or size), or appearance attributes (colour or texture [22]).

Several types of glyphs have been used to display multivariate data. In some cases the glyph is based on familiar objects such as human faces [6] or bugs [7]. Chernoff faces [6] were one of the earliest glyphic representations for displaying multivariate statistical data. Abstract glyphs have also been used: these augment basic objects – boxes [13] or wheels [7] – with a attributes that encode data dimensions. Glyphs in general are limited by people's perceptual ability to separate dimensions, subjective rating of colour codings, and perceptual sensitivity to the context of use. Nevertheless, they have been successfully used to convey a large amount of information about an object in a small space, and these techniques led us to the idea of rich embodiments for groupware.

INFORMATION-RICH EMBODIMENTS

Information-rich embodiments are visual representations of people that encode several additional variables (other than presence, location, and movement) in the graphical space of the embodiment. Three questions arise in the design of a rich embodiment: what information to display, what visual techniques to use to represent this information, and how to map information to visualization.

Question 1: What information to display?

There are many things that could be displayed on an embodiment. It is clear from social psychology literature that humans gather a wide variety of information about others from their real-world physical appearance, including gender, race, social status, membership in groups, occupation, personality, and mood [1,9]. In collaborative work, other factors such as current tool, rate of activity, or level of concentration could also be gathered by watching people work. In general, we have identified seven different types of information that could be valuable in a groupware system (although this list is not exhaustive):

- *personal variables* such as name, age, or gender;
- *experiential variables* such as familiarity with particular artifacts or tools;
- *session variables* such as time in the system or idle time;
- *application variables* such as roles or capabilities;
- *state variables* such as current tool, current colour, or communication status;
- *activity variables* such as amount or recency of action;
- *distributed-system* variables such as network delay or available bandwidth.

Question 2: How to represent the information?

The basic mechanism for representing information on a rich embodiment is the *visual variable*. These are qualities of a visual glyph, such as size, shape, colour, texture, orientation, or transparency. To increase the number of variables that could be displayed, embodiments can also be considered as a composite of several glyphs: for example, the border of a 2D avatar can display certain variables (e.g., line width, colour), while the interior of the shape can show different information. Furthermore, different parts of the embodiment could be subdivided into regions (e.g., the pointer and tail of a cursor), or additional secondary glyphs could be added (e.g., the floating display in Figure 1).

Question 3: Mapping variables to visualizations

There are simple guidelines from visualization literature that can help designers determine the mapping of information variables to visual representations. In the examples to follow, we used rules proposed by Mackinlay [17] that include guidelines suggested much earlier by Bertin [3]. Mackinlay states that the effectiveness of visualization is based on the type of the variable (i.e., scalar, ordinal, and nominal) and the appropriateness of the corresponding visual representation. Certain visual effects are more appropriate for certain types of variables (e.g., hue is more effective for nominal than for scalar variables). Mackinlay also states that when attempting to display multiple variables, the designer should not include visualizations that will obstruct or alter other graphical representations being applied.

The specific mappings chosen for an embodiment, however, will be greatly affected by the domain and tasks for which the embodiment will be used [18], and therefore the designer will have a strong influence on the eventual mapping. In our case, we were able to achieve reasonable results by designing several paper prototypes that were refined through basic usability testing.

Below, we describe the two types of rich embodiment that we built: a spaceship avatar for a multiplayer game, and a rich telepointer for a shared drawing application. We added thirteen information variables to the spaceship, and ten to the telepointer – far more than has been previously used.

Example 1: Information-Rich Avatar

The domain for the first embodiment example is the classic multiplayer videogame *Spacewar* [4]. The base spaceship avatar is a simple 2D triangular shape, onto which we add visual variables for thirteen different pieces of information (Figure 2). The information includes personal information (*name*, *gender*), experiential variables (*game experience*), application variables (*team*, *number of kills and deaths*, *time alive*), and state variables (*communication status*, *damage*, *shield strength*, *gun reload*, *engine and gun heat*).

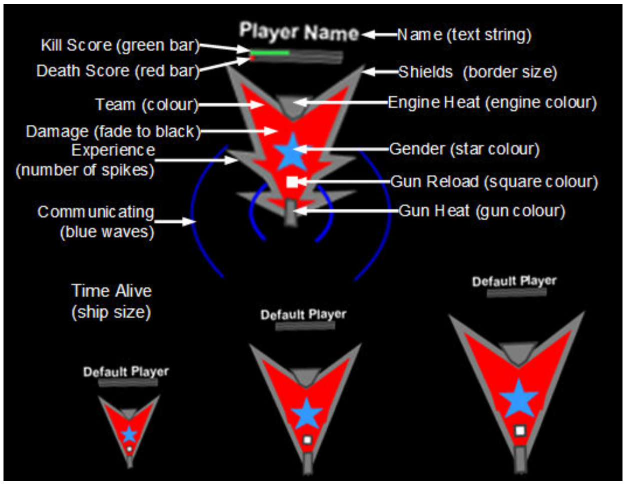

Figure 2. Rich avatar embodiment

The visualizations were designed following the process described above. Three examples illustrate the different techniques for representing information. First, we modeled *experience* as the number of total kills across all sessions of the game, and displayed this variable by changing the overall shape of the avatar to show a number of spikes (with each spike indicating a different level of experience). Second, *damage* was displayed by altering the colour of the ship's body: an undamaged ship had a fully-saturated interior, and with more damage, the colour would fade to black. Third, *player name* was shown as a secondary glyph (a text tag) that followed the ship.

Example 2: Information-Rich Telepointer

The domain for the telepointer example is a shared drawing application with several tools. The mappings used in the telepointer embodiment are similar to those used in the spaceship avatar, and included personal data (*name*, *age*, *gender*, and *user colour*), application information (*activity level*), state variables (*tool*, *brush colour*, *stroke size*, *click and communication status*) as shown in Figure 3.

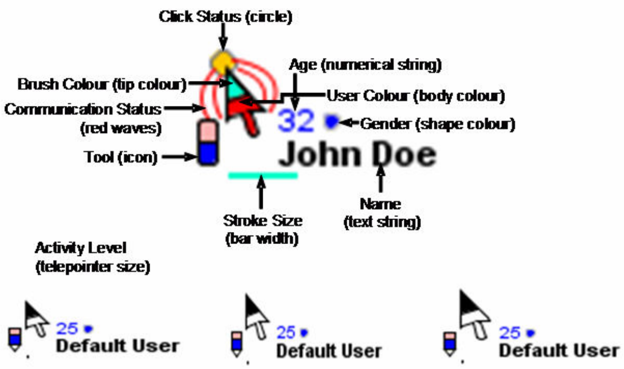

Figure 3. Rich telepointer embodiment

STUDY 1: INTERPRETATION OF RICH EMBODIMENTS

The first question that arises when attempting to create richer embodiment is: how many variables are people able to remember and interpret? Our first study used simple retrieval tasks with non-groupware systems to get a basic understanding for the feasibility and limits to interpretation on an augmented embodiment.

Methods

Twelve participants (10 male, 2 female) were recruited from a local university. Participants carried out three tasks that asked them to answer questions about particular rich embodiments. Each task was completed with embodiments similar to the spaceship and telepointer described above (but with fifteen variables each, instead of thirteen and ten).

The first two tasks were carried out with printed pictures of the embodiments; the third was carried out in a custom-built experiment system. The tasks were:

- *Remembering mappings***.** The first task assessed ability to remember and identify the variables used in the rich embodiments. After a five-minute training period, participants were shown a diagram of an embodiment and were asked to list all of the encoded variables they could remember. For each embodiment type, participants were given four images, one after another.
- *Determining values***.** The second task examined accuracy in determining the specific values of the variables. Participants were shown a picture of an embodiment and asked to specify the values of each variable. Participants carried out four trials for each embodiment type.
- *Finding specific embodiments***.** The third task measured time and accuracy in selecting an embodiment that matched a set of criteria. A custom application presented a question and a set of 24 embodiments, and the participant was asked to click on an embodiment that matched the given criteria. Participants were given 15 questions for each embodiment type. The first five questions used a single variable; the next five used two variables; and the last five used three.

Results

The first study showed that people are extremely good at remembering and interpreting visual mappings on rich embodiments. A brief summary of the results, by task:

- Task 1: people remembered a mean of 13.73 of the fifteen mappings presented on the embodiments;
- Task 2: overall, people were more than 95% accurate in determining the values of the variables (mean 96.6%);
- Task 3: people selected correct embodiments 87% of the time, in a mean time of 17.4 seconds.

No differences were found between the spaceship and telepointer embodiments, and similar findings emerged from both embodiment types. For example, the mappings that were difficult to remember were those that had a 'not shown' state (e.g., telepointer *click status* is shown only when clicking). Similarly, questions with more criteria were more difficult to answer, but there were no differences between the ship and telepointer embodiments.

The results of this study show that people can recall and interpret a large amount of information from a rich embodiment. However, this study did not set the embodiments into an actual groupware system and an actual task, and so obvious questions remained about whether these representations will work in real-world environments. In order to investigate these questions, we implemented rich embodiments in two working groupware systems, and tested them in two further user studies. The first was an eight-week study of rich avatars in a Spacewar game, and the second was a scenario-based experiment with rich telepointers in a drawing application.

STUDY 2: RICH AVATARS IN A SPACEWAR GAME

This study examined information-rich embodiments in a multiplayer game. We were interested in three questions:

- How were rich avatars used – and were they used to improve recognition and characterization?
- Did the rich avatars clutter the visual space?
- Did the embodiments change the collaboration?

To explore these questions, we implemented rich avatars in a groupware version of the Spacewar video game (see Figure 4). In our version of Spacewar, players fly ships in a 2D universe, shoot at other ships, try to dodge others' bullets, and try to avoid running into planets.

Figure 4. Group Spacewar, showing five players.

The rich avatar built for Spacewar was the spaceship shown in Figure 2. The avatar maps thirteen variables, including *player name*, *team*, *experience*, *time alive*, *damage level*, *shield strength*, *kill score*, *death score*, *communication status*, *player gender*, *gun heat*, *reload status*, and *engine heat* (see Figure 2). The avatars also show basic information such as the location, orientation, and movement of the ship, and whether the engines and guns are firing.

In order to explore longer-term use of and adaptation to rich embodiments, we ran the study over several weeks with the same people. Eleven male participants were recruited from a local university, and played twice-weekly games (of approximately one hour each) over an eight-week period. The first session began with simple avatars and more variables were introduced on the embodiments over time. The sessions were conducted in a networked computer lab, so that participants could talk normally during the game.

Data collection included observations during gameplay, post-session questionnaires, and interviews carried out with all participants at the conclusion of the study.

Results

Overall, participants had fun with the game and seemed quite willing to continue playing. The information-rich spaceship avatars were used in a variety of ways by the participants, some expected and others unanticipated. In addition, all participants stated that they liked the rich avatars and preferred them to plain ships.

Were the rich avatars used, and how?

It was clear from observations and interviews that all the participants did extract information from the spaceship avatars. Several variables were frequently used (*name*, *team*, *experience*, *damage*, *time alive*, and *shield status*), several were occasionally used (*death* and *kill scores*, *communication status*, *gender*), and some were rarely used (*gun heat*, *reload status*, *engine heat*).

It was also clear from questionnaires and interviews that all participants were easily able to remember how the variables were represented on the avatar, and were easily able to interpret the values of those variables (even if they did not often use them). As discussed below, the participants quickly integrated the mappings into their gameplay, and after the first couple of sessions there were no questions or difficulties with the mappings. Furthermore, it was also clear that participants used the information for recognition and characterization of other players.

Recognition

Participants did use the encoded variables to identify and recognize other players. In the interviews, people regularly stated that they needed to recognize others, and that they were able to do so with the rich avatars. Players wanted to identify others for four main reasons: to know who to avoid, to know who to attack, to be able to get revenge on a player who had killed them, and to be able to find and hunt down a favorite opponent. The variables that they used for these purposes varied, but several were frequently mentioned: *name*, *team*, *experience*, *kill score*, and *death score* – all either static values or values that change slowly, which makes the avatars visually consistent over time.

Recognition can be divided into two types: recognizing a ship during a session, and recognizing the person behind a ship. Even when it was not clear who the real people were, specific ships in Spacewar had a strong identity that was constant for the session. Session-based recognition was the primary type of recognition used in the game. Since one-on-one battles were a major component of the game, people quickly learned to identify their opponents, and when a player lost a battle, they would often start looking for the ship that destroyed them as soon as they respawned.

Name was regularly mentioned as the best way to identify a ship. Although the actual player may not have been known in the real world, the participants formed a mental model of a player and associated knowledge about them with the name of their ship. For example, one person stated: "…but I didn't really need to know who they are in person, because I see that name and develop some kind of understanding of what kind of player this is, like a good shooter or a good runner." A good example of this scenario involved a player using the handle 'Defaulter,' who was the best player in the sessions. Many players did not know who Defaulter was in real life, but they quickly began recognizing him, and would avoid him in the game or attempt to gang up on him.

In addition to the name tag, other visual variables were also used to determine who was who – particularly when there were many ships on the screen and reading the names was difficult. *Team*, *experience*, and *kill/death score* often produced a unique visual combination that could be used for fast recognition: e.g., 'the blue ship with one experience spike and a lot of kills' would be easy to recognize.

The second type of recognition was to identify the real person behind the ship, and here too the rich embodiment was used, with name again playing a primary role. However, in some cases, *name* could not be used to determine real identity, because some people signed on with a different nickname each session. One participant mentioned that he was able to track a player whose nickname changed regularly, based on the state of his *experience* variable (which stayed relatively consistent across sessions) and from his *kill/death ratio* (which would show a characteristic pattern, since he was a skilled player).

Overall, the ability to recognize players allowed the participants to more easily perform certain tasks. The Spacewar game involved continuous interaction with other participants and therefore being able to tell who an opposing player was, or being able to identify a certain ship was important. Recognizing ships was critical for avoiding skilled players, attacking poor players, seeking revenge on a particular player, or hunting a favorite opponent.

Characterization

Players also used the visual variables on the avatars to characterize other players. This was particularly important in situations where people did not have enough experience with another player to be able to recognize them. If a ship was unknown, the avatar allowed players to gather enough information about the other person to be able to engage with them in the game.

Characterization was done in two ways. First, the variables in some cases reflected a specific and intentional aspect of the game. For example, the importance of *team* was clear – players were automatically assigned to one of two teams (red or blue), and the gameplay was organized around teams trying to destroy ships of the other colour. During interviews, the majority of the participants stated that the colour of an avatar was one of the first variables they looked at when approaching a ship in Spacewar. Since there were only two colours, *team* was easy to interpret.

Another kind of characterization used variables in a more implicit fashion, and in a way that became vitally important to the way the game was played. Once avatars started displaying variables like *damage*, *kill and death scores*, *shield energy*, and *time alive*, a ship's strength and condition became a new factor in the game that greatly enriched the gameplay. When a ship's strength and damage became visible, players immediately began forming more complex strategies – in particular, it became possible to use the strategy of looking for visual indications of vulnerability, and maximizing your chances for kills by hunting a ship who was weaker than yourself.

Damage, *time alive* and *shield energy* were all used to characterize an opponent's potential strength. For example, players would often look for weak ships – small, showing damage, and with low shield energy – since these ships would be easier to fight. Many players noted that they would go after ships showing signs of damage, since these could be destroyed with fewer shots. As one participant stated: "the damage indication, if that wasn't there then you don't know what is happening, is he shot, is he damaged?"

Time alive also became very useful to players, since a large ship revealed that a player was doing well enough to stay alive for a substantial amount of time. This could either result in a player being more cautious about attacking, or could encourage people to attack, because a larger ship was easier to hit (and there was also considerable satisfaction in being the person to destroy a big ship). *Shield energy* worked similarly: if a ship had exhausted its shields, it was a much more attractive target.

Effects on Interaction and Gameplay

The rich embodiments allowed people to develop richer ways of interacting in the game. The increased complexity and subtlety in gameplay appears to be a result of two main factors: better awareness of other players, and better potential strategies. The ability to identify ships and players over several sessions enabled a variety of strategies and interactions: for example, users were able to repeatedly attack players that they had a grudge against, or take on a challenge by attacking the more dominant players in the game. These new ways of interacting, although simple, made the game much more engaging; soon after the introduction of the rich avatars, many of the participants developed more of an interest in the game, and would continue to play even after the study times were complete.

Without access to variables such as *damage*, *experience*, *shield strength*, and *time alive*, it was not possible to determine how to approach another ship in the game. This is illustrated by the comments of one participant who stated: "[the variables] are the ways that you actually organize yourself: Who to kill? Are you doing well? Strategy is based on these embodiments." Similarly when talking about the progress of rich embodiment in Spacewar, another person commented that: "Rich embodiment changed the way the game was played…. It has made it easier for technique: pick on the weak, avoid the strong." One of the participants also noted that with more information in the game, rich embodiments would become more important: "the richer the game, the more potential pieces of information you might need. And if it comes down to where there are situations where you want to use that information in the game, then this [rich avatars] is the sort of stuff you want to do."

Clutter and Distraction

We were also interested in whether the added visual information would clutter the workspace or distract players from the game. We asked participants on questionnaires and in interviews whether they saw clutter or distraction as problems, and none of them expressed any concerns, even with thirteen variables on each avatar. Many of the participants stated that the interpretation of the information encoded on the spaceships became an automatic part of the game, and that they stopped even noticing the information as 'extra.' As the sessions went on, players simply looked at the ships and extracted the information that they needed. As one participant noted: "[the variables] become more intuitive. You don't think about 'this means this', it becomes part of the game – you just know."

STUDY 3: RICH TELEPOINTERS IN A DRAWING TOOL

The Spacewar study showed that rich embodiment can have a substantial positive effect on interaction in a groupware system. The information in the rich avatars was extensively used by players, and none of the participants found the extra information distracting. However, since the study used a game setting, we still had questions about whether the idea would generalize to other types of groupware.

We carried out a third study that tested rich embodiments in a canonical groupware setting: a shared drawing tool. This more traditional 'work' application allowed us to explore a different and smaller embodiment type (telepointers instead of spaceships), and to investigate what happens in situations where there are different requirements for group interaction (interacting with others is not explicitly required in a drawing application, whereas it is the basis of Spacewar). Therefore, our goal in the third study was to follow up the results from the Spacewar evaluation, and to test the generalizability of the earlier successes.

Methods

A custom shared drawing application (called *Grouper*) was built for the study (see Figure 5). Like Spacewar, the system was built using Java and the GT groupware toolkit. Grouper is a basic sketching system that lets groups draw and paint on a shared canvas; Grouper also provides text chat for communication. Embodiments in Grouper are rich telepointers that display 10 different variables about the user, their actions, and their application state (see Figure 3).

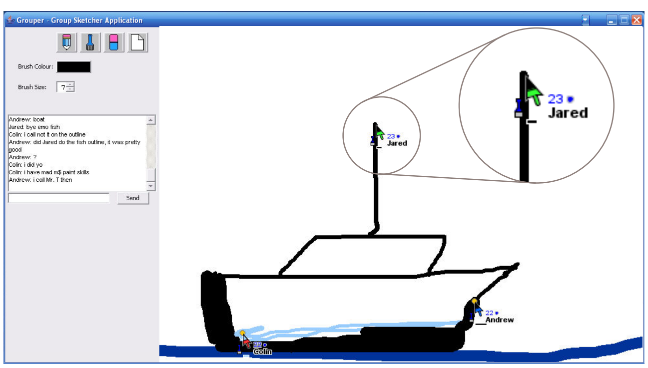

Figure 5. The Grouper drawing tool, with three users.

Eighteen participants were recruited for the study from a local university (8 male and 10 female); ages ranged from 19 to 38, (mean of 27). Participants signed up in groups of three, and so were familiar with their collaborators.

People carried out the activity in separate rooms, to better simulate a distributed setting. After an introduction to the system, the group jointly completed four different drawings (based on target images given to them). Groups were given eight minutes for each drawing. For the first three drawings, the rich telepointers shown in Figure 3 were used; for the final sketch, the system showed only basic colour-coded telepointers. Switching from rich to basic telepointers was done so that participants could compare the two types of embodiment. As in the Spacewar study, we collected a variety of data, including observations, system logs, post-experiment questionnaires, and individual interviews.

Results

Overall, the third study confirmed that rich embodiments also work with telepointer representations in more traditional groupware domains. Participants made use of a number of the variables (such as *name*, *age*, *telepointer colour*, *brush colour*, and *stroke width*), both for recognition and for awareness that helped participants coordinate the activity. Once again, none of the participants felt that the rich representations cluttered the workspace or distracted them from their tasks. When they had the chance to compare rich telepointers to more basic versions and to an alternate list-based information display, all participants stated that they preferred the rich representations.

Recognition

As in Spacewar, participants in the Grouper study used the rich embodiments to aid recognition. On the questionnaire, 17 of the 18 participants stated that rich telepointers better allowed them to recognize people than the basic (colour-only) telepointers used in the final task. Although our drawing tasks did not require the degree of one-on-one interaction that was seen in Spacewar, participants in Grouper also used the embodiments both to recognize the real person behind a telepointer, and to differentiate between participants during the session.

Although the group members knew one another, we asked them to choose different names for the trial; therefore, it was not immediately obvious who the real person was behind the embodiment. These session names, just as in Spacewar, provided people with 'session identities' that were recognizable to others. It was clear from the interviews that people formed a mental model of a person and used the *name* as a handle for that model – but that it took time to form the association. As one person stated, "the names were only good after I got to know the behaviors [of the other participants]." Once some experience had been built up, then these identities were relatively strong: as another participant stated, "I had an image in my head of Oscar and what he was doing and stuff like that. I could picture what Gabrielle is like and you could have an image in your head [of that person]."

Colour was also used to differentiate between session identities, although participants stated that it was not as valuable as the name tag. This is interesting because colour is used in many groupware systems as the only indication of identity, and this choice may be inferior to simply showing a name, even if it is not the person's real name.

To actually determine the real person behind the telepointer, people used the *age* and *gender* variables, something that we did not observe in the Spacewar study.

From the interviews, it appeared that some participants knew their friend's ages well enough to be able to identify who their real-world companions were. This result suggests the value of providing real-world information in the avatar, even if it is not important for the groupware task.

Characterization: awareness and coordination

Characterization was used in Spacewar primarily as a way of putting other ships into classes based on strength, in service of choosing an opponent. In Grouper, there was not the same need to choose a particular person from among the others in the group, and so characterization worked differently. In the drawing task, characterization was used much more for awareness of current activity – that is, it involved characterizing what a person was currently doing, and therefore primarily involved activity variables on the telepointer – *brush colour*, *current tool*, and *stroke width*.

Several participants stated that they would keep track of these variables on their collaborator's telepointers, in order to determine the part of the sketch that the other person was about to work on. This helped groups coordinate the task, and avoid duplication of work. For example, one participant stated "I use the stroke size and brush colour to see what they are working on, and to see what I should be doing." This behavior was common among the majority of the groups – only one of the six groups used the text-chat feature to discuss the division of labour in the task. This kind of group coordination also occured in Spacewar, in situations where team members were jointly attacking an opposing ship. This required that teammates stay aware of each others' locations and orientations, so that they could position themselves appropriately.

The short duration of the Grouper study (one 40-minute session) meant that we could not display longer-term experiential variables. However, we asked participants about whether they would like to see these in a real-world usage situation, and several agreed that if there were more people in the session and the tasks were larger and more complex, that longer-term data about the other group members would become more useful.

Clutter and distraction

The telepointers in Grouper were considerably smaller than the spaceship avatars, but still represented ten variables. During interviews, all participants stated that the additional visual information did not clutter the workspace or distract them from their own work. The only negative comment (from one person) was that the *click-status* visualization (a circle drawn around the tip of the cursor) could cover up a line segment if the stroke size was small. For the most part, however, participants stated that (as in Spacewar) the additional information simply became part of the landscape.

Alternative information sources

Like Spacewar, Grouper provided an alternate representation for the information on the rich telepointers – the participant list that could be seen by pressing the 'Tab' key on the keyboard. This representation was provided to see whether users would prefer to find information through a list format rather than on the telepointers themselves.

However, the alternate representation was rarely used. Fourteen of the 18 participants stated they did not use it – and usually because they simply forgot about it. From the system logs we saw that more people used the information panel in the final task, where only basic telepointers were available, but even in this task it was only used seven times. This experience indicates one of the advantages of displaying the variables on the telepointer itself – users do not have to expend extra effort to find the data, and in situations where the information is useful but not essential, this can make the difference between using and not using it.

DISCUSSION

The three studies provide both quantitative and qualitative evidence of the feasibility and effectiveness of rich embodiments. The main findings are:

- People are able to remember and interpret a large number of variables that are graphically encoded on a 2D embodiment–many more than have been previously used.
- In Spacewar, people used rich embodiments for recognition of both real and session identities, and for characterization of player and ship strength.
- Recognition and characterization became important to the way the game was played; several new aspects of gameplay (e.g., 'get revenge,' 'go after the weak, run from the strong') were tied to these activities, and the interaction was enriched as a result.
- Interpretation of the variables on the spaceship avatars became second nature for the participants, and there were no concerns about clutter or distraction.
- The Grouper study showed that people also used the rich embodiments in a more traditional groupware setting, and with telepointers rather than ships.
- Participants in the sketching tasks used the rich telepointers both to identify their collaborators, and to maintain awareness of activity that helped them coordinate the completion of the task.

In the following sections, we discuss reasons for these findings, consider how rich embodiment can be adopted by designers, and discuss issues that require additional study.

Explanation and interpretation of results

Why did the rich embodiments work?

Participants in all three studies were very successful at remembering mappings and using the variables. The ease with which they used the embodiments suggests that people are accomplished at these kinds of memory tasks – certainly they have a great deal of practice with such mappings as they observe people in the real world [1,9]. There are also a few reasons specific to groupware that may explain the success: first, the information values represented on our embodiments were concrete and well-understood concepts, like name, age, damage, or drawing tool, and it is likely that these are easier to remember and use than the complex dimensions that may appear in standard multivariate visualizations; second, the information could be interpreted in the context of the collaborative application, which restricts interpretation; and third, rich embodiments can often take advantage of natural mappings (e.g., the 'click' indicator at the tip of the telepointer) to aid interpretation.

Learning the mappings did not appear to be a difficult task for the participants. There is an obvious trade-off between the number of variables that are visualized and the time needed to learn them. However, our studies suggest that users will quickly learn the mappings they find most useful, and will learn the other variables over a longer time period.

How did rich embodiments change interaction?

There are two main reasons to explain how the rich avatars in Spacewar changed the gameplay: they provided a richer environment in which more complex behaviour was possible, and they made it much easier to obtain information about that environment.

First, the rich avatars led to an environment where people had more information about each other than they did previously, and this allowed for much more complex decision-making and strategy in the game. It is important to note that it is the display of the information through the avatar, rather than simply the presence of the information in the game, that led to this complexity – if variables such as *shield energy*, *damage*, and *experience* were present but not visible, it would not be possible for people to form strategies around these variables (as we saw in the game.)

Second, it was clear that displaying information on the spaceship itself played a major role in allowing people to make use of the richer environment. Information was easy to obtain, and could be found without interrupting current activities. Even though there was a separate information panel with the same information that was displayed on the avatars, players universally preferred to gather the information from the ships themselves.

Lessons for Groupware Designers

There are several lessons that designers of real-time groupware can take from this work. The most important lesson is that designers should add more information to groupware embodiments: our studies show that the idea is feasible, and that people can and do use augmented representations for a variety of purposes. Avatars and telepointers can potentially convey far more information than has previously been seen in groupware embodiments, and this can lead to enhanced and more subtle interaction.

It is also important for designers to consider the situations where rich embodiment will be effective. People's existing knowledge of their collaborators is a key factor – there will be little advantage in visualizing information that is already known. Therefore, information-rich embodiments are likely to be valuable in three settings: first, in situations where groups are large or where participants do not know one another well (here all variables will be valuable); second, in situations where people know their collaborators but not their characteristics in a particular situation (experiential, application, and session variables will be valuable here); and third, in situations where information changes dynamically during the session, and people need to stay up to date (session and application variables like current tool, network delay, and idle time will be valuable here).

Unfortunately the graphical encoding of information is not an exact science. However, by taking into account the actual groupware context, and by using visualizations that map logically to a particular graphical representation, it is possible to create successful rich embodiment. Pilot testing is also helpful in determining weak mappings of information and conflicting visualizations. Finally, the results of the two groupware studies show that it is feasible to create visualizations that are easier to interpret. The findings also reveal that as long as the information is encoded in a way that can be found on an embodiment, users will determine what variables they need and how to interpret them. The majority of participants in the studies were able to easily deduce the values of the variables they found helpful in the particular groupware tasks, regardless of the visualization applied.

Finally, the success of rich embodiments argue for a richer information environment more generally in groupware. Although even basic groupware has always been able to support the bare necessities of group tasks, it almost never feels natural or subtle. One of the ways to provide more expressiveness and more interaction range is simply to provide more information, and then let the participants themselves figure out how to make use of it – as described above, a more detailed environment allows people to engage in much more complex behaviour.

Future Work

Our experiences building and evaluating rich embodiments raise a number of issues and possibilities for further study.

- *Privacy*. Many work and play groups will be willing to share information with others, particularly if that information is also available in face-to-face settings. Nevertheless, we plan to explore privacy issues in more detail, and investigate methods for giving people flexible control over what information gets collected and how it is displayed.
- *Personalization*. Many people will want to customize their avatars, as they already do in on-line games. This could enhance the power of rich embodiments, since it would lead to improved recognizability; however, it is also important to maintain some degree of consistency so that variables can still be understood and interpreted.
- *Dissembling*. In the real world, people go to considerable effort to alter their appearance and present a different set of characteristics to others. More work is needed to determine groupware should handle this issue: although people already alter session variables such as *name*, it is

difficult to know whether they should ever be allowed to change other variables such as *experience* or *damage*.

- *Visualization improvements*. Our current visualizations involve simple 2D effects; more complex mechanisms could convey more information, or convey it in more natural ways. For example, texture synthesis could be used to provide more subtle cues about variables like weathering or damage. Similarly, we could extend the display space to the environment surrounding the embodiment, and visualize traces left behind by actions and interactions (e.g., telepointer trails to show past activity [11] or smoke trails to indicate ship damage).
- *Simplifying development of rich embodiments*. In our examples, information collection and visualization was done manually; we plan to develop a toolkit that will simplify the design and construction of information-rich embodiments. One possibility is to use shape grammars [16] – visual transformation rules that can be applied to any 2D shape – to develop a vocabulary of effects that designers can draw from as they develop embodiments.

CONCLUSION

Standard groupware embodiments convey far less information than what is available from the real world. We introduced the idea of information-rich embodiments, which attempt to maximize the amount of information that an avatar or telepointer can provide. In three studies, we found that rich embodiments are viable and valuable for real-time groupware: people are able to remember and interpret a large number of visual variables, they are able to use the extra information to improve both recognition and characterization of others, and they quickly take advantage of the enhanced information space to change the ways that they interact with one another. Our studies suggest that information-rich embodiments should be considered by groupware designers, as a way to support richer and more natural interaction in distributed shared spaces.

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