Information-Rich User Embodiment in Groupware

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Abstract

Embodiments are virtual personifications of the user in real-time distributed groupware. Many embodiments in groupware are simple abstract 2D representations such as avatars and telepointers. Although current user embodiment techniques can reveal information related to position and orientation, they show far less than what is available in a face-to-face situation, and as a result, collaboration can become more difficult. The problem addressed in this research is that it is difficult for groupware users to recognize and characterize other participants using only their embodiments. The solution explored in this thesis is to provide more information about groupware users by enriching their embodiment. This scheme encodes state and context variables as visual augmentations on the embodiment. Providing information about characteristics such as skill, expertise, and experience can be valuable for collaboration; increasing the information in visual embodiments makes it easier and more natural for collaborators to recognize and characterize others, and thus coordinate activity, simplify communication, and find collaborators.

Rich embodiments were tested in three separate experiments. The first experiment showed that users are able to recall a large number of variables displayed on embodiments, and are able to accurately determine the values of those variables. The second study showed that rich embodiments are useful in terms of collaboration and interaction in an actual groupware context – a multiplayer game. The final study further examined information-rich embodiment in a shared drawing task, and further revealed the potential of increasing awareness using embodiment.

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Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

Real-time distributed groupware applications allow multiple users in different locations to interact in a shared virtual space. For example, a level in an online game or the drawing canvas of a distributed whiteboard application are considered shared spaces. In these spaces, users must be supplied with some form of presence in order to facilitate awareness among the participants. Traditionally, presence is achieved through a visual representation called an *embodiment*. Embodiments act as the virtual personification of the user and can be expressed using a cursor, an avatar, a picture, or a video stream. This thesis is concerned with embodiments within a two-dimensional space. The workspaces and embodiments found in most academic groupware applications are two-dimensional, and therefore I focus on 2D embodiments such as cursors and avatars.

Current groupware embodiments can show presence, activity, and limited identity within a shared workspace. However, they do not show many of the relevant details and characteristics about the person being represented. By not presenting these visual cues, that are common in real-world interactions, groupware users are restricted in their collaboration.

1.1 Problem

The problem addressed in this thesis is that: *It is difficult for groupware users to recognize and characterize other participants using traditional embodiments*.

Recognition refers to the user's ability to identify another user from their embodiment (the person behind the visual personification). There are two types of possible recognition: recognition of someone familiar (e.g., "John"), and recognition of someone that has been seen before (e.g., "that person I saw earlier"). *Characterization* refers to the interpretation of important traits and features of others. For example, a participant may not know who another user is, but can compile an understanding of the type of person they are (e.g., male, female, doctor, engineer, novice, expert).

The difficulties arise from the fact that traditional embodiments in groupware reveal limited information and much less information than what is available in real-world collaboration. Although current embodiments help provide presence information and some information related to identity (e.g. name tags, or team colour), it is often difficult for a user to determine who they are interacting with and what their characteristics are. For recognition, people have to remember which colour belongs to whom, which is much more difficult than identification in face-to-face interactions. Determining a person's characteristics is similarly difficult; users are forced to search for user traits by examining player data in a table or separate display, or by directly asking others for the information. Conversely, it is possible to determine more character information from visual cues in the real world.

1.2 Motivation

In order to make interaction in groupware more natural, it is important for participants to be able to recognize others and deduce important characteristics about their collaborators. Evaluation of people based only on appearance is a common real-world task used in everyday social interactions. For example, a person in dark uniform with a badge is recognized as a police or security officer, and a person's social class can often be estimated based on their everyday appearance.

Collaboration in the real world is often more effective when one person knows who has the required knowledge to perform a given task, and we naturally seek out the type of person we require at a particular point in time. This ability to locate the right person for assistance is impeded in current groupware applications, and may require additional and time consuming steps (e.g., looking at user statistics, polling other users to find the right person) that are more difficult and less rich than in the real world. Finding people of interest will occur more easily by mapping relevant information into graphical traits visible immediately on a user's embodiment.

By improving people's ability to recognize others and distinguish specific characteristics of other users, interaction among participants could occur more naturally. More specifically, rich user embodiment would allow participants to rapidly deduce others' characteristics. More effortless collaboration in groupware will make it easier for distributed users to coordinate on a variety of tasks. Thus, interacting with people in different physical locations becomes simpler and more efficient.

1.3 Solution

The solution given in this thesis is to provide more information about groupware users by enriching their embodiment in the virtual space.

This solution is achieved by overloading the visual representation of current embodiments, such as telepointers and avatars, with additional visual information that reflects specific user data. Multivariate visualization techniques are used to create the rich embodiments.

Information-rich user embodiments can be built to reflect details relevant to the context of specific groupware systems. For example, the context in a videogame is quite different from a collaborative workspace. In a videogame, it might be helpful to know the strengths and weaknesses of your opponent; while in a collaborative environment it may be more useful to know a person's skill set and expertise. Thus embodiments should be constructed to reveal data that applies to the current context.

Possible drawbacks to overloaded user embodiment include clutter in the workspace and added user distraction. More specifically, if we increase the amount of information presented in groupware applications, users may find this overwhelming. Additionally, the graphical representations may overlap with other items of interest and clutter the shared space.

1.4 Steps in the Solution

Two main parts have been carried out in this research: the definition of an information-rich user embodiment framework, and the application of the framework to a set of groupware domains. The steps in the solution that were performed are as follows:

1. *Selection of two groupware applications*. Two applications in different groupware genres were chosen for the study of rich user embodiment. The genres are a video game (a 2D Spacewar game), and a workspace application (a group sketching system). The result of this step is two example applications used throughout the project.

2. *Determining the perceptual limits of information-rich embodiments*. This step was aimed at determining how much data users are able to perceive and interpret with a limited amount of training. Additionally, there may be limitations based on the context of a specific groupware system. For example, more information can probably be mapped to a large avatar than to a small telepointer. The results of this step provide evidence of the potential for embodiments to display a larger set of data than traditional embodiments.

3. *Creation of a framework to provide guidelines for the creation of information-rich embodiment*. The rich embodiment framework is made up of three parts: input variables, display techniques, and mapping between input and output. This step provides guidelines to use when designing and implementing rich embodiments for groupware.

4. *Implementation of two prototypes*. Once the rich user embodiment framework was completed it was applied to two groupware applications. The framework was applied in order to enrich the embodiments within the two separate groupware applications. The result of this step is two functioning groupware applications with information-rich user embodiments.

1.5 Evaluation

The principle of rich user embodiment in groupware was evaluated through three separate user studies. The three studies in the evaluation were:

1. *Examine the potential and limitations of information-rich embodiment.* At the outset of this research, it was not known how many variables could be encoded on an embodiment and interpreted accurately by people. Therefore, a user study was performed in order to gather quantitative data to determine: the number of variables that can be recalled by people; how accurately the values of the variables can be determined; if people are able to find embodiments that match a set of criteria; and how embodiments are interpreted in a given scenario. Additionally, this study used two separate forms of embodiment (an avatar and a telepointer) to investigate whether there are differences between the two. The results of this study show that people consistently remembered more than thirteen of fifteen mappings of information on embodiments, and could determine the associated values of the variables with about 95% accuracy. The results collected in this study provide evidence for the potential and feasibility of information-rich embodiment.

2. *Assess the real-world performance of information-rich embodiment.* The first study revealed the potential for rich embodiment; however, the study was performed outside of an actual groupware system. In order to study the ability of rich embodiment to solve the problem of recognition and characterization in groupware, a longer term user study was performed. A multiplayer game prototype, which included overloaded user avatars, was used for this study. A group of participants played the game over eight weeks; qualitative data including observations, questionnaires, and interviews was collected. Analysis of the results shows that the recognition and characterization of groupware participants was improved by the rich embodiments.

3. *Test of information-rich embodiment in workplace groupware.* In order to further support the results of the second study, an additional groupware study was created in which the context and user embodiment were based on more traditional workplace tasks rather than games. A shared sketching application was developed that used telepointer embodiments. A usage study was performed in which groups of three participants collaborated on a series of sketches. Data was collected using observations, system logs, questionnaires, and interviews. The results of this study support the use of rich embodiment and show how overloaded user representations perform in a collaborative-work scenario.

1.6 Contributions

The primary contribution of this thesis is to provide empirical evidence that information-rich user embodiment is feasible, and that it succeeds in improving people's ability to recognize and characterize others. There are also several secondary contributions: this project resulted in the development of a framework that can be applied to create rich user embodiment in groupware; the instantiation of the framework to two example applications confirms that rich user embodiment is possible in groupware.

1.7 Thesis Outline

The thesis is arranged as follows:

Chapter 2 discusses background work that relates to this project. This includes a review of current embodiment techniques, groupware, information visualization, and social interaction in the real world.

Chapter 3 presents the theory of information-rich embodiment and the design methodology. The chapter also provides two examples of creating rich embodiment for separate embodiment types (an avatar and a telepointer).

Chapter 4 describes the methodology of the quantitative study performed to examine the feasibility of rich embodiment, and presents the results and analysis.

Chapter 5 gives the details of a study performed in order to examine the performance of rich embodiments in a multiplayer game.

Chapter 6 presents a study to further investigate the performance of embodiments in a more traditional groupware setting.

Chapter 7 provides an overall discussion of the results from all the studies and their implications for groupware designers. The chapter also includes design guidelines and lessons for practitioners based on the findings of this research.

Chapter 8 presents a summary of the research, the overall contributions of the thesis, and a set of topics for future work on information-rich embodiment.

Chapter 2

Review of Literature

Several areas of research have relevance to the development of information-rich user embodiment. This chapter reviews the main areas of study essential to this work: groupware, awareness, embodiment, social interaction, interaction histories, and information visualization.

2.1 Groupware

Groupware systems are applications that allow multiple distributed users to interact within a shared space. More formally, Ellis et al. [13] define groupware as "computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment." The authors propose that groupware interaction can be divided into a taxonomy based on time and space variables, as shown in Table 1.

Table 1. Taxonomy of Groupware Interaction

	Same Time	Different Times
Same Place	face-to-face interaction	asynchronous interaction
Different Places	synchronous distributed interaction	asynchronous distributed interaction

Face-to-face interaction is supported by applications such as electronic meeting rooms and single-display groupware systems (e.g. [38], [43]). Asynchronous interaction occurs in location-based systems: examples include GeoNotes [40] and digital bulletin boards [8]. Email, newsgroups, and document repositories all support asynchronous distributed interaction (e.g., [42],[53]). Finally, synchronous distributed interaction is supported with real-time distributed groupware application such as internet messaging, real-time multiplayer games, and shared workspaces. The proposed research in this project is concerned with synchronous distributed interaction.

2.1.1 Real-Time Distributed Groupware

Real-time distributed groupware is described by Greenberg and Marwood [19] as a system that allows multiple users in different geographic locations to collaborate at the same time in a virtual space. The aim of real-time distributed groupware is to allow for people to collaborate and interact without being in the same physical space; thus allowing collaboration anywhere at any time. There are several types of groupware applications that allow for different forms of real-time collaboration:

- Distributed whiteboards [18]
- Shared editors [12]
- Workspaces [24]
- Video conferencing [30]
- Chat systems [36]
- Multiplayer online games [35]

Interaction in a real-time groupware system is still not as natural as real-world collaboration. Various aspects of groupware have been studied in order to improve performance and usability:

- Architectures / Infrastructures: researchers have considered different architectures and how they affect performance and complexity (e.g., central and replicated) [21].
- Toolkits: several types of toolkits have been developed to simplify low level programming such as network connections and session management [15],[16].

- Interfaces: researches have created groupware interfaces and specific widgets for supporting groupware [28].
- Group and collaborative work: studies have been performed to improve the understanding of large groups working in the real world [26].
- Networks: research and development has been done on the basic protocols for supporting groupware [10].
- Group awareness: as discussed in Section 2.1.2, researchers have looked at different frameworks and devices to support awareness [23].

2.1.2 Awareness

More attention has been paid recently to the area of group awareness, and is of particular importance to this thesis work. Awareness in groupware refers to the current knowledge used to identify another person's actions in the shared space. Group awareness is concerned with the dynamic information of other users in a group and, as Dourish and Belotti [12] state, awareness of individual and group activities is essential in collaboration. Based on studies of collaborative writing and studies they performed with collaborative systems, the authors conclude that without awareness of individual activities group collaboration is hindered. The initial studies of Dourish and Belotti laid the foundation for further exploration into increasing awareness in groupware, including the detailed framework for groupspace awareness presented by Gutwin and Greenberg [23]. Their work suggests three main categories that make up workspace awareness in groupware: who, what, and where. The focus of this work is concerned with "who," and this includes awareness of presence, identity, and authorship.

Users are often represented within real-time groupware with a form of embodiment to increase awareness; however, although there have been changes in embodiments, they still lack the ability to appropriately reflect the user. There is a need to further increase identity awareness within groupware to allow participants to rapidly identify potential collaborators and make interaction more natural.

2.2 Embodiment

Users require some form of presence (a state showing that they are present) within real-time groupware applications in order to participate. User presence is commonly revealed through an embodiment or visual representation which acts as the virtual personification of a groupware participant, and helps to facilitate awareness of others. Embodiments have the added advantage of being a possible vehicle on which additional information can be revealed within the workspace.

Groupware embodiments can be organized into three categories: telepointers, avatars, and video overlays [2]; Gutwin [22] includes view rectangles as another form of embodiment. Gutwin and Greenberg [23] proposed an organization for the display of embodiments (see Table 2).

Table 2. Presentation and Placement of Awareness Display Techniques.[23]

		Placement	
		Situated	Separate
Presentation	Literal		
	Symbolic		

The matrix in Table 2 presents two dimensions: presentation and placement. Presentation refers to the manner in which information is represented and is broken down into *literal* and *symbolic* presentation. Literal presentation is that in which information is displayed in the same way it is obtained; for example, a telepointer's movement reflects the movement of a mouse. Symbolic presentation displays information from an input source in a more abstract fashion. An example of symbolic representation is an instant messenger (IM) client using a clock symbol to reflect that a user is away.

The placement dimension deals with how information is displayed, and is further divided into *situated* and *separate* placement. Situated placement of information appears in the workspace or environment, whereas separate placement situates information outside of the main workspace. For example, contact lists in an IM client normally appear outside of the chat area (separate), whereas video game avatars appear within the game panel (situated).

2.2.1 Literal and Situated Embodiment

In this section we discuss examples of literal and situated embodiments; that is, embodiments that occur in the workspace that mimic the input information in some way.

2.2.1.1 Video

Video is a high fidelity method of embodiment capable of literal user representation in real time. As Benford et al. explain [2], video in groupware reflects presence, location, identity, activity, gesture, and facial expression nearly identically to the real world.

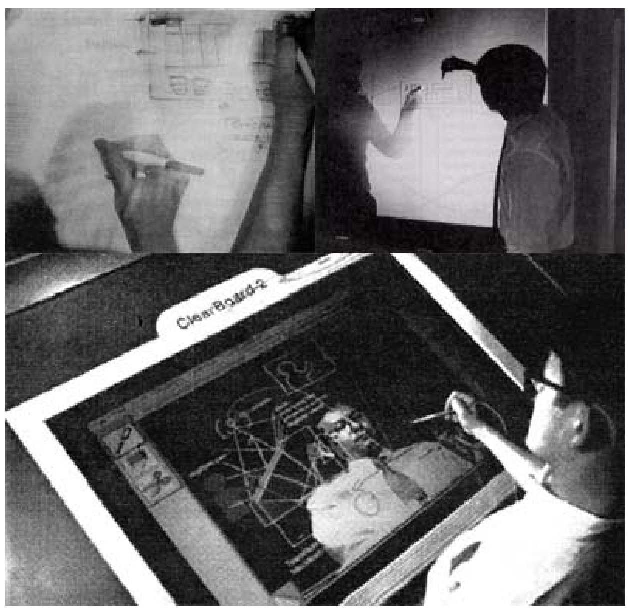


Figure 1. Video Embodiments. Top-Left: Video hands in VideoDraw [45]. Top-Right: Shadows and local user in VideoWhiteboard [46]. Bottom: Clearboard local and remote users [29].

Video can be applied to groupware in different ways, such as: shadows, arms, and upper bodies (see Figure 1). Although these systems help solve several issues of collaboration, shadows and arms only reveal a limited degree of identity and there are difficulties in creating collaborative systems involving more than two participants with upper body video [22]. Additionally, video or 3D embodiment is not always logically applicable to groupware systems; for example the functionality of a user's cursor is lost if it is replaced by a video window.

2.2.1.2 Avatars

Avatars are typically designed with a humanoid or animal-like appearance to represent a user in a virtual world (see Figure 2). Although some systems have the ability to customize an avatar's body, face, and clothing, the embodiment is normally abstract making identity difficult to determine [44]. More specifically, avatars can be considered icons that are abstractions of the person in the real world. Therefore, a nametag is usually displayed along with the avatar to make identification easier. This type of embodiment is commonly seen in video games and multi-user environments [2],[5].

Figure 2. Avatars. Left: Humanoid avatars in the Bad Dudes videogame (Data East Corp.). Right: Animal-like avatar from the Crash Bandicoot videogame (www.naughtydog.com).

Video games have often used avatars to express additional information other than presence, location, and movement. It is common in many popular massively multiplayer online games for information elements (e.g., character race and gender) to be shown visually (see example in Figure 3). Additionally, clothing and other items (e.g., amour or weapons) are placed on an avatar to represent variables such as achieved experience, character advantages or power-ups, or current action. For example an avatar wearing a particular outfit in *Final Fantasy XI* can reveal the players experience level.

Figure 3. Examples of character, race, and gender in World of Warcraft (www.blizzard.com). Left: Male and female human avatars, Right: Male and female gnome avatars

Figure 4. Avatar creator in the City of Heroes videogame (www.crypticstudios.com).

Customization of avatars is also popular in many online games. The advantage of allowing customization is that each player can give their avatar a unique look which can help in recognition; however these visual effects normally express no additional information. For instance, *City of Heroes* includes the most extensive avatar creator seen too date (see Figure 4). A player begins by selecting their gender and basic body type. Following this, an extensive amount of physical features and costume elements can be selected and modified. Some costume elements in this game do reflect experience level; for example, at level 20 a cape slot is unlocked and at level 30 aura effects can be applied. Although more detailed forms of avatars exist in many groupware games, the affects of the visualizations at improving recognition and characterization has not been studied.

2.2.1.3 Vehicles

Vehicular embodiments are similar to avatars; however the embodiment appears as a mechanical or motorized structure such as a car, boat, or ship (see Figure 5). It is more difficult to recreate a user's identity with a vehicle, since it is considered a non-living form of embodiment. For example, mood is easier to express with a face in a humanoid avatar when compared to an automobile embodiment.

Figure 5. Vehicles. Left: Spaceship embodiment in the Spacewar videogame. Right: Automobile embodiment in Gran Turismo 3 (www.polyphony.co.jp).

2.2.1.4 Abstract Representation

Additional methods of literal and situated embodiment exist, the most common being that of telepointers and viewports. Telepointers are similar to mouse cursors found in the common graphical desktop; they have the ability to reflect presence, and activity. The existence of a telepointer in a collaborative space suggests that there is a user behind the embodiment, and the movement of the telepointer can reveal what actions the user is taking. However, no identity or character traits are revealed from simple telepointers (see Figure 6).

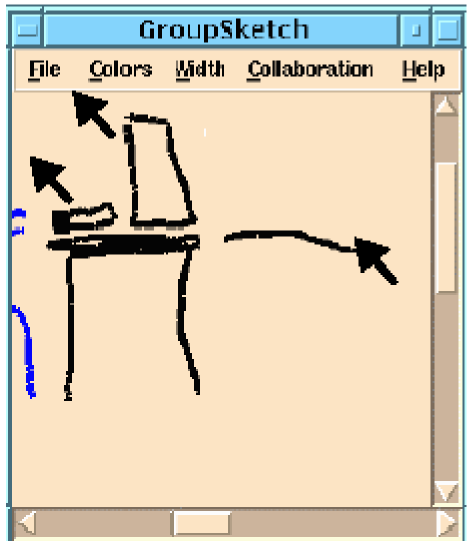


Figure 6. Telepointers in GroupSketch [20].

Viewports are normally drawn on a workspace as a rectangle that represents a participant's current view area. A viewport can be coloured or tagged in order to reflect who the view rectangle belongs too. Other then ownership, no other identity information has been revealed through viewports.

2.2.2 Literal and Separate Embodiment

A literal and separate embodiment reflects the user's movement directly; however it is separate from the main workspace. Examples of literal and separate embodiment include: radar views, external video-conference windows, or other secondary displays.

2.2.2.1 Radar Views

Participants are embodied separately from the main workspace in a radar view. Radar views are commonly applied in videogames and shared workspace systems where players or collaborators are embodied as small elements in a radar to help locate their position (see Figure 7).

Figure 7. Radar (bottom right) providing location awareness in the videogame Delta Force: Black Hawk Down (www.novalogic.com).

Simple embodiment in a radar reveals little identity information. However, Gutwin [22] proposes attaching identity information, such as a nametag or image, to radars to help participants recognize others within the radar space (see Figure 8).

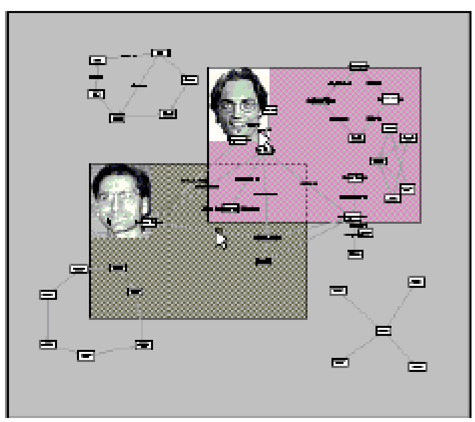


Figure 8. Enhanced radar to reveal identity and a participant's workspace view [22].

2.2.3 Symbolic and Situated Embodiment

In this section we discuss embodiment that occurs within a collaborative workspace, but where the information representation is a symbolic representation of the actual source. The two applications described are semantic telepointers and the Chat Circles systems.

2.2.3.1 Semantic Telepointers

Semantic telepointers attempt to increase the awareness information that can be revealed through telepointers. Greenberg et al. [20] enhance awareness by applying additional glyphs to the cursor in order to reveal user action such as mouse clicks and menu selection. As mentioned in Section 2.2.1.4, traditional telepointers reveal little to no identity information. However, Gutwin [22] suggests that colour, nametags, images, or icons can be applied to increase identity awareness (see Figure 9).

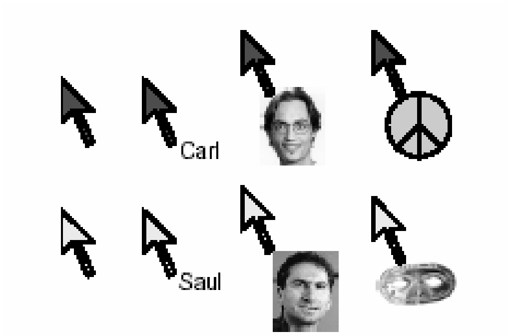


Figure 9. Methods for revealing identity in telepointers: colour, nametag, image, and icon [22].

2.2.3.2 Chat Circles

Chat circles were developed to create chat systems that encourage engaged conversation through awareness [11]. In the initial chat circles implementation, user embodiment takes the form of a coloured circle, and a nametag is attached to reveal identity. As a user types, their circle grows and shrinks in order to display the typed messages in the centre of the embodiment (see Figure 10).

In a later implementation called Chatscape, users are embodied with coloured icons (basic shapes) and associated nametags. Although the nametags reveal identity, the shape and colour are continuously modified during interaction and thus serve little purpose in identifying others, but reflect mood and action.

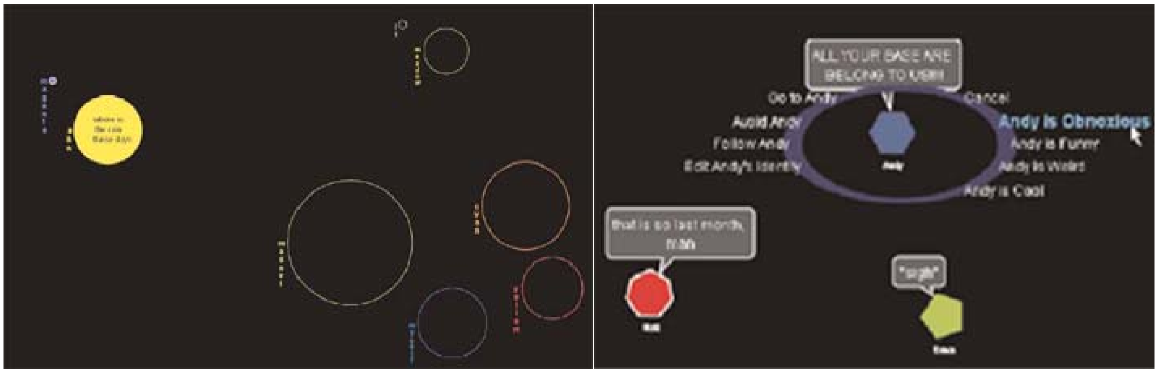


Figure 10. Chat Circles. Left: Embodiment in the original Chat Circles. Right: Embodiment in Chatscape [11].

2.2.4 Symbolic and Separate Embodiment

Symbolic and separate embodiment occurs outside of the workspace, where information is represented abstractly from the input source. Here we describe Babble, PeopleGarden, and Instant Messengers as examples of symbolic separate embodiment.

2.2.4.1 Babble

Erickson et al. [14] created the Babble system in order to increase awareness of the current activity within a chat system. User embodiment within Babble takes the form of coloured circles in the “commons area” of the interface. Participants are identified by the colour of their dot which is mapped to their name in the top-left corner of the display (see Figure 11).

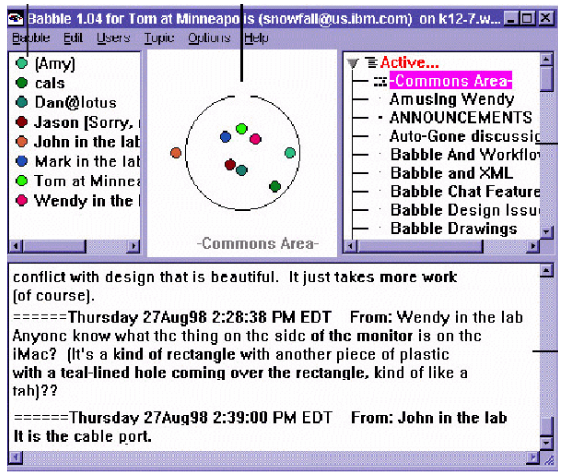


Figure 11. The interface of the "Babble" system [14].

Embodiment position within the commons area reflects the level of activity of a user. The more active a user currently is in the chat system, the closer their embodiment will move to the centre. Alternatively, the embodiment of a less active user appears closer to the edge of the commons, and once a user leaves the chat their embodiment moves outside of the commons area circle.

2.2.4.2 PeopleGarden

The PeopleGarden project [56] applies data portraits of users in order to help with the difficulty of distinguishing users and interaction levels within chat systems. The authors of PeopleGarden use the unique embodiment of a flower, displayed outside of the chat system, to reveal user participation levels, and posts and replies made over time. This embodiment reflects the type of user a person is (e.g. heavy or light contributor) and the overall makeup of the message board users (e.g. a single dominating user or a democratic posting distribution) can be seen from the PeopleGarden (see Section 2.3). The PeopleGarden embodiment is a good example of character representation; however the embodiment is entirely separate from the workspace.

2.2.4.3 Instant Messengers

Instant Messengers (IMs) are a popular form of communication between acquaintances. User embodiment in these groupware systems can be found in contact or "buddy" lists. Participants in the list are normally represented with their name, and popularly include an icon representation (e.g. MSN). This icon embodiment typically reveals the user's status or basic action; for example, a participant could be online, away, busy, or offline (see Figure 12).

Figure 12. MSN Messenger Embodiment. User status represented from left to right: online, away, busy, and offline.

In all the example embodiments discussed in Section 2.2, regardless of presentation and placement, a limited amount of identity information is available. In those situations where identification is possible, it is normally limited to simply recognizing who the person behind the embodiment is or their activity level. Therefore, these current embodiments fail to reflect context-specific characteristics of a user that would be relevant for collaboration and interaction, such as a person's skill set and level of experience (although PeopleGarden and Babble do reflect participation levels).

2.3 Interaction Histories

One source of awareness information in groupware is past activity. In order to increase user information awareness in groupware, it will often be necessary to reveal past activity. For example, past activity in an application would be necessary to qualify someone as an expert user. Therefore, a better understanding of research into interaction histories is required. Gutwin and Greenberg [23] propose five categories of history awareness information: what happened, how it happened, when it happened, who did the action, and where it occurred.

Hill et al. [27] were one of the first to propose using visual elements to reflect past activity of people in documents. They employ the real-world metaphor of physical wear that will occur with items that are used frequently. For example, a page that is referenced often in a telephone directly will become dog-eared and worn. Thus, the authors use coloured marks on a document scroll bar to reflect the amount of reading and writing that has occurred on the lines of text.

Gutwin [24] proposes the use of traces to reflect immediate interaction history for telepointers. The traces techniques use a temporary visualization to show the trail of a cursor's past positions (see Figure 13). This approach helps in situations involving network jitter, and emphasizes cursor gesturing.

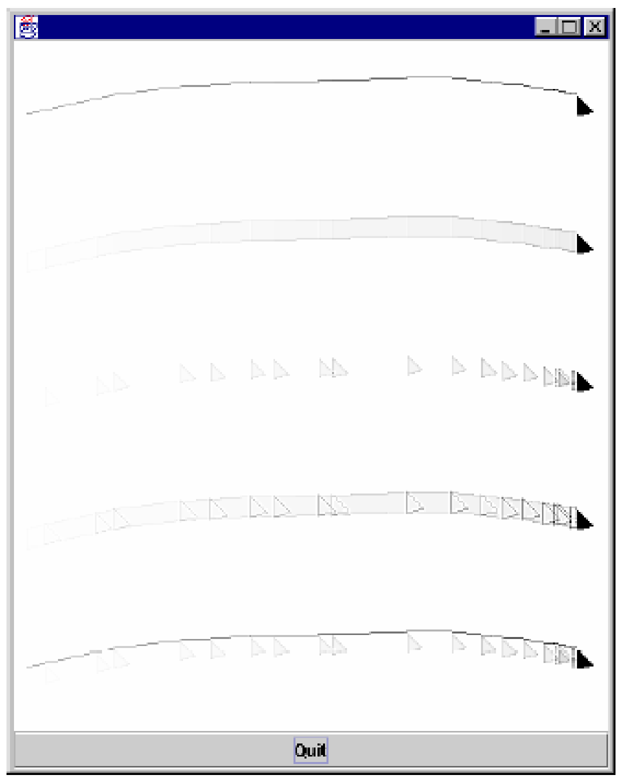


Figure 13. Example telepointer traces [24].

As Xiong and Donath [56] state, there is relatively little work on visualizing a person's past activity in groupware. Their PeopleGarden program visualizes the past activity (i.e., posts and replies) of a chat system user with a graphical flower embodiment. A flower's height represents the amount of time a user visits the message board, and the number of flower petals and their colour reflect the amount of posts and replies on the board. Looking at the flower representations of all the users gives an overall impression of the user activity on the chat system, as shown in Figure 14.

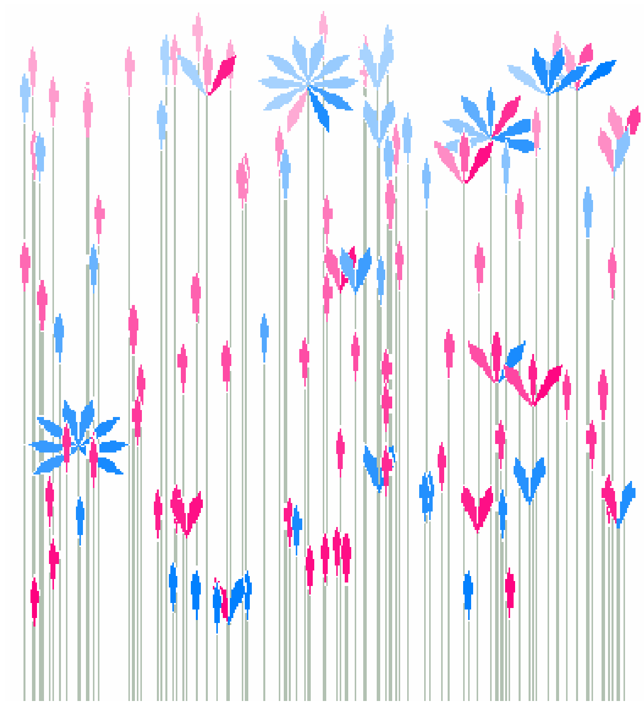


Figure 14. An example PeopleGarden of several chat users [56].

The Chat Circles [11] system, described in Section 2.2.3.2, has a separate panel where the chat history for each user is shown as a time line with specific markings of where the user typed a message. Similarly, the anthropomorphic visualization presented by Perry and Donath [39] attempts to reveal historical data about an individual. They apply visual techniques to a humanoid embodiment (anthropomorph) to reveal a users activity in a Usenet chat server. By adjusting features such as facial elements, colour, raised and lowered arms, and leg separation space, the authors are able to reveal multiple information variables of a user. For instance the average message tone, amount of messages written, and number of initial posts and responses can be interpreted from the embodiment. Some example anthropomorphs are shown in Figure 15.

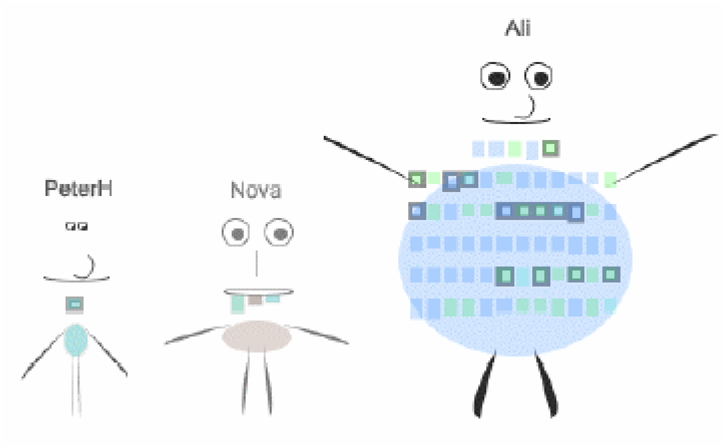


Figure 15. "Anthropomorphs" created from Usenet data [39].

The PeopleGarden, the Chat Circles timeline, and the anthropomorphic visualization systems reveal interaction history separate from the main application window (i.e. the chat area) and embodiment; however, they provide different forms of interaction history information.

The FatBoy modification for Unreal Tournament is another example of visualizing past activity. The modification causes a player's avatar to grow with each kill (see Figure 16), and shrink after each regeneration [51]. This visual cue allows players to distinguish expert players from novices.

Figure 16. Screenshot of the FatBoy modification in the Unreal Tournament videogame (www.epicgames.com).

The FatBoy modification is one of the few examples where situated embodiment is used to express a form of interaction history. All other examples require separate space, outside of the embodiment or workspace, to reveal the awareness information. The FatBoy example shows that rich embodiment can allow for past information to be revealed directly on the user representation itself, making identification of past activities more rapid.

2.4 Social Interaction

There are numerous sources of information, other than verbal communication, which humans apply in social interactions. Manninen and Kujanpää [35] suggest nine main categories of nonverbal communication. Although all of these nonverbal aspects help to reveal contextual information and personality traits in the real world, there is much debate on how to reflect them in collaborative virtual environments. The idea of information-rich user embodiments is to map user traits to their virtual representation, thus the focus will be on nonverbal communication through appearance.

As Gerhard et al. [17] suggest, humans use their physical appearance to express themselves. Therefore social status, occupation, personality and mood can be interpreted from a person's appearance. The authors also propose that appearance can be used to reflect attitudes towards others, such as rebelliousness or formality. Argyle [1] extends this idea and suggests that physical appearance is often used to display a variety of aspects including: membership of groups, membership of social classes, and occupational roles. His work reveals that a series of character traits are all expressed and perceived via clothing, bodily physique, and accessories. Thus, if humans have the capability to interpret character traits of others simply with visual cues, it appears feasible to apply the similar principles to the appearance of users within a groupware space. A better approach to applying visual cues to embodiment is possible by understanding the way in which humans interpret these nonverbal cues.

2.5 Information Visualization

The field of information visualization covers a very broad range of topics. In this research we are concerned with three main areas of interest: multivariable information visualization, glyph visualization, and human cognitive capacities.

2.5.1 Multivariable Information Visualization

In order to create rich user embodiments, several pieces of information need to be reflected by the virtual representation of a user. Therefore, previous work into multivariable information representation must be explored.

The works of Bertin [3] and Tufte [47] explore techniques for successful visual representations of information, including multiple variables. Their work examines the application of colour, textures, size, shape, and other visual approaches in order to reveal information. Tufte's formulation of "data density" examines the amount of information relative to the visual area. He proposes the following formula to measure data density:

Data density = number of entries in a data matrix / area of the data graphic

Although Tufte does not present a key data density ratio to achieve, his work discusses the amount of information that can be represented in a given area. This research may prove useful when attempting to overload small embodiments such as telepointers.

2.5.2 Glyph Visualization

When representing multiple variables of information on a single object, the object is typically referred to as a glyph. Therefore, by using a graphical embodiment as an object onto which several variables are encoded, the embodiment itself can be considered a glyph. According to Wickens [54], the advantage of mapping several data dimensions onto a single glyph ensures that these variables will be processed more rapidly than if they were placed on several separate objects. Ward [50] proposes that data can be represented graphically using a geometric attribute of the glyph (such as size, shape, and orientation), or an appearance attribute (such as colour, texture, or transparency). In order for users to be able to discriminate between multiple data points, careful mapping based on the type of data is important. Although the mapping of information to a graphical representation is still somewhat of an add-hoc process, some guidelines do exist (e.g., [9][34]). Mackinlay [34] presents a set of rules that orders (from best to worst) graphical effects based on data type (see Table 3). The data types used are scalar (data in which ordering and arithmetic are possible), ordinal (the data can be ordered based on ranking), and nominal (categorical data that can only be compared for equality). The rules put forward by Mackinlay are based on psychophysical results; however they have not been empirically verified. Additionally, Nowell et al. [37] have recently proposed that the visualization used (colour, shape, or size) is less dependent on the type of data it represents and is influenced more by the type of task performed by the user.

Table 3. Order of graphical effects (from best to worst) for data types [34].

Scalar	**Ordinal**	**Nominal**
Position	Position	Position
Size	Colour	Colour
Orientation	Size	Shape
Colour	Orientation	Size
Shape	Shape	Orientation

There have been several different types of glyphs used to display multivariate information. Some of the familiar objects that have been used as glyphs are: bugs [7], trees [31], and human faces [6]. The faces proposed by Chernoff [6] are one of the earliest proposed glyph representations to display multiple variables of statistical data. Based on human perceptual abilities to recognize a wide range of facial expressions, Chernoff encoded eighteen attributes of geological data onto facial features. The result was the ability to perceive patterns in the data, and enhanced the exploration of the data. However, there are limitations to glyph-based visualizations such as the Chernoff faces: the difficulty in separating individual facial features to extract the variable values; prominent features may not reflect the important relationships in the data; and groupings of the facial representations may be subjective and inconsistent.

Abstract objects have also been used as glyphs for multivariate visualization. Hartigan [25] used boxes in which variations in height, depth, and width represents scalar values. The use of arrows for encoding uncertainty variables in flow visualization was proposed by Wittenbrink [55]. The direction, length, width, taper, and colour of an arrow is used to show uncertainty in vector fields. Chuah [7] used wheels for encoding several variables over a period of time. In all of these examples, the glyphs are limited by people's abilities to separate the various dimensions, as well as the context in which the glyphs are applied.

The exploration of glyph-based visualizations as a means of expressing multiple categories of information provides strong motivation for the idea of rich embodiment. The previous findings in glyph visualization and multivariate information visualization are applied in the design and creation of information-rich embodiment.

2.5.3 Aspects of Perceptual Memory

The area of cognitive psychology examines perception, understanding, and thought [41]. This branch of psychology covers a broad range of topics including: sensation, pattern recognition, memory, and neuroscience. One subject of particular interest to this project is how much information humans can perceive at a quick glance.

The principle of what is experienced at a brief moment in time is referred to as "perceptual span" [41]. The amount of information collected, and the amount of time the data is stored in memory, has been studied for over a century by philosophers and psychologists alike. Since this project deals with encoding information within a 2D space, we are most interested in how easily visuals can be perceived and recognized in the perceptual span.

Research done by Luck and Vogel [33] provides insight into the number of features that can be retained in working memory. Through experimentation, the authors discovered that four features of an object can be recalled for a limited set of objects. The experiment consisted of displaying a series of simple objects containing graphical features, and then removing them from the screen. Objects were then presented once again, and the participant of the study had to determine if any of the objects had changed. The results show that humans can almost always recall all features when only two objects are displayed; of course the performance decreases as the number of objects in the set increases.

Wheeler et al. [52] extend the work done by Luck and Vogel by performing similar experiments, including the examination of binding between features (where more then one feature needs to be recalled). The work suggests that there are separate memory stores for features and the binding between them. Thus several features may be bound together for a single object.

There is clearly a limitation on the amount of visual data humans can interpret at a glance. Thus, if the goal is to reveal relevant data with visual embodiment, care must be taken in determining the amount of information variables that are possible and how they are encoded through the embodiment.

Chapter 3

Information-Rich Embodiment

Embodiments in groupware commonly act as a placeholder for the users. Typically embodiments reveal basic awareness information such as presence, location, and movement. In this section, the idea of using embodiment as a platform for revealing more information is presented. Additionally, the approach and methodology to creating such a graphic is discussed and two examples are presented.

3.1 Information-Rich Embodiment

The idea of expressing information using embodiment has been seen previously in other groupware research. For example, the semantic telepointers – presented by Greenberg and Gutwin [20] – show the use of graphical cues on telepointers to reveal user actions such as mouse clicks and menu selections. Vaghi et al. [48] presented the idea of displaying information about network delay above the avatars in a collaborative virtual environment. However, even in these examples only a few pieces of information are given, and the variables do not necessarily help in recognition and characterization of other groupware users.

Information-rich embodiments are visual user representations that display several additional variables (other than presence, location, and movement) in the graphical space of the embodiment. The idea is to express as many practical pieces of information as possible using groupware embodiments. In order to represent multiple dimensions of information about a person, rich embodiments use visual effects such as size, shape, transparency, colour, orientation or texture. These effects can be applied to the figure of the embodiment itself by subdividing the figure into regions, or by adding secondary glyphs around the figure (see examples in Figure 18 and Figure 19).

These visual effects can be applied in order to display several types of information that are useful for a cooperative task situation:

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

Once a set of input variables are chosen, they must be mapped to graphical output visualizations. The following sections describe the method in which information-rich embodiments are created. In Section 3.1.1 the method of variable selection is discussed and Section 3.1.2 describes the approach in mapping the selected variables to a visual form. In Section 3.2, two example embodiments are used to illustrate the process of creating information-rich embodiment: an avatar for a multiplayer game, and a telepointer from a shared photo-editing application. The goal in building these rich embodiments was to see how far the idea could be taken. That is, to add as many variables that were deemed to be potentially useful and still be reasonably displayed on an embodiment. Fifteen variables are included on each user embodiment – far more than has been shown in current groupware systems. The example embodiments discussed were used for the study presented in Chapter 4. Finally, Section 3.3 discusses the implementation details of building rich embodiment in software. The two examples presented are taken from the applications developed for the studies discussed in Chapter 5 and Chapter 6.

3.1.1 Information Variables

There are a few examples of augmented embodiments that can be seen in multi-player games and previous groupware research [5], [20]. However, no guidelines exist to help determine what information to encode in rich embodiment. As mentioned above, there are several types of variables that could be used. Therefore, when creating richer forms of user embodiment, the chosen variables should be selected based on their importance in the groupware domain to which they are applied. Additionally, since the goal of rich embodiment is to allow for better characterization and recognition of other people, the information variables should help to better personify the person behind the representation. As Gutwin and Greenberg [23] suggest in their framework for workspace awareness, identity is a core aspect of group awareness. Similarly, the work of Xiong and Donath [56] illustrates the importance of a user's past and present activity in helping others to better understand the person behind their visual representation. From these findings, there appears to be two main categories of variables that will improve recognition and characterization: identity-specific and context-specific. These variable types are discussed below.

3.1.1.1 Identity-Specific Variables

Since the variables chosen to be encoded on an embodiment should help interaction in shared workspaces, the variables that are known to be used in real-world interaction can be used as a source of inspiration. Gerhard et al. [17] propose that humans use their physical appearance to express details about themselves such as social status, occupation, personality and mood. Argyle [1] further suggests that the physical appearance of a person in the real world displays a wide variety of attributes such as membership in groups, social class, and occupational role. Thus, by including variables like these in groupware embodiment the resulting effect should allow for better recognition of other collaborators.

If appropriate to the environment of the groupware system, real-world personal variables can be chosen for an embodiment such as: name, age, gender, occupation, location of residence. As has been suggested in previous research [49], users are curious about the people they interact with in groupware. Therefore, groupware designers should consider providing personal information variables about each user in order to improve the naturalness and richness of interaction.

3.1.1.2 Context-Specific Variables

Information related to the actual groupware system in which an embodiment appears should also be considered. For example, variables such as the particular tool a user has selected, or the amount of experience a user has with the application may be helpful in characterizing people. In order to determine what variables may be effective in increasing awareness, designers of rich embodiment should consider all possible tools, functions, or actions that can occur within the group task.

In addition to showing current actions or user states, it may be useful to display variables related to overall experience. Therefore, groupware designers must determine what variables are important (over time) and how to calculate usage or experience measurements. This could include a simple measurement, such as the time spent in the application, or something more complex such as the ratio in which a combination of actions occur.

Overall, when selecting the potential variables to encode in an information-rich embodiment, it is important to consider all aspects of the groupware system itself. Since each groupware system will have unique tasks or interaction models, some pieces of information will be more important in different contexts. For instance, a person's real-life occupation is probably irrelevant in a videogame context, but could be considered useful in a collaborative programming environment.

3.1.2 Mapping Variables to Visual Representations

The graphical representation of data has been examined extensively in the field of information visualization. More commonly, the types of visualization examined are of plotting information in a graph or map. However, Wickens [54] states that several dimensions of information are processed more quickly when they are encoded onto a single object. In this research, the idea is to present information variables on a graphical embodiment, which can be considered an icon or glyph. There have been some examples of multivariate glyph visualizations such as human faces [6], bugs [7], or trees [31];

however, the literature offers no guidelines on how to map variables to glyphs or single objects.

Once all of the information variables to be encoded have been chosen, the rules of Bertin [3] and Mackinlay [34] provide insight on how to graphically encode the information. Mackinlay proposes that the effectiveness of visualization is based on the type of variable (i.e., scalar, ordinal, and nominal) and the appropriateness of the corresponding visual representations (see Table 3). For example, certain visual effects are more suitable for certain variable types (e.g., hue is more effective for nominal than scalar variables) [34]. Moreover, when attempting to display multiple variables, the designer should not include visualizations that will obstruct or alter other graphical representations being applied.

The mapping of variables to a visual representation on an embodiment does require some discretion from the designer. Unfortunately, the mapping of information is not an exact science and the effectiveness of the chosen visualizations will be dependent on many factors such as the type of embodiment or the context in which it will appear. This is supported by the findings of Nowell et al. [37] who suggest that the effectiveness of a particular set of mappings is strongly dependent on the nature of the task in which the information will be used. Therefore, I suggest that once all of the variables have been mapped, the designer should consider pilot testing of the rich embodiments to see if they successfully encode all of the data, and to determine if there are situations where the information will be obstructed.

Taking into account the particular groupware task can make it easier to develop better visualizations for embodiments. Consideration of the embodiment type in a particular context can make some visualisations easier to remember and interpret. For example, a vehicle embodiment in a game scenario could show a damage score by the appearance of blemishes on the main body of the avatar; or a clicking action with a telepointer can be reflected with a visual cue at the tip of the cursor.

Additionally, taking advantage of visualizations that map logically to a graphical representation will make interpretation more natural. For example, variables such as name or age, that are most commonly reflected in text, can be written out on or around an embodiment. Moreover, information that is visual in nature (e.g., colour, width, height, shape, size) can be mapped easily to a similar graphical effect. For instance, in a shared whiteboard application, the current colour a user has selected could be coloured directly on their cursor.

Finally, the results of the studies in Chapter 5 and Chapter 6 show that it is feasible to create visualizations that are easier to interpret by applying logical mappings where possible and pilot testing the embodiments. 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.

3.2 Examples

This section presents two examples of rich embodiment for different types of groupware systems. The context of the applications are different as well as their embodiment type. The first example uses an avatar in the context of a multiplayer videogame, and the second uses an avatar for a shared image editing system. Both of the rich embodiments presented here were used in the first study of this research (see Chapter 4).

3.2.1 Rich Avatars

The first example embodiment presented here is an avatar for a multiplayer game. The construction of the avatar is broken down by the context in which it appears, the chosen information variables, and the mapping of the variables to graphical encodings.

Context: The context for the avatar is taken from the classic multiplayer videogame Spacewar [4]. The concept of the game is simple: two players control their ships around a gravity-well and fire at each other in an attempt to destroy their opponent’s ship. It should be noted that in this example a hypothetical version of Spacewar is considered and would include multiple game features not found in the original version.

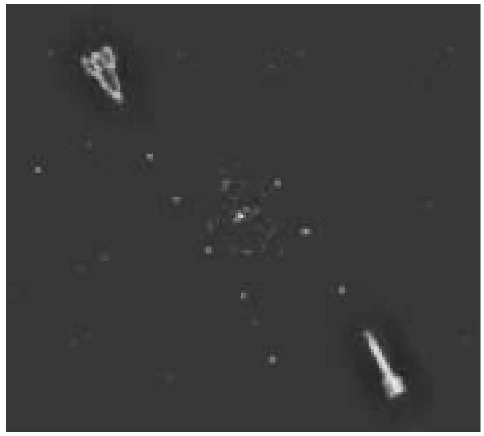


Figure 17. The original Spacewar game.

The user embodiment in the original Spacewar game is a spaceship avatar (see Figure 17). The simple 2D triangular shape of the ship is used as the base avatar upon which graphical elements are encoded to represent the chosen information variables.

Information Variables: Since the players in a groupware version of Spacewar may not be familiar with each other, three main identity variables are chosen to better help with recognition. A user specified name, and a person's gender and age are selected as information that would allow for participants to better understand who their collaborators are.

In terms of context-specific variables, a large set of data is chosen in order to gain a better understanding of the amount and type of information that can be encoded onto an avatar. Therefore, activity variables (thrust, engine heat, gun heat), player variables (experience, role, team, death score, kill score), and state variables (shield strength, damage, communication, lifetime) are selected.

Although the actual context for this example is hypothetical, it is anticipated that the variables chosen here would be considered helpful in the recognition and characterization of other players in the game. An actual groupware avatar and telepointer are studied in Chapter 5 and Chapter 6.

Mappings: The mapping of the selected information variables to graphical effects on the ship avatar are based on the guidelines described in Section 3.1. The mappings take advantage of the real-world metaphor of the spaceship embodiment (see Figure 18). For example, thrust is shown via the presence of a flame at the rear of the ship, or the heat of the gun is encoded with colour on the location of the gun on the avatar. For a breakdown of each variable and the corresponding visualization used, see Table 4.

Table 4. Variables and visualizations for the Spacewar avatar.

Variable	Variable Type	Visualization	Visualization Type
Age	Scalar	Numerical string	Text
Name	Nominal	Text string	Text
Gender	Nominal	Star colour	Hue
Communication	Scalar	Coloured waves	Shape (additional glyph)
Thrust	Scalar	Flames	Shape (additional glyph)
Damage	Ordinal	Transparency	Saturation
Team	Nominal	Ship colour	Hue
Shield strength	Scalar	Border thickness	Size (length)
Role	Nominal	Icon	Shape (additional glyph)
Death score	Scalar	Red bar	Length
Kill score	Scalar	Green bar	Length
Engine heat	Ordinal	Engine colour	Hue
Gun heat	Ordinal	Nose colour	Hue
Lifetime	Ordinal	Size	Size (length)
Experience	Scalar	Ship “spikes”	Shape

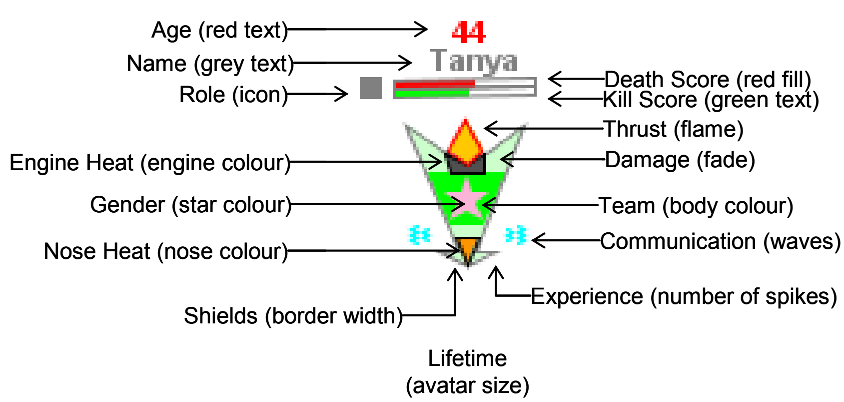


Figure 18. Example avatar created for Spacewar.

3.2.2 Rich Telepointers

A telepointer is chosen for the second example of designing rich embodiment. A telepointer is a remote cursor, and is commonly found in many groupware research applications and collaborative work environments. The context, chosen variables, and visual mappings of the enriched telepointer are presented below.

Context: The chosen context for the telepointer is a hypothetical groupware version of an image editing application similar to Photoshop. In this context, we can imagine that the system would share all the same functionality of Photoshop (such as layering, editing tools, image effects) with the added feature of allowing multiple distributed users to edit the image collaboratively.

The embodiment included in this context is a traditional 2D telepointer that is found in most desktop applications. A telepointer is usually smaller in size than an avatar; however, the goal here is to determine if a cursor can also include a large set of information variables.

Information Variables: Similar to the Spacewar example, real-world identity characteristics are chosen for the telepointer in order to allow participants to better tell each other apart. The identity specific variables used for this example are age, gender, geographical location (city), and name.

There are an extremely large number of states, tools, and actions that are possible in Photoshop. Therefore, for this example the chosen context-specific information variables are limited to only a small set. The variables that are chosen relate to system information (idle time, ping time), state variables (layer, communication, session time), user information (experience, expertise, reputation), and activity (mouse click, foreground colour, background colour).

Once again the chosen context for this example is hypothetical; however, the variables are chosen based on their potential to increase characterization and recognition of users. A similar avatar is created for a share sketching system and studied in Chapter 6.

Mappings: The telepointer visualizations of the chosen information variables follow the guidelines presented in Section 3.1. Once again, discretion is used in order to make the mappings intuitive and understandable (see example telepointer in Figure 19). Although the telepointer is smaller than the avatar, several variables are encoded on the embodiment itself. A summary of the variables and the chosen visualizations are listed in Table 5.

Table 5. Variables and visualizations for the Grouper telepointer

Variable	Variable Type	Visualization	Visualization Type
Age	Scalar	Numerical string	Text
Name	Nominal	Blue string	Text
Gender	Nominal	Star colour	Hue
Communication	Scalar	Coloured waves	Shape (additional glyph)
Mouse click	Scalar	Circle at cursor tip	Shape (additional glyph)
Idle time	Ordinal	Transparency	Saturation
City	Nominal	Cursor Colour	Hue
Ping time	Ordinal	Border thickness	Length
Foreground colour	Nominal	Tip colour	Hue
Background colour	Nominal	Tail colour	Hue
Session time	Ordinal	Size	Length
Layer	Nominal	Black string	Text
Experience	Scalar	Cursor "spikes"	Shape
Expertise	Nominal	Icon	Shape (additional glyph)
Reputation	Scalar	Green bar	Length

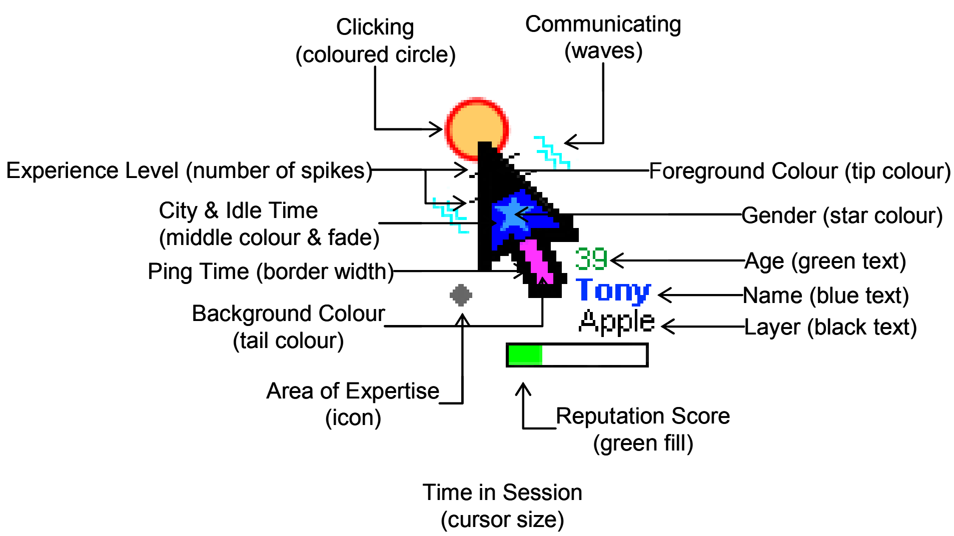


Figure 19. Example telepointer for the shared photo editing system

3.3 Implementation Details

The information-rich embodiments implemented for this research (used for the systems discussed in Chapter 5 and Chapter 6) were built in Java, using the Graphics and Graphics2D classes that are part of the Abstract Windowing Toolkit (AWT). Due to the object-oriented nature of Java, a separate embodiment class was created for the embodiments in their respective applications. Thus, a Ship class and a Telepointer class were built to handle the creation, drawing, and various event handling for the embodiments. Figure 20 shows the class structure of the Telepointer embodiment, including the Tool Icon class (note that not all the variables and functions are listed). The tool icon class is used to handle the drawing of a separate glyph beside the telepointer which reflects what tool a user has selected. Figure 21 is the class diagram of the Ship embodiment class (which inherits from the class Drawable). The Player class does not have a draw function; however, variables from this class are mapped to visualizations on the ship embodiment.

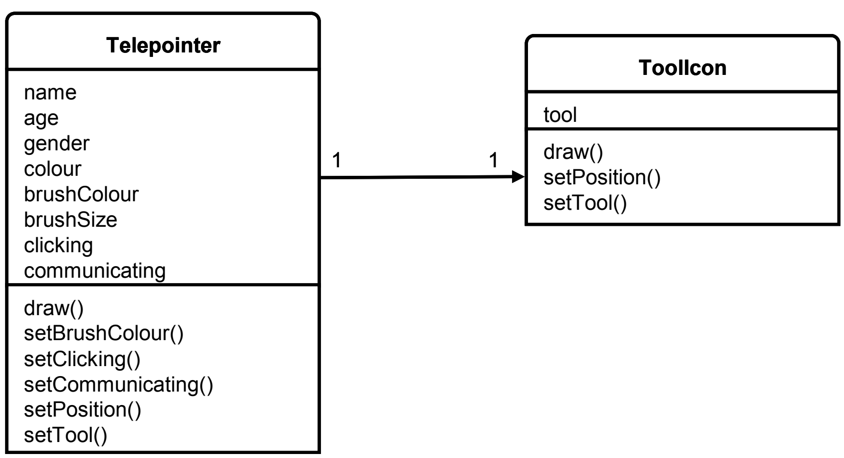


Figure 20. Class diagram of the Telepointer class used in the Grouper application

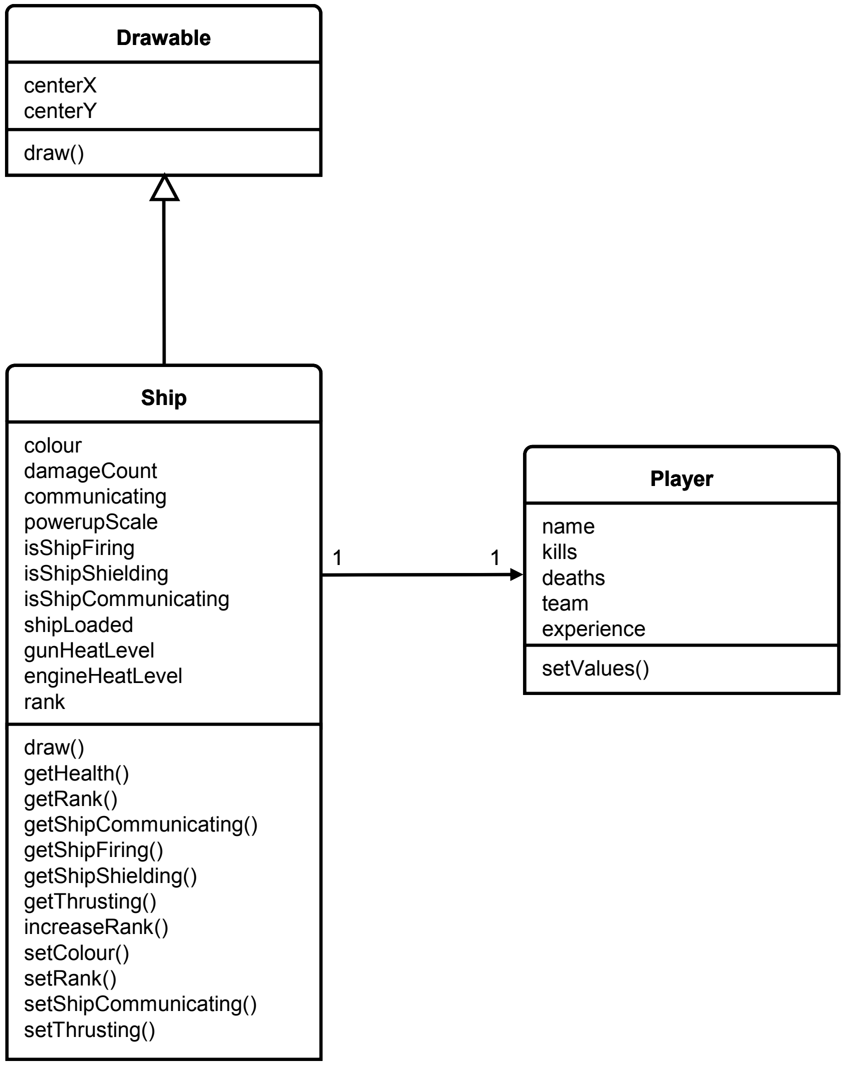
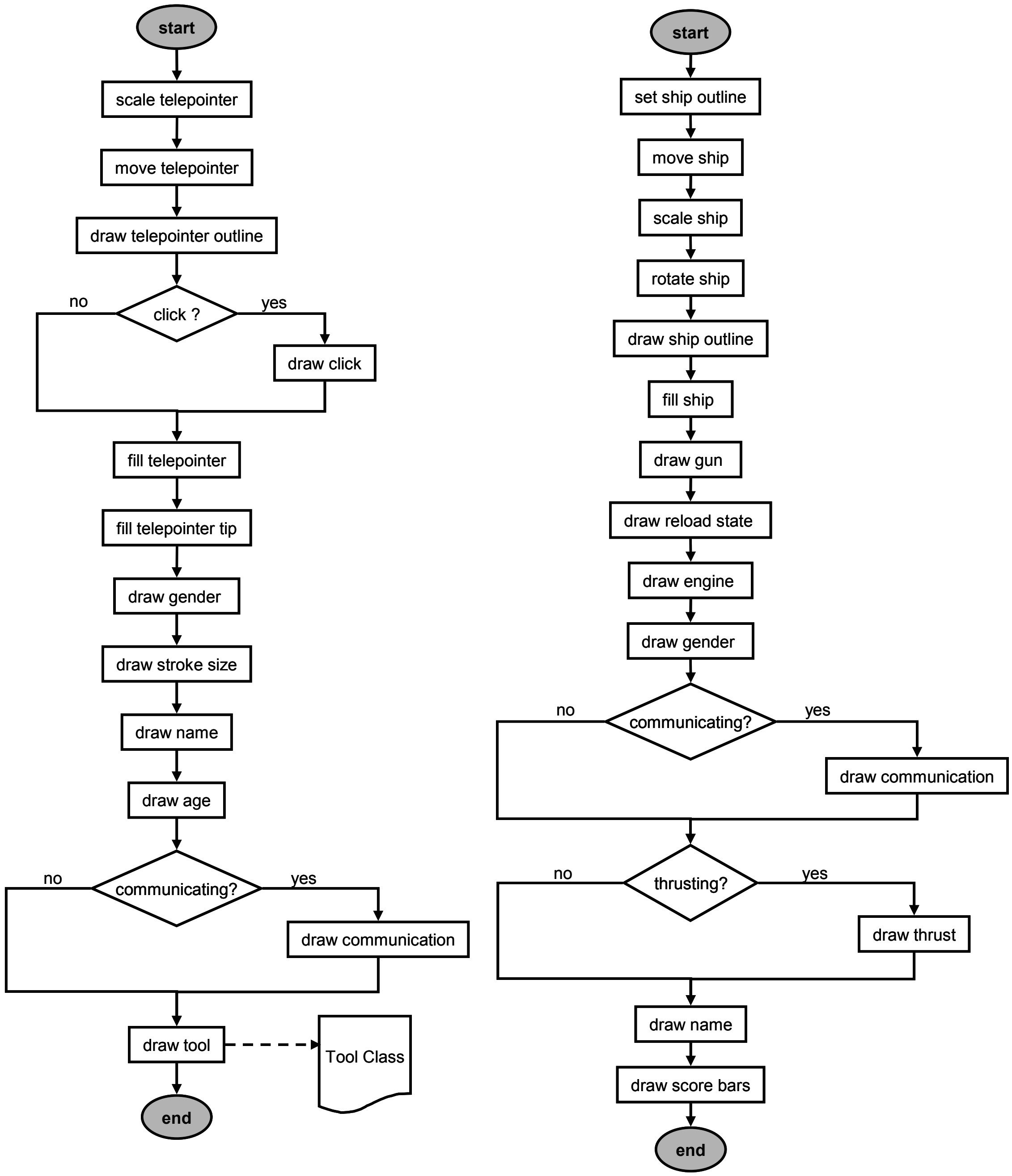


Figure 21. Class diagrams of the Ship class used in the Spacewar game.

Both embodiment classes have a draw function that is responsible for drawing the graphics of embodiments in the respected shared spaces. The basic shapes of the embodiments are defined by general paths (a sequence of coordinates that make up a 2D shape). Affine transforms are then applied to the shapes in order to achieve certain effects, such as: position, rotation, and size. These same techniques are applied to secondary glyphs that appear on or around the embodiments (e.g., the tool icon).



(a) (b)

Figure 22. Process diagrams for the rendering loop of the embodiments. (a) The Telepointer drawing process used in the Grouper application; (b) The Ship drawing process used in the Spacewar game.

Other effects such as colour, transparency, border width, and text, are applied in the drawing function. All effects are adjusted and applied based on certain variables that define what effect to apply. For example, if the player in Spacewar is male then a blue star is drawn over their ship; otherwise the star is coloured pink (for female). Within the draw loop, any of the graphical effects could be implemented as separate function calls or even separate classes. For instance, the tool icon used in the telepointer embodiment was implemented as a separate class and even includes its own draw function; this was done due to the complexity of the tool icon glyphs. The drawing functions use a process of drawing from back to front (see Figure 22). Items such as the main body of an embodiment are drawn first, then elements such as colour or texture are applied, finally glyphs on or surrounding the embodiment are drawn.

Chapter 4

The Feasibility of Information-Rich Embodiment

An initial study was carried out in order to answer basic questions about the feasibility and potential limitations of rich embodiment. Since information-rich embodiment has not been studied in detail, there were a set of unanswered questions about how well people would be able to interpret graphically encoded information in a groupware setting.

4.1 Goals

When developing rich embodiments, the first question that arises is how many information variables are people able to remember and interpret. The information-visualization literature suggests that the number of variables that people can interpret on a glyph is context dependent, and studies seem to show varying results. Thus, the aim in this study was to attempt to answer the following questions:

- How many variables can users recognize on an embodiment with minimal training?
- How accurately can users interpret the value of encoded variables on rich embodiment?
- Are people able to use the encoded variables to locate specific embodiments?
- Can users answer specific questions based on rich embodiments?
- Which mappings are easier or more difficult to remember and interpret?
- Are there differences between embodiment types?

Overall, this study was aimed at examining the limitations and possibilities of information-rich embodiment before they were implemented and studied further. The intention was to use the results of this study in order to motivate the further development of rich embodiments.

4.2 Study Design

A study was designed in which participants were asked to carry out a series of tasks using two types of rich embodiment: spaceship avatars from a multi-person video game and cursors from a multi-person drawing application. Each embodiment type used 15 information variables, and each representation mapped to a unique category of information that was relevant to the task domain. Participants carried out four tasks with each avatar type to assess their abilities at interpreting information encoded in the representations and to investigate whether there were performance differences between the telepointer and avatar.

The two embodiments used in this study were a spaceship avatar from a groupware version of Spacewar, and a telepointer from a hypothetical version of Photoshop. These embodiments were not actually implemented in real groupware applications; however, they were designed around the groupware context in which they would appear. For a complete discussion of the design of the avatar and telepointer used in this study, see Section 3.2.

Four tasks were developed for the study. The first task tested how well people were able to remember the mappings; the second task tested how accurately people could determine the specific values that were encoded in the embodiments; the third task measured the amount of time people need to select embodiments from a set of 24, using a pre-specified set of criteria; and the fourth task asked users to apply the encoded information based on a given scenario. In the two first tasks and the final task, participants viewed pictures of rich embodiments on paper and answered questions about them. In the third task, participants carried out timed trials using a custom test application developed in Tcl/Tk (see Figure 25). For a more detailed description of the tasks, see Section 4.5.

A variety of measures were taken, and included accuracy and completeness at extracting information from embodiments (tasks 1 and 2) and completion time for selecting an specific embodiment (task 3). The fourth task gathered information about how the participants made sense of the embodiment mappings. Subjective data was also gathered several times during the session. Finally, questionnaires allowed participants to rank each mapping according to the difficulty they had in understanding it and interpreting the values; and the participants specified whether there was a difference in the level of difficulty they encountered when using the two types of embodiment.

All of the participants carried out the four tasks with both embodiment types. Embodiment order was balanced; half of the participants carried out the tasks using the spaceship avatar first, and the other half used the telepointer first.

4.3 Methods

Twelve participants, ten male and two female, were recruited from the University of Saskatchewan. Participants ranged in age from 21 to 42 years (mean of 29 years). All were regular computer users (more than ten hours per week), and were students or graduates from technical degree programs. Every participant was moderately familiar with Photoshop or similar applications, but only five of the participants were regular players of multi-user online games. An Ishihara colour-blindness test was used to screen participants to determine whether they would have difficulty interpreting representations that used colour.

Participants carried out the four tasks that were designed to test participant's abilities to interpret the rich embodiments. At the start of the session, the participants were given training on the embodiments: the experimenter described the task domain, and then explained the mappings for the embodiments. Participants were given a handout that summarized the variables and the levels of each variable, and were given five minutes to review (training time was determined through pilot testing, and by the amount of time that would be reasonable for a real groupware application). The participants then carried out the tasks. After each task, participants were given one minute to rest and were allowed to review the summary handout. After completing all tasks for an embodiment type, the participants were given a short questionnaire that asked them to assess the difficulty they had in remembering the variables and determining the associated values. At the end of the session, participants were also asked about their overall preferences with the embodiment types.

4.4 Apparatus

In three of the experimental tasks the participants viewed avatar representations that were printed on paper and answered questions either verbally or by writing their responses on paper questionnaires. In task 3, participants carried out timed trials using a custom test application that was developed in Tcl/Tk. During the experiment, the application was deployed on a laptop with a screen resolution of 1280 x 800. Figure 25 shows the interface for the application, and the functionality of the application is discussed in Section 4.5.3.

4.5 Tasks

As mentioned earlier, four tasks were designed for this study. They were designed in order to collect mainly quantitative data about the potential for information-rich embodiment.

4.5.1 Task 1: Recalling the Variable Mappings

The first task assessed peoples' abilities to remember and identify the variables used in the rich embodiments. Participants were shown a picture of an embodiment and were asked to verbally list all the information variables they could remember. The responses of the participants were coded by the experimenter. For each embodiment type, participants were given four separate images one after another (Figure 23). The participants were given two minutes to complete each trial.

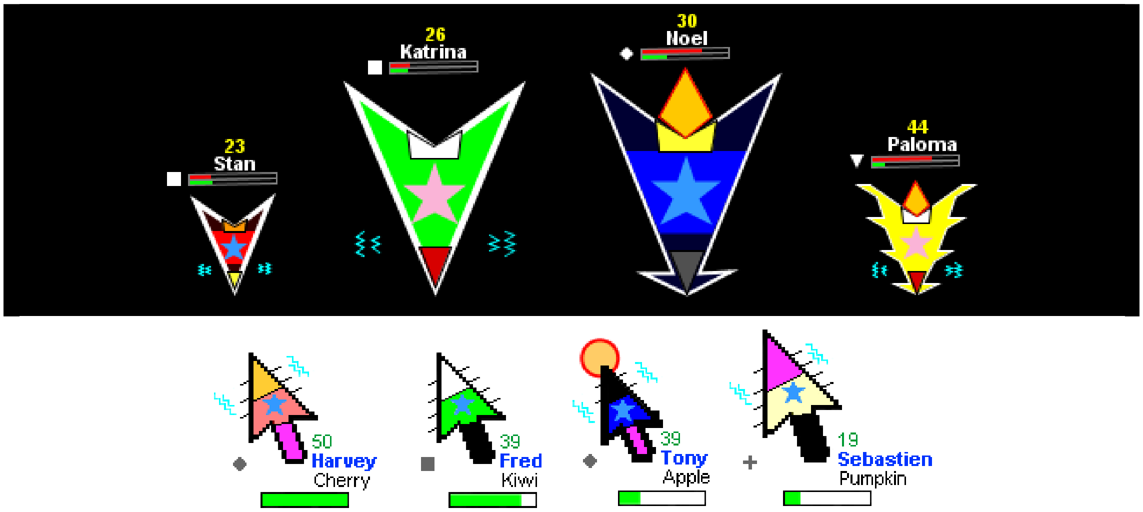


Figure 23. Rich embodiment used for Task 1 (pictures given to participant one at a time) Top: avatars; Bottom: telepointers

4.5.2 Task 2: Determining the Values

The second task assessed peoples' accuracy at determining the values of the information variables. The participants were shown a picture of an embodiment and asked to specify values for each variable on a paper answer sheet. The sheet provided a list of variables that were embedded in the embodiment. For the variables with limited categories (such as team) a list of possible values was given, and the participant had to check the appropriate response. For variables such as name and age, participants had to write the answer. For scalar variables, participant had to mark where the value lay on a given scale. The participants carried out four trials one after another for each embodiment type (see the avatars and telepointers used in Figure 24).

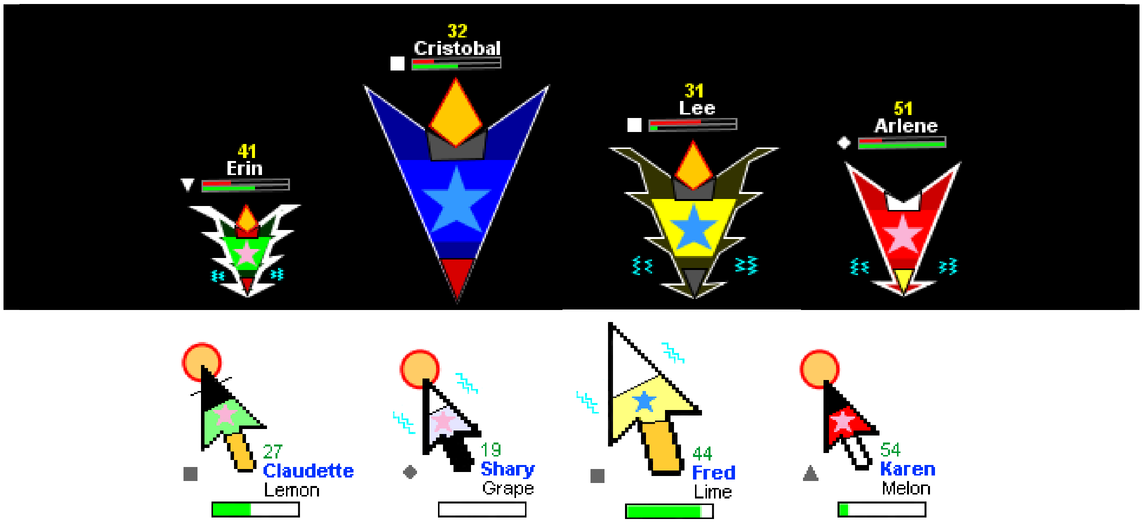


Figure 24. Rich embodiment used for Task 2 (pictures given to participant one at a time) Top: avatars; Bottom: telepointers

4.5.3 Task 3: Locating Specific Embodiments

The third task measured completion time and accuracy in selecting an embodiment, which matched a certain criteria, from a set of 24 embodiments (see Figure 25). A custom application first presented the question. Once the participant had read the question and was ready to select, the "Start Answer" button was pressed and a set of embodiments were displayed. The participant was asked to click on an embodiment that matched the criteria. After an embodiment was selected, the screen cleared and presented the next question. The participant was given 15 questions for each embodiment type: the first five questions used a single variable (e.g., "Pick a ship from team Alpha"); the next five used two variables (e.g., "Pick the telepointer of a female user who is clicking"), and the last five used three variables (e.g., "Pick a ship with level 2 experience, that is communicating, and that has high damage").

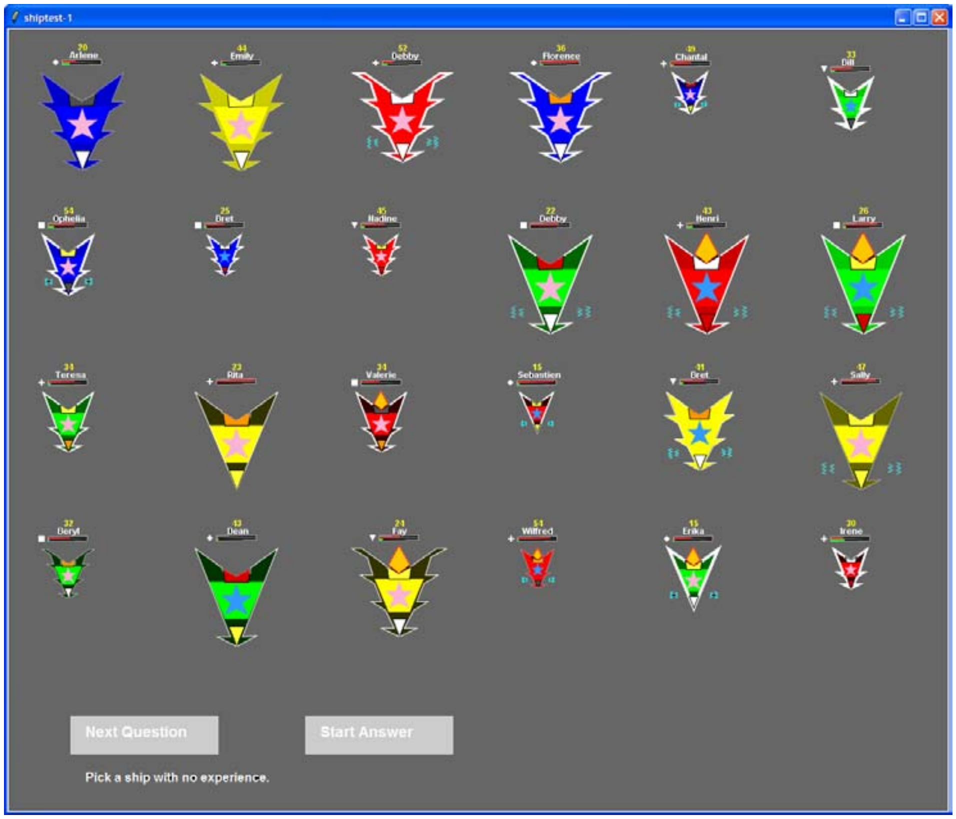


Figure 25. System used for Task 3
(participants clicked the ship that matched a given set of criteria).

4.5.4 Task 4: Scenario-Based Embodiment Selection

In this task, participants were given a scenario related to the embodiment's task domain, and were asked to select an embodiment from a set of five that would be most appropriate for addressing the situation. The scenarios did not have an answer that was clearly better than others – instead, the main goal of the task was to gain initial experience with how participants make sense of information presented in the embodiments. Participants were asked to write their selection on the paper and to provide a written description of the reasons why they selected the particular embodiment. For each type of embodiment, participants were presented with two scenarios with five possible embodiments to choose from (e.g., "When facing the following ships, which one would you attempt to avoid the most?").

4.6 Results

The results are broken down and explained by task in the following sections.

4.6.1 Task 1: Recalling the Variable Mappings

Task 1 asked participants to identify as many variables, represented in the embodiments, as they could without the use of an index for the mappings. Overall, most participants were extremely accurate: across four trials and both embodiment types, participants identified a mean of 13.73 variables out of the total of 15. As expected, there were accuracy differences based on trial (see Figure 26): a 2x4 ANOVA showed a significant main effect of trial number ($F_{3,33}$=16.5, p<0.001). However, there was no significant difference between spaceship and telepointer embodiment types ($F_{1,11}$=0.27, p=0.62), and no interaction between type and trial number ($F_{3,33}$=0.28, p=0.84).

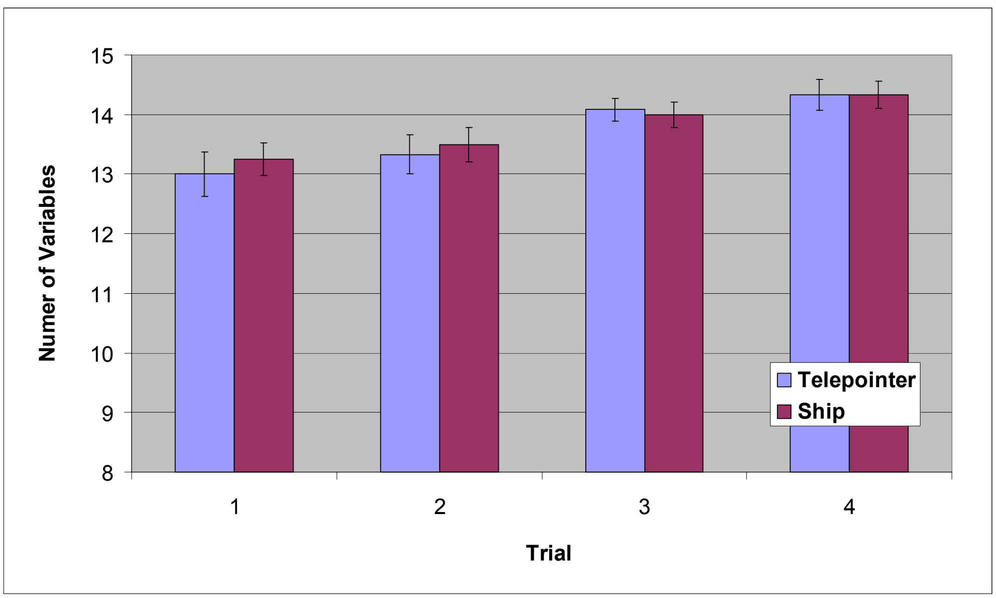


Figure 26. Mean number of variables identified, by trial number and embodiment type. Error bars show standard error.

Analysis was also carried out to determine whether there were specific differences between particular variables. Separate one-way ANOVA tests showed significant main effects of information variable type for both the ship ($F_{1,14}$=5.81, p<0.001) and for the telepointer ($F_{1,14}$=8.00, p<0.001). A post-hoc Tukey test showed that the variables *thrust state* and *experience* were remembered significantly less often than the other variables for the ship avatar; for the telepointer, the variables *click state*, *idle time*, and *city* were remembered significantly less often. Possible explanations for these differences are considered in the analysis section (see Section 4.7).

4.6.2 Task 2: Determining the Values

The second task collected data about how accurately people could determine the values represented by each variable. Accuracy in categorical variables (e.g., name, gender, team) was assessed by strict error rate (i.e., number incorrect); accuracy in interval/numerical variables was determined by error amount (i.e., normalized difference between answer and correct answer). Overall, participants were very accurate: the mean accuracy over all trials and embodiment types was 96.6% (see Figure 27).

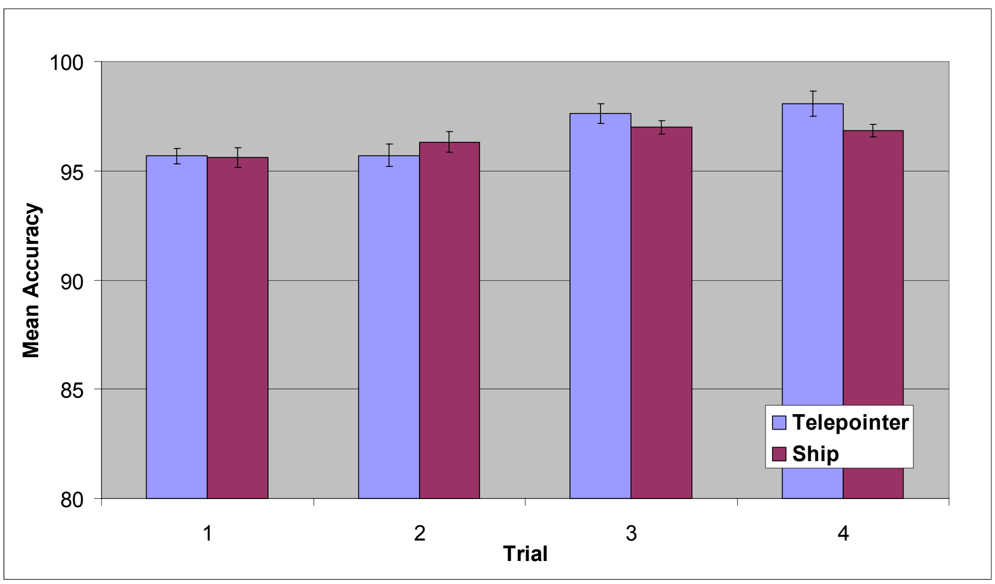


Figure 27. Mean value accuracy of all variables, by trial number and embodiment type.

There was again a main effect of trial number ($F_{3,33}$=4.28, p<0.05), although even on the first trial accuracy was high (95.63%). There was no difference between the embodiment types ($F_{1,11}$=0.180, p=0.680), and no interaction with trial ($F_{3,33}$=0.763, p=0.523). We again tested whether there were differences between variables. Separate one-way ANOVA tests again showed a main effect of variable type ($F_{1,14}$=9.17, p<0.001 for the ship; $F_{1,14}$=8.78, p<0.001 for the telepointer). A post-hoc Tukey test showed that accuracy with the variables *lifetime*, *death score* and *shield strength* was significantly lower than for most of the other variables in the ship embodiment; for the telepointer, accuracy with *city*, *session time*, *ping time*, and *idle time* were significantly lower than the other variables. These differences are examined further in the analysis (see Section 4.7).

4.6.3 Task 3: Locating Specific Embodiments

The third task recorded people's ability to select particular embodiments that matched certain criteria (one, two, or three variables) from a set of 24 images. Over all trials and embodiment types, people selected a correct embodiment 87% of the time, and took an average 17.4 seconds to make their selection.

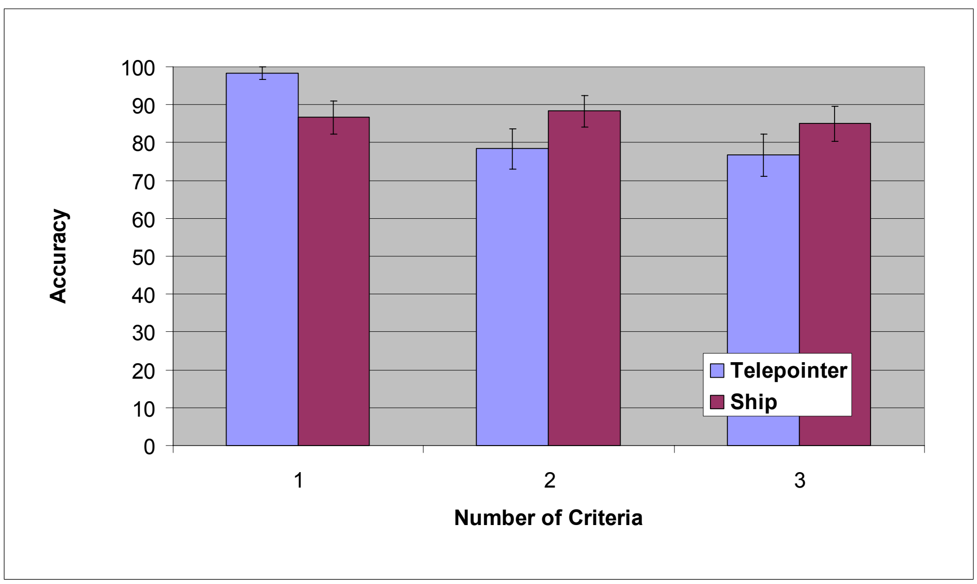


Figure 28. Mean value accuracy, by number of criteria and embodiment in Task 3.

Accuracy. A 2x3 ANOVA (embodiment type x number of criteria) was used to test the effect of embodiment and number of criteria. The test revealed a significant main effect of number of criteria ($F_{2,22}$=5.88, p<0.01), as shown in Figure 28. There was no main effect of embodiment type ($F_{1,11}$=0.880, p=0.368), but there was a significant interaction between type and number of criteria ($F_{2,22}$=4.51, $p<0.05$). As shown by Figure 28, two- and three-criteria questions resulted in a larger accuracy drop for telepointers. Follow up t-tests indicate that telepointers and ships are significantly different with one-criteria questions ($p<0.05$), but these were no different with two-criteria ($p=0.14$) or three-criteria ($p=0.25$) questions.

Time. There was also a main effect of number of criteria for the time required to answer the questions ($F_{2,22}$=108.46, $p<0.001$), as shown in Figure 29. Again, there was no main effect of embodiment type ($F_{1,11}$=2.05, $p=0.180$); there was also no interaction between embodiment type and number of criteria ($F_{2,22}$=0.701, $p=0.507$).

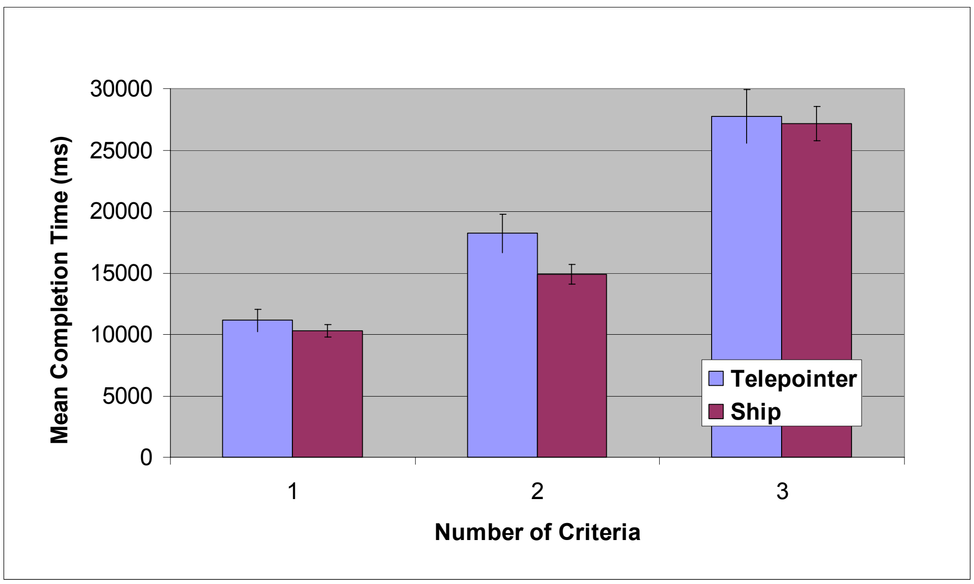


Figure 29. Mean completion time (ms), by number of criteria and embodiment type in Task 3

4.6.4 Task 4: Scenario-Based Embodiment Selection

The results for the fourth task did not reveal any substantial quantitative data. However, the results show that people were able to interpret the information variables found on the embodiments. From this information, the participants formed a mental model of the embodiments and made their own assumptions as to how to approach the given scenarios. This task served as inspiration for the studies on rich user embodiment that would follow (see Chapter 5 and Chapter 6).

4.6.5 Preferences and Perception of Effort

After testing with each embodiment type, participants rated the difficulty of remembering both variables and values on a scale of 1 (easy) to 5 (difficult). The mean difficulty level for remembering the variables was 1.56, and the difficulty of obtaining the values was 1.83. For both embodiments, the variables that were marked as more difficult to remember were also the ones that were difficult to interpret. In the case of the spaceship, these were: *team*, *lifetime*, and *ship damage;* and for the telepointer these were: *city*, *session time*, *ping time*, and *idle time*.

At the end of the session, participants were asked several questions about their experience with the embodiments. Eight of the twelve participants felt that the spaceship avatar was easier to use throughout the study, while two preferred the telepointer, and the remaining two felt that there was no difference. When asked if they would like to see applications of the rich embodiments in real-world applications, all the participants said 'yes' for the ship avatar, whereas only eight thought that the telepointers would be useful.

4.7 Analysis and Implications

Participants were very successful at remembering the meaning of the different variables in the embodiments – even with only a few minutes of training. Why were they so successful, when remembering fifteen different variables seems like a difficult task? There are three reasons that can help to explain the success. First, many of the attributes were concrete and well-understood concepts, like *name*, *age*, *damage*, or *layer*; it is likely that these kinds of variables are easier to remember than more complex dimensions that may appear in other glyph-based visualizations. Second, the context of the collaborative application restricts the type of variables that could be represented (to information about the person represented by the embodiment); this means that the mappings are not completely arbitrary, which may assist users as they interpret the visualizations. Third, the embodiment images were able to take advantage of natural mappings: the parts of the spaceship (e.g., guns or engine) already have well-known meanings and even in the more abstract telepointer, the location of the information may have aided performance. For example, placing the *click* indicator at the tip of the pointer may help people remember the mapping.

When people did forget the mappings, there appeared to be two reasons. First, in some cases people forgot variables that were not currently visible on the embodiment (e.g., mouse *click status* or ship *thrust status*). Second, in some cases people forgot that one of the areas of the embodiment carried information (e.g., the *damage* area in the ship, or the *idle time* indicator in the telepointer). These areas were also less visible, in that they used transparency in one small area inside the main figure of the embodiment. It is possible that these problems could be solved with improved design of the visualization; for example, recall could be improved by making all variables visible, even when the value of the variable is 'off,' or by avoiding the use of transparency.

Although the participants in the study were not always able to remember all of the variables in the embodiment, the results still argue strongly for the potential of rich embodiment. First, the findings have shown that people can recall many more variables than any groupware system has used to date. Second, rich embodiments are used to add information that is usually not otherwise available, and so people will gain value from the representations even if they cannot decode them fully. Third, people's recall of the variables should improve with increased experience, and any real groupware system will provide much more opportunity for people to learn the mappings.

In the second task, it was surprising that participants were so accurate in determining the values of variables in the embodiment. One reason for the high accuracy is the limited number of possible values in many of our variables (e.g., four possible values for *expertise* or *team*; two values for variables such as *gender* or *thrust status*); however, even with variables that used larger scales, participants were still fairly close to the true value. These results are consistent with what is already known about visual representations – that it is difficult to determine exact values. As with other visualization systems, the degree to which accuracy is required for the task should determine the type of visual representation. If complete accuracy is required, than a numerical representation is needed; if relative accuracy is required, than other visual representations can be used. The high degree of accuracy in the second task (greater than

95%) suggests that a ceiling effect may be occurring. However, the fact that no difference was fount at this level is still valuable, although there may be larger differences with more variables. There are several other types of test that could be done with the values in a rich embodiment in order to look at accuracy in different ways. For example, in some situations it may only be required to choose the person with the highest level of a certain variable, and this comparison may be simple, even if it is difficult to accurately determine the exact value of the variable.

The first tasks looked at whether people were able to translate from graphical representations to variables and values; the third task looked at whether people could do the opposite. People were again very accurate, although it is clear that the increasing complexity of the search criteria leads to longer search times. Whether these times are acceptable depends on the task – what is too slow for a real-time game may be fine for a drawing application. Again, since it is not currently possible to answer *any* complex questions using embodiments, the results demonstrate a substantial advance. It is also worth noting that the time required depended on the type of question as well as the complexity: for example, even single-variable questions like "find the youngest person" could be time-consuming since they required inspection of all 24 embodiments. In contrast, other queries would be much faster, such as “find someone on an opposing team.”

Finally, the fourth task was added to the study to see if the information encoded on the embodiments would be useful in a real groupware setting. The responses for this task varied greatly among the participants; however there was no right or wrong answer. The comments given by the participants for their choice of a specific embodiment clearly demonstrated that users were able to interpret the information variables and use it in a manner that could be helpful for awareness in groupware. These were promising results which helped to inspire the following two studies (see Chapter 5 and Chapter 6).

The results show that people are able to correctly recall an average of 13 variables; however it is possible they could recall a much larger set with additional training or more exposure the rich embodiments. In the real world, people are able to interpret and recall hundreds of variables. Therefore, overtime and with more experience with the embodiments, it is anticipated that users would pickup the variables as needed.

4.8 Conclusion

This study was performed in order to examine whether people can remember, interpret, and use the additional information variables encoded visually on a particular user embodiment. The results of this study provide evidence for the potential of the amount of information that can be effectively conveyed with rich embodiment. The tasks demonstrate that people were able to correctly recall an average of 13 of the 15 variables represented on the embodiments, determine the values of the embodiments with greater than 95% accuracy, and were able to successfully find embodiments matching a given criteria 87% of the time. The final task showed that users are able to form understandings from embodiments in order to answer particular questions regarding them. From the analysis we see that some mappings, such as those using transparency or that have a state where they are not shown, were more difficult to remember and interpret. Additionally, no differences were found between the avatar and telepointer embodiments. These results suggest that groupware embodiments have the potential to convey considerably more awareness information.

Overall, the results of this study are positive; However, generalization of the findings are dependent on what factors could interfere with the performance observed in actual groupware applications. That is, the measurements taken in the study involved groupware embodiments outside of real groupware environments. In a groupware setting, the variables encoded on the embodiment could be constantly changing, the embodiments themselves would be moving, and other actions would be occurring in the workspace. All these factors mean a much busier visual context which could add to clutter and distraction. Therefore, the next step in this research is to examine information-rich embodiment in a more realistic context. The following chapter discusses the follow-up study that takes what was learned from this initial study to implement and examine rich embodiment in an actual groupware environment.

Chapter 5

The Performance of Information-Rich Embodiment in Spacewar

It was decided that two separate studies would be required for the qualitative study of rich embodiment. The first task (presented in this chapter) involved longer term use of rich embodiment, to examine the performance over time and to be able to collect a larger set of qualitative data. The study design and methodology, as well as the results and conclusions for the first task are presented in the following sections.

The initial study (discussed in Chapter 4) was performed in order to examine the feasibility and potential of information-rich embodiment. However, that experiment did not examine how rich embodiment performs in actual groupware applications. The study discussed in this Chapter was designed in order to gather qualitative evidence for the use of richer user representations.

5.1 Goals

The main goal of this study was to examine the performance of information-rich embodiment in a real distributed groupware application. More specifically, the aim was to see if rich embodiment can provide better characterization and recognition of groupware users. Additionally, there were three other research questions about rich embodiment at the outset of this task study:

- Is information-rich embodiment useful to groupware users?
- How effective is rich embodiment as a means of expressing user information variables?

- Is rich user embodiment a satisfactory solution for increasing user awareness in groupware?

These questions were broken down further into three separate categories related to the performance of rich embodiment: usefulness, effectiveness, and satisfaction. The specific questions were:

Usefulness:

- Do users actually use the information found on the embodiments?
- How often do people use the information-rich embodiments?

Effectiveness:

- Can users successfully extract information about another person from their embodiment?
- Do rich embodiments allow the user to answer questions about other participants?

Satisfaction:

- Do users like information-rich embodiments?
- Are rich embodiments preferred over more simple embodiments?
- Do people continue to interpret information from embodiments over long-term use?

In order to answer these questions, data was collected over a long-term period. The results of this study allowed us to see if rich embodiments do actually solve the initially-described problem and if they are an adequate solution.

5.2 Study Design

The study was designed to be a long-term task that took place over several weeks. It was decided that a videogame would be used for the groupware environment, as it would be able to keep the participants interested and occupied over the span of the study. Eleven participants played the game for half an hour, twice a week, for eight weeks. Many of the game sessions continued past the allocated time, so some players gained additional experience with the game.

Three main methods of collecting qualitative data were used throughout the study: observations, questionnaires, and interviews. Several of the game sessions concluded with an online questionnaire that the participants were asked to complete. User observations were used throughout the study to see how users reacted to the rich embodiments, and to notice any effects related to the interaction among the players and overall gameplay. Finally, at the end of the eight weeks, all of the participants were interviewed individually and were asked to complete a post-study questionnaire.

5.2.1 Spacewar Game

The application developed for this study was a groupware version of the classic videogame of Spacewar [4]. Spacewar is considered to be one of the first computer games; it was created in 1961 at MIT. Interestingly, this original videogame was a multiplayer game, where two users would play on the same console. This is not surprising, since making a game multiplayer avoids the need to program any AI for computer controlled players or actions. The original Spacewar game was fairly simple and involved two player-controlled spaceships flying around a gravity-well in the centre of the screen (see Figure 17). The objective was to shoot the opposing player without getting caught in the gravity-well.

Spacewar was used as the inspiration for the groupware game that was developed for this study based on its significance and its simplicity. The idea was to create a distributed groupware version of Spacewar that could be used for multiple studies related to groupware. The version built for this study focused heavily on the spaceship avatars used in the game and evolved over the course of the study. The initial version of the game was quite simple with a limited play-space and planets scattered throughout the area as obstacles. The Spacewar avatars also evolved throughout the study and began as simple triangular shapes filled with a user-selected colour. In the final version, the spaceship avatar was encoded with thirteen information variables, and the game had two separate teams which users were automatically assigned to in order to balance the number of players on both sides (see Figure 30). The goal of the game remained the same: attempt to demolish opposing team ships while trying not to get destroyed.

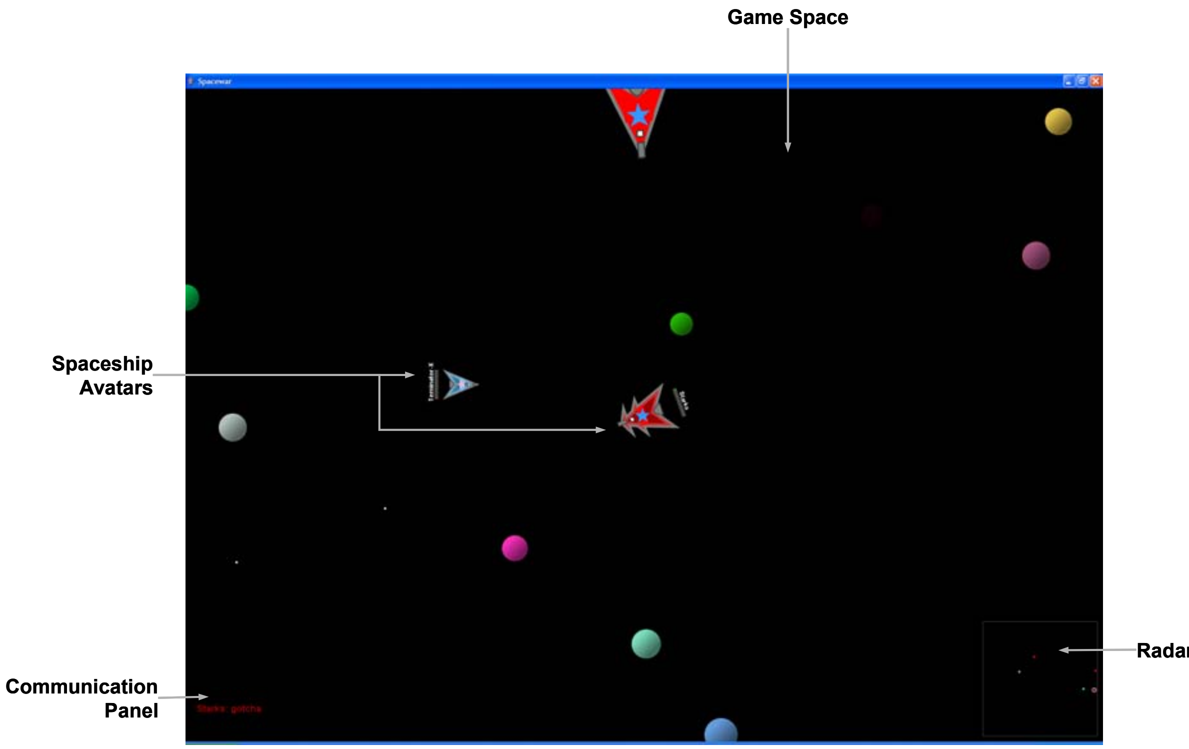


Figure 30. The features of the Spacewar system.

To play the game, a user controls their ship with the ‘A’ and ‘D’ keys (left and right), ‘W’ to thrust, ‘Space’ to fire, and the ‘K’ key to activate the shields. In order to broadcast a message to all the other players, a user presses the ‘Enter’ key and types a message; pressing the ‘Enter’ key again sends the message. All messages appear in the communication panel in the bottom left-hand corner of the screen. A radar view of the entire space is shown at the bottom-right corner of the screen to allow for better navigation. A zoom feature is also included so that a player can increase or decrease the scale of the space; this is done with the ‘Z’ and ‘X’ keys. Pressing the ‘F’ key brings up a panel with the accumulated death and kill scores of all the players. As can be seen in Figure 30, there are a series of coloured planets randomly scattered in the space. The planets act as obstacles that need to be avoided. If a player’s ship strikes a planet their ship accumulates damage.

5.2.2 Spacewar Embodiment

The embodiments used for the Spacewar application are modelled closely on the avatars created for the initial study (see their design in Chapter 3). The results of the feasibility study (in Chapter 4) suggest that the mappings of the variables appear to be successful in terms of recall and interpretation. Using a similar avatar allowed us to better answer the questions that remained about how the embodiments would perform when applied to an actual groupware application. More specifically, when playing Spacewar, there are numerous embodiments on the screen at once that are constantly moving, rotating, and changing. This was assumed to be a difficult setting for users to interpret the variables encoded on the avatars.

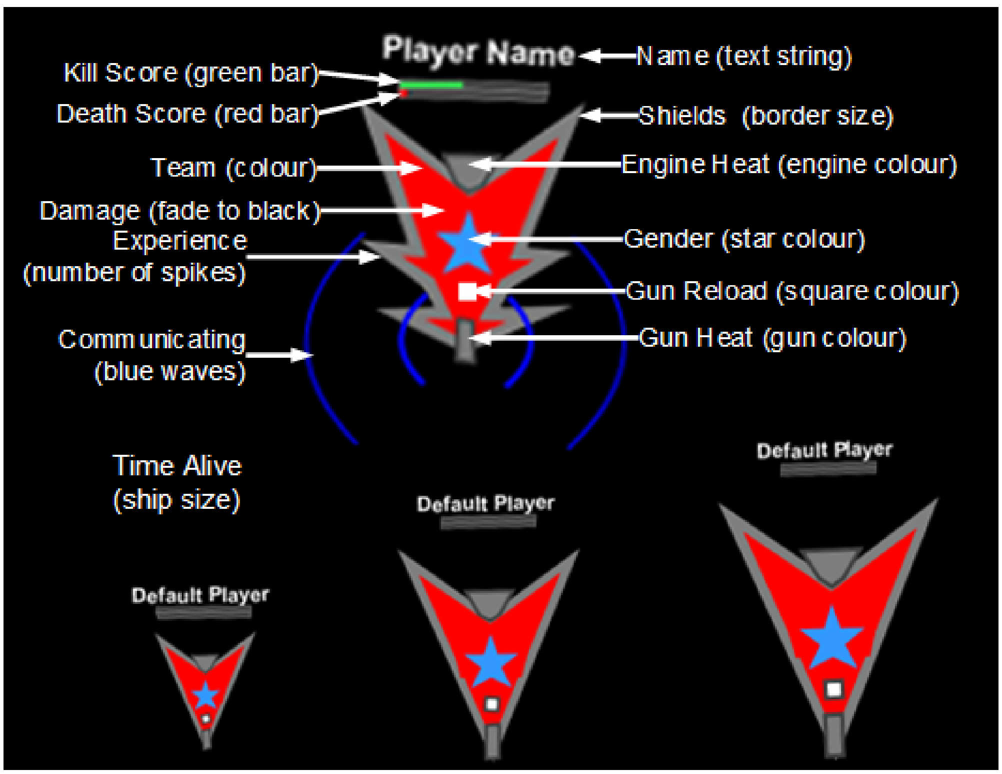


Figure 31. Rich avatar index for Spacewar

Table 6. Variables, descriptions and visualizations of the Spacewar avatars

Variable	**Description**	**Visualization**
Name	The user's name or handle	Text string
Gender	The gender of the user	Coloured star (blue for male, pink for female)
Kill Score	The number of accumulated kills in a session	Green bar below name. The width represents the number of kills
Death Score	The total number of deaths in a session	Red bar below kill score. The width represents the number of deaths
Team	The team a player is automatically assigned to	The colour of the body of the ship (red or blue)
Damage	The amount of damage a ship has sustained (1 to 5)	The more the body is faded to black, the more damage the ship has sustained
Experience	The amount of experience a player has accumulated (based on the total number of kills)	The number of 'spikes' on either side of the ship (ranges from 0 to 4)
Communication Status	Expresses if a player is currently typing a message	Animated waves emitted from the nose of the ship
Shields	Indication of the amount of shield power a ship has, and whether the shields are activated or not	The thickness of the border reflects the amount of shield remaining, and the colour reflects if the shields are engaged (white=on, grey=off)
Engine Heat	Indication of how frequently the engines have recently be engaged	The more white the engines appear, the hotter they are
Gun Heat	Indication of how frequently the guns have recently been fired	The more white the gun appears, the hotter it is
Gun Reload	Indication of if the gun is reloaded and ready to fire	When the gun reload box is white, it is loaded. Otherwise, the gun is not ready to fire
Power-Up Level	Represents the amount of time a ship has managed to avoid being destroyed (total of 5 levels)	The ship size reflects the power-up level achieved

There are a total of thirteen information variables encoded on the Spacewar avatars. All of the variables were chosen to be relevant to the task of playing the Spacewar game, or helpful in recognizing or characterizing other players (see Table 6). An index of the graphical representations can be seen in Figure 31. There are several categories of information variables mapped onto the avatars:

- **Personal:** These are variables related to the actual person behind the avatar in the real world. Personal variables include *name* and *gender*; however, both of these variables are set by the user, so they can be changed to anything the player desires.

- **Experiential:** Experiential variables are based on a user's experience or performance with the game or within a game session. The experiential variables displayed in Spacewar are: *kill* and *death scores*, *game experience*, and *power-up level*. The *kill score* and *death score* represent a user's overall performance in the current game session. The two scores show a ratio of how well a player has done by achieving the goal of destroying opponents while not being destroyed themselves. The *experience* variable is a basic overall measure of the player's performance or time spent playing Spacewar. In order to increase to the next experience level, a user must accumulate 20 kills over any number of game sessions. Finally, the *power-up* variable is a reflection of short term performance in the game. The longer a player manages to pilot his or her ship without being destroyed, the better power-up level they will achieve. After a ship re-spawns, it will increase to the next power-up level every 30 seconds. It is actually quite challenging to achieve a high power-up level if there are several players in the game.

- **State:** State variables are based on a mode or situation that a groupware user may be in. These are different than experiential variables in that they are limited and focused more on a particular task. State variables have a discrete set of states or modes (e.g., on/off). The *communication status* is a good example of a state variable. When a player is typing a message, they are shown to be in a communication state. The *gun reload* variable is an indication of if a ship is in a ready-to-fire mode or not. Additionally, the *shield* information variable is also considered a state variable because it indicates if a player is currently shielding.

- **Activity:** Both state and activity variables are related to a particular status; however activity variables have a value of a current action associated with them. The *gun* and *engine heat* reflect how recently and frequently the gun has been fired or the engines engaged, respectively. The *shield* variable can also be considered an activity variable, in that the mapping shows the amount of shield strength that a ship has remaining. Thus, by looking at an avatar's shield strength, a player can tell if the ship has recently engaged its shields and if they have been exhausted.

5.2.3 Methods

Eleven male participants were recruited from the University of Saskatchewan. The participants were selected based on their availability during the study period, and their proximity to the HCI lab where the sessions took place. At the beginning of the study, the participants were introduced to the game and its main functionalities. The players were also told about the information encoded on the embodiments at the outset of the experiment. As the study progressed and more features were added to the avatars in Spacewar, the participants were informed via email and web references about the information variables and mappings.

The majority of the game sessions were held every Wednesday and Friday afternoon. An email reminder was sent to all the participants as well as any further information required, such as new features or post-session questionnaires to be completed. Other people outside of the main pool of participants were welcome to join the game session out of interest or curiosity; this was not seen as having a negative impact on the study results. This occurred on several occasions and none of the results suggest an affect of having other people join.

The task given to the participants in each session was to simply play the groupware Spacewar game. The goal of each game session was to avoid being destroyed and to shoot as many of the opposing ships as possible.

At the end of the eight weeks, each participant was interviewed individually regarding the avatars and the Spacewar game in general. Following the interview, a post-study questionnaire was completed by the participant.

5.3 Apparatus

The groupware version of Spacewar was developed in Java using the Java 2D graphics library for graphics processing. The underlying networking for the game was developed using the GT Groupware Toolkit created at the University of Saskatchewan's HCI lab. Several people worked on the initial Spacewar game in order to increase its features and robustness. The game also included an automatic updater that ran when the program was launched in order to add on any of the new features that were created.

Each of the eleven participants ran the Spacewar game on their own independent machines. Although the game is platform independent, the majority of the participants played on Windows XP computers; however, some occasionally ran the game on a Macintosh machine. Each player had different screen resolutions when playing the game. However, all of the participants were able see the variables encoded on the rich embodiments. Moreover, the game included a zoom feature which allowed the players to adjust their magnification of the game to the level that they preferred.

5.4 Results

In this section the findings from the long-term Spacewar study are presented. The results are examined in order to answer the main questions regarding the performance of rich embodiment and its ability to improve interaction in groupware. The results are arranged in the order of the questions outlined at the outset of the study (see Section 5.1).

5.4.1 Recognition

One of the main goals of information-rich embodiment is to improve the ability of groupware users to recognize their fellow collaborators. In order to measure recognition in Spacewar, we examine if and how the participants were able to recognize particular users or avatars in the game. The results of the interviews show that the participants did use the encoded information variables on the avatars to identify other players. This is shown by the fact that the majority of the users recognized players or avatars of interest for particular tasks, such as: knowing who to avoid or who to attack, or for seeking revenge. The main variables used in recognition were: *name*, *experience*, *kill score*, and *death score*.

Based on the responses in the questionnaires and interviews, the *name* variable was the easiest way for the participants to identify a ship – not necessarily the person controlling it. It did not seem to matter if the actual player behind an avatar was known in the real world, because the participants would form a mental model of a player and associate that model with the name displayed on the particular player's spaceship. This is illustrated by the statement of one of the participants: "… I didn't really need to know who they [the other participants] 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 player recognition using the *name* variable involved a player who used the handle 'Defaulter'. The person using the Defaulter name was clearly the best player in the game sessions, and it did not take long for the other participants to recognize his impressive skill level. Interestingly, not all of the participants knew who Defaulter was in real life, but they would avoid him or attempt to gang up on him in the game.

The value of the *experience-level* variable did not change frequently and only increased once a player had accumulated a certain amount of kills (in intervals of 20). The majority of the participants noted that the visual effect used for the *experience* variable ('spikes' on either side of the avatars) was quite prominent. Some of the users stated that the visualization made the ships appear more ominous. However, the mapping was frequently used to identify who was a better player in the game (more spikes), and was also used as a cue to attack or flee from an opposing ship – assuming players with more experience are difficult opponents.

The *kill* and *death score* variables were encoded visually as coloured bars behind the ship avatar. These variables were reset at the beginning of each game session. Looking at the combination of these two values gave an overall kill-to-death ratio of a player for the current game session. This ratio is a common performance measure in first-person-shooter videogames. The responses from the player interviews indicate that the *kill* and *death scores* were not used frequently, but when they were examined they acted as a measuring-stick of a person's performance. Therefore, the score bars afforded the participants the ability to identify good, mediocre, or poor players based on the number of kills and deaths that had been accumulated in a game session.

Overall, the ability to recognize other players allowed the participants to more easily perform certain in-game tasks. The groupware version of Spacewar involved continuous interaction with other users in the shared space. Thus, being able to tell who an opposing player was, or being able to recognize a certain ship was important for gameplay. Recognition was used mostly for strategy, such as: avoiding good players, attacking the ships of poor players, seeking revenge on a particular person, or hunting a favourite opponent.

5.4.2 Characterization

The action of characterizing a spaceship avatar was also very common during gameplay in Spacewar. The results from the questionnaires and interviews show that if a ship or player was unknown, the encoded information variables on the avatar allowed the players to determine the type of player or state of the ship. The variables most commonly used in characterization were: *team*, *damage*, *power-up level*, *kill score*, *death score*, and *shield strength*.

The importance of *team* in the version of Spacewar used in this study is clear. The players were automatically assigned to a team, and the objective was to destroy as many opposing ships on the opposite team as possible. Therefore, the ability to easily identify an avatar as being a friend or foe was important. The embodiments were colour coded based on the team they were associated with (red or blue). The mapping of team to colour allowed the participants to easily distinguish what team a ship belonged to. During the interviews, the majority of the participants stated that avatar colour was one of the first variables that was looked at when approaching another ship in the game.

The *damage*, *power-up level* and *shield strength* all tended to be used in characterizing the overall type of a ship. For example, a player would look for a small ship (low *power-up level*), with damage, and low shield strength as it was considered an easier opponent to face. Many of the participants noted in the interviews that they would attempt to go after ships showing signs of damage (fading to black), since it would require fewer hits to destroy the ship. This is shown by the statement of one participant: "… the damage indication, if that wasn't there then you don't know what is happing. Is he shot? Is he damaged?" The *power-up level* variable was a measure of how long a player was able to keep their ship from being destroyed. Every thirty seconds, a player's ship would grow one level and a notch of damage would be removed. In addition, as a ship grew in size, it could fire more quickly yet would fly more slowly. This became very useful to the participants since it revealed if a player had done something right in order to keep their ship undamaged for a long period of time. It also had an effect on strategy because a large ship would turn much more slowly and as a result it was easier to attack from certain angles. Similarly, if a player had exhausted the shields of their ship or the shields were not engaged, the ship was more vulnerable to being damaged. These three variables (*damage*, *power-up level* and *shield strength*) were used regularly by the participants, and allowed them to characterize other players and distinguish the current state of a player's ship, such as: a strong or weak ship, or a good or poor player.

Characterization was helpful for strategy in the Spacewar game, and appears to have made gameplay much richer. As the participants stated, characterizing good and bad players, strong or weak opponents, and powerful or damaged ships were all part of the game strategy. Without the addition of rich embodiment to Spacewar, the participants would not have been able to apply such a strong strategy because their tactics were based on several of the variables encoded on the spaceship avatars.

5.4.3 Usefulness

This section examines the usefulness of the rich embodiment in the Spacewar game based on the responses provided by the study participants.

Do users actually use the information found on the embodiments?

The results of the questionnaires and the interviews show that players used at least some of the information found on the rich embodiments. Some of the variables were used much more frequently than others, as can be seen in Figure 32. The graph shows the average usefulness of each variable as scored by all the participants; 5 is very useful, and 1 means the variable was never used.

The most useful variables were: *name*, *damage*, *team*, *experience level*, and *power-up level*. The graph from the post-study questionnaire suggests that there appears to be three levels of usefulness: strongly useful, moderately useful, and least used.

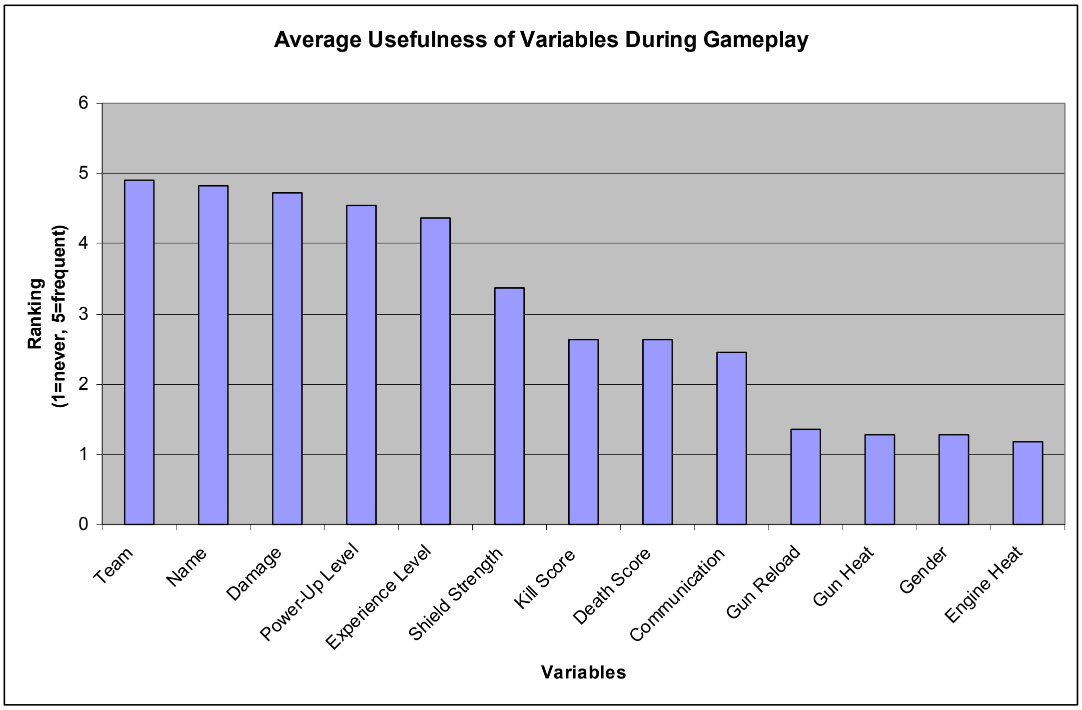


Figure 32. The Usefulness of Variables during Spacewar Gameplay.

Strongly-Useful Variables:

Team and *name* remained constant during a session and were considered key for interaction. Most specifically, team was very important since the goal was to attack only ships on the opposing team. All the participants listed *name* as a variable used to identify someone in the game, thus it is clearly important for interaction. It was the easiest way to associate an avatar with a person in the real world, so this is probably why it was considered so useful. From the interviews, it appears as though many of the participants enjoyed hunting specific players. For example, during the interviews, participant X mentioned that he enjoyed attacking participant Y in a game session. Similarly, participant Y stated several times that he continually looked out for participant X throughout his sessions. *Name* was also important because it was the quickest way to identify specific players.

Experience level was relatively constant and only changed once a player had a certain number of kills. The participants stated that it was useful in determining who the better players were in the game and when to attack or flee from an opposing player.

The *damage* and *power-up level* changed often in the game sessions. *Damage* was important to the players because it allowed them to determine if an opponent would be an easy kill or not. *Power-up level* was used as a measure of how long a player was able to survive in space. Every thirty seconds, a player's ship would grow one level. In addition, as power-up level increased, a ship would be slower-moving yet fire more rapidly. This fact had an effect on strategy because a large ship tended to be a more difficult ship to attack.

Moderately-Useful Variables:

The moderately useful variables were rated on average less than 3.5, but greater than 2 in terms of the 5 point usefulness scale. Not surprisingly, *kill* and *death score* were rated with the same score as they were very similar. These scores were displayed visually as bars behind the ship avatars (green for accumulated kills, red for accumulated deaths). The interviews indicated that they tended not to be used that often, but when they were they acted as a measure of a person's performance. As one participant noted, the game space was not that large and it was fairly easy to tell who was killing or dying a lot, this may have had some effect on the scores being less important. Additionally, the users were able to hit the "F" key in order to bring up a panel displaying the scores of all the players. This score panel was probably more useful since a player could get everyone's score at once, as opposed to having to find each avatar in the game. However, players did rate the score bars as somewhat useful in interaction, and as the interviews suggest when the score bars were used it was to get a quick impression of how well a player was doing.

Communication status showed when a player was using the chat feature in the game. Although not a lot of chatting occurred in the game sessions, the chat mapping made it clear when a player was about to say something. This provided cues for when to look for a message, and in addition it allowed players the possibility to choose not shoot a player who was in the middle of typing a message.

Shield strength indicated the amount of shield a ship had remaining, as well as if the shields were activated or not. Users found this important during dogfights, since a ship is easily damaged if it has exhausted its shields. This was a common strategy among most of the participants, hence the usefulness of the shield awareness.

Least-Useful Variables:

Least-useful variables had an average usefulness score approaching one. These variables were rarely or never used during gameplay. It is obvious from the interviews that *gender* was useless since the pool of participants were all male. Interestingly though, in one of the early sessions a female did log on and some players immediately noticed her arrival.

Engine heat and *gun heat* indicated how frequently the engines or guns were fired. All participants said they never looked at this visualization, and it appears as though it was because it was of no importance to strategy. Some players noted that if the guns or engines overheated and temporarily disabled their functions these visualizations would have been much more important.

Finally, the *gun reload* cue was added to show when a ships gun was ready to fire again. Most players mentioned they never even noticed this feature, and this may be because the visualization was only a few pixels square. Additionally, one user stated that over time they became used to the frequency of which bullets were fired (if a player was holding the fire button); otherwise it was clear that the player could fire at any point since the reload time was short.

How often did people use the rich embodiments?

The frequency with which users actually used the information-rich embodiment variables is difficult to measure. However, the majority of players noted in the post-study interviews that the variables they did use became an integral part of the game and were noticed and interpreted almost every time they looked at a ship. This result shows that interpreting the most useful variables became essentially subconscious. This is similar to what is done in face-to-face interaction where, for example, it is relatively easy to tell a person's mood from their facial expression. Thus, the number of times a participant would read the variables in a game session is probably very high, especially with the constantly changing variables such as *damage* and *power-up level*.

5.4.4 Effectiveness

The effectiveness of the Spacewar avatars at expressing the information variables is examined in this section and we consider two questions: can users successfully extract information about another person from their embodiment, and do rich embodiments allow the user to answer questions about other participants.

Can users successfully extract information about another person from their embodiment?

Based on the results of the questionnaires and interviews, people could and did extract information about other people and ships form the embodiments. Examples include:

- A user reading the names of his team mates;
- Attacking a ship that is showing damage;
- Running away from a large ship with little damage;
- Checking one's own ship for damage in order to decide on what actions to take.

Many of the participants noted in the interviews that extracting information from the avatars became automatic after several sessions. Thus, it can be concluded that users did successfully extract information about other players throughout the game.

Do rich embodiments allow the user to answer questions about other participants?

This is related closely to the previous question. None of the participants appeared to have consciously asked questions about another participant. However, sometimes a quote was overheard of "who is that?" if a new player logged on. Nevertheless, when strategizing in the game, the embodiments clearly played a role in answering questions such as:

- Who is the weakest opposing ship around?

- Should I avoid that ship?
- Is this player better than me?
- Should I run from this battle?

Thus, although the players rarely explicitly stated that questions arose during the game, it is clear from their strategies that the users were constantly scanning the avatars to determine what actions to take.

5.4.5 Satisfaction

At the outset of the study, it was not known how the participants would react to the idea of overloaded embodiments. This section covers the details of the overall observed user satisfaction of the rich avatars.

Do users like rich embodiments?

None of the participants complained about the rich embodiments, and since some of the variables were an integral part to strategy it would appear as though they were almost required. When asked if they liked rich embodiments, all the respondents said “yes” they did like the avatars. Not only did the overloaded spaceship avatars allow for better interaction, they increased the overall richness of the game. This result was clearly appreciated by all the users based on their interview responses.

Are rich embodiments preferred to more simple embodiments?

In the beginning of the study, the Spacewar game was very simplistic with no rich embodiment whatsoever (users could only change the colour of their ship). As one participant put it: “The early version sucked without it [rich embodiment], who knew what is going to happen [in the game]?”

Over time, as more information was added to the embodiments, strategies changed and players became more intrigued with the game. In several cases, the sessions went over their allotted time slots because the participants were enjoying the game enough to continue playing. Therefore, it is clear the rich embodiments were preferred, as illustrated by this quote: “It would be a way different game without the rich embodiments. You would actually lose a lot of motivating things if you took them away.

These are the ways that you actually organize your self: Who to kill? Are you doing well? Who you are going to kill because they are damaged? ...strategy is based on these embodiments."

Do people continue to interpret information from embodiments over long term use?

The questionnaire results from several weeks of study suggest that the variables are continually used over time. One participant noted that he began to use more and more variables as the weeks progressed, and his recognition of the data become more automatic.

Most of the participants stated that eventually the variables were interpreted automatically as they became an essential part of the game. This behaviour suggests that the information variables were continuously used throughout the entire study. One quote is a good illustration of this fact: "I don't think the variables become less useful over time, but they become more intuitive. Like you don't think about this means this, it becomes part of the game, you just know. I think if you play the game without these later on, you would be like 'there is something wrong here.'"

5.4.6 Potential Problems

The initial feasibility study in Chapter 4 showed the potential for information-rich embodiment. However, there still remained numerous questions about how richer forms of user embodiment would perform in actual groupware. This section examines these questions based on the responses from the participants of the Spacewar study.

Do rich embodiments clutter the workspace?

The interview results show that there were no issues of clutter. The visualizations were assumed to be part of the game and were treated as such. Even if the variables were never used (like *gun* and *engine heat*) there were no complaints of unnecessary clutter. Only one participant noted that the score bars and names seemed slightly awkward as they looked as though they were being towed by the ships; however the participant stated it did not contribute to clutter in the game space.

Are the mappings of information to visual representations understandable?

The participants were asked if they found any of the mappings unintuitive, or if they would have chosen to represent them differently. Perhaps because they had become accustomed to the mappings, none of the participants had any different suggestions. Only one user suggested that the score bars could be placed inside the spaceship avatars perhaps, as opposed to being shown outside of the ship. The users appeared to be able to recognize most of the variables and interpret their values. Some of the participants did not know some of the mappings due to a lack of training or experience. Still the most popular variables (the ones most frequently used) were clearly understandable enough to satisfy the requirements of the players. This result is encouraging in that it shows that with some consideration the mappings can be understood and used.

Does revealing more user characteristics affect privacy?

Privacy was not an issue within the participant group. The only personal information that was displayed was a person's gender and name (if they decided to enter in their correct information). None of the users were concerned about privacy since many of the participants knew each other.

When asked in the interviews if they would reveal this information in a game played with strangers, the majority of participants did not have any concerns. Only one participant expressed that they would be uncomfortable sharing their personal information such as: name, age, and gender. However, numerous participants stated that privacy would not be a concern since most people would not enter in their true data. Additionally many participants felt that things like age and gender might be intriguing, but are not necessary for a game.

5.4.7 Other Observations

In addition to the main findings, several other interesting observations were made. This section presents some of the important issues that were discovered in the study that were not necessarily anticipated at the outset of the work.

Motivation to Gain Experience

As a player accumulated a certain number of kills, their experience level was represented by spikes on either side of their ship avatar (see Figure 31). This was a very noticeable visualization and was a significant change to the look of a ship. Naturally, players strove to obtain more experience points, as one user stated: “Spikes of course, you want to have as many spikes as you can. It makes it look like you are doing really well.” Additionally, the idea of having a more unique spaceship (as opposed to a basic triangle) seemed to be very appealing to the players. After only a few sessions with the experience visualizations, players came up with names for the look of a ship. For example, one experience spike at the front of the ship was referred to as a “moustache” (because the spikes began at the nose of the ship). If a ship was filled with spikes (experience level of 4) it was called a “Christmas tree,” because all the spikes made it look like tree branches when the ship’s nose was pointed upwards. In later sessions, players could be overheard shouting “I got a moustache!” or “the opposing team is filled with Christmas trees.” Thus not only did the experience level mapping improve awareness, but it also increased the motivation to perform well in the game and get a more interesting looking avatar.

Characterization from Player Behaviour

Spacewar is fairly simplistic as a videogame – compared to today’s popular games – and thus there was little finesse in what a player was capable of. As one person stated in the interviews “It’s not like the game is so expressive that you can tell who someone is by style, like play-style in chess or something.” However, surprisingly some players did feel that player types could be deduced from player styles, such as a player that is good at dodging bullets or shielding at just the right moment. This was enforced even more so by one of the participants who was clearly the best player in the sessions (his player handle was ‘Defaulter’). When Defaulter was interviewed, he explained a strategy of observing a player in order to characterize them, even more so than looking at the mappings. If the opposing player performed several dodging moves to avoid being hit, or was proficient in their shield use, Defaulter would classify them as a good player. Otherwise, it was quite obvious that a player was unskilled if their ship was destroyed easily. It is especially interesting that the Defaulter player's strategy used this mental mapping of players based on behaviour, considering that Defaulter was always the best player in a session. This is not to say that Defaulter did not use the variables encoded on the spaceship embodiments, but looked to behaviour for additional information when characterizing opponents.

The Potential for Information-Rich Avatars

The majority of the participants in the study also played together in weekly games of *Enemy Territory* (outside of this study). Enemy Territory, or ET (www.games.activision.com/games/wolfenstein/), is a free multiplayer game based on the *Wolfenstein* series. It is a first-person shooter where players are distributed among two teams and must accomplish a certain goal on each map. The avatars in ET are 3D humanoid models and much more detailed than those found in Spacewar; however, they express fewer information variables. If a player's cross-hairs are placed over a team member in Enemy Territory, the name of the team mate will be displayed as well as their health level. However, for opposing teams none of this information is shown. Additionally, there are several classes of characters (i.e., engineer, medic, soldier, field-ops, and covert-ops) and gun types; these variables can be determined by looking at an avatar's clothing and the weapon they are holding in their hands. The only other information that is displayed is that of invincibility when a player re-spawns or is revived in the game – this is shown with an icon above the avatar.

During the interviews the participants were asked about the potential for increasing awareness in a multiplayer online game such as ET. All of the respondents said that having access to more player information in Enemy Territory would allow for richer gameplay. For example, several of the participants gave the scenario of being attacked by a group of opposing players. They described that if they had access to the all of the player health levels, it would be beneficial to try to kill the more damaged players first in an attempt to gain experience points (XP) and weaken the enemy team. Similarly, experience points in Enemy Territory gives a player some advantages such as better armour and speed. Experience is not displayed on an avatar and the only way to see this information is by pulling up an information panel. However, this is inconvenient as one participant stated: “You can [find out] the XP while you play, but you have to leave the game. That is not very useful, because then you have to associate the name with the avatars in the game. And while the XP screen is up you will probably get killed.” Thus, the comments of the participants suggest that there is potential to increase the richness of video games, and perhaps other groupware applications, by increasing the richness of user embodiment in these applications.

Adapting Information-Rich Embodiment to Context

An interesting observation arose from the earlier versions of Spacewar and some of the features present in the game. A zoom feature was added early on and allowed the players to zoom out to get a better view of area around them, as well as to zoom in for closer inspections. The ability to increase or decrease the level of magnification revealed an important point about the design of rich embodiment. It soon became apparent that if a player zoomed out to a high level the information on the ship avatars became too small to read and interpret. This was a problem and caused several users to comment or complain on the inability to read some important cues such as names, shield strengths, and score bars.

In order to address this problem, a context-sensitive zoom was applied to some of mappings. Variables such as *team*, *damage*, and *gender* were still visible at the furthest level of zoom so they did not need to be adjusted. However, the player name, kill and death score bars, as well as shields all remained constant in size regardless of how far in or out the player’s view was scaled. This adjustment provided a substantial improvement to gameplay directly related to the rich avatars. Players no longer complained about not being able to interpret the variables. Moreover, the majority of those who had commented about the issue did not even notice that the context-zoom had been added but noted that is just “seemed right.” This scenario is an important lesson for the development of information-rich embodiment. Designers must consider all the potential scenarios in which an embodiment may be viewed in order to adjust the mappings appropriately so that the variables and values can still be accessible.

Richer Embodiment Leads to Richer Gameplay

Although the game evolved over the long-term study, few game elements changed outside of the richness of the embodiments. The concept of teams was added, as well as shields and ship damage. All other changes were related directly to the visualization of variables on the spaceships. However, the game became much richer and playable with the introduction of the overloaded avatars. The increased richness in gameplay appears to be the result of two main factors: better awareness of other players, and better potential strategies.

The ability to identify ships over time as well as specific players encouraged changes in gameplay. Users were soon able to pick on players that they had a grudge against, or go after the more dominant players. These effects, although fairly simple, made the game much more fun and inviting. Many of the participants soon developed more of a desire to play.

Even more important to the participants was the ability to actually form a strategy or technique based on what was known about opposing players. Without access to variables such as *damage*, *experience*, *shield strength*, and *power-up level*, it was not possible to determine how to approach another ship in the game. 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, and avoid Defaulter – who could have hid before [when the rich avatars were not present]."

The result of richer gameplay by overloading the embodiments is not that surprising. One of the main motivating factors for the creation of rich embodiment was to facilitate better interaction and collaboration in groupware. Thus, by creating rich avatars in Spacewar, an increase in interaction (in this case gameplay and strategy) among the players was seen. This provides strong evidence for the potential of richer embodiment in groupware. One of the participants noted that: "In some cases, 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."

The Importance of Real-Life Identity in Groupware

Throughout the game sessions, it became apparent that the real-life identity of a player was not as important as originally anticipated. Because players could enter whatever name they wanted, few players used their real names. Some of them used common handles and were more recognizable. However, it was difficult to figure out who a player was in the real world when they changed their Spacewar name. Nevertheless, most participants were able to eventually figure out who a player was by a process of elimination.

Similarly, when the participants were asked in the interview about privacy issues in sharing their name, gender, and perhaps age when playing online, most had no concerns. However, the majority said that it is easy to lie about those pieces of information, and moreover it isn't that important in a game setting.

Some of the users said that it might be interesting to see the real-world variables of other people. Perhaps in other groupware scenarios outside of a videogame this information would be valuable. For example, in chat systems it is common for people to ask "A/S/L?" for age, sex, and location. Some of the participants who play massively multiplayer online games noted that probably about half of the people in those games lie about their age and gender. However, one user stated that some players definitely do use games as a form of socializing and state their real name, age, and gender in order to get to know the people they are playing with and to form relationships.

Increased Personal Awareness

All of the participants were asked in the final interview if they looked to their own ship for information during the game. All of the users stated that they did in fact use at least one variable from their own avatar while playing. The most common attributes that were looked at were: *team colour*, *shield strength*, *damage*, and *power-up level*.

These variables were used for strategy mostly, such as running away when damaged or when having low shield strength. One player even noted that they would sometimes destroy their ship by striking a planet when they were really damaged, in order to avoid giving the other team a kill point.

Other variables that were used allowed the players to better analyze their performance. For example, some players stated that they looked to their own kill score and death score bars in order to see how they were performing in the game. Similarly, many players looked to see if they had gained a new experience level.

These results imply that information-rich embodiment not only allows for a better understanding of others within the shared space, but also has the potential to increase a participant's awareness about themselves within the groupware system. This is an additionally benefit from overloading embodiment in groupware.

5.5 Analysis and Implications

The qualitative analysis of the Spacewar study shows that the rich spaceship avatars did allow the participants to better recognize and characterize other users. The questionnaire and interview results show that in addition to being able to recognize other players, the avatars allowed for easier characterization of ship and player types.

The results show that users can and do use the encoded information, especially the variables that are most relevant to the task. In this case, information variables useful for game strategy were used, such as: *team*, *damage*, and *power-up level*. Similarly, the frequency with which this information is used is also dependent on the groupware task. In this study it was found that since Spacewar is a fast-pace groupware environment with a larger set of users, the participants frequently used the variables mapped onto the rich embodiments. The players expressed that the interpretation of avatars was almost constant during play, and soon became an integral part of the game. Not all of the variables were useful, and some appeared to never be used at all (e.g., the *gun reload* variable). This implies that not all information variables will be useful, but the key for designers is to reveal the variables that can enrich the interaction. Although these results may not be as apparent outside the context of groupware games, they show that there is a strong argument for the usability of information-rich embodiments.

As mentioned earlier, the interpretation of the variables became almost automatic when playing Spacewar. It did not take long for the participants to realize what information variables can help them better strategize their attacks and retreats. Once the importance of these variables was clear, they were read almost continually off of the spaceship embodiments. This automatic method of interpreting the data is a clear indication about the effectiveness of the mappings of the information variables. This result provides encouraging evidence that people can in fact successfully interpret the variables and the associated values of information that are graphically encoded on embodiments, even in situation where there are numerous embodiments moving within the shared space.

Although there are examples of rich embodiments in some current groupware systems [2][20], it is not known how content groupware users are with overloaded embodiment types. The data collected in this study shows that in the case of Spacewar, not only did the users like the rich embodiments, but they became a key part of the groupware system in general. Many of the participants stated that as the avatars became richer, the game itself became richer and interaction became more engaging. This result is encouraging; it reveals that rich avatars can be accepted by groupware users and they have the potential to become an almost integral part of the groupware systems. These results are specific to the Spacewar system, but they suggest the potential for increased richness and naturalness of groupware interaction by increasing the awareness among the participants using embodiment.

There were some initial concerns about the introduction of rich embodiment into a groupware application. One concern was the possibility of increased clutter in the groupspace by adding additional graphical elements. However, in the case of Spacewar, a total of thirteen additional graphical effects were applied to each avatar and none of the participants expressed confusion or frustration. There are two possible reasons for this result: a careful approach to the design of the rich avatars, and the user’s ability to disregard the graphical cues. Firstly, the mappings were chosen based on previous work on information visualization, as well as their appropriateness to the context. Secondly, people appear to be capable of ignoring the elements they do not require. This is an interesting outcome, and suggests that if users do not find a variable useful they are able to simply disregard its mapping.

Finally, there were several surprising results that arose from the study which were not anticipated at the outset. For example, it was not known how users currently recognize and characterize other people in existing non-rich groupware systems. However, even though the Spacewar application used rich embodiments, some characterization was still achieved by observing the actions of other users. Some players stated that, in addition to using the rich embodiments to recognise other players, they were also classified (i.e., novice, expert) based on their style of play. Additionally, the results showed that by enriching the avatars, the participants also gained awareness about themselves in the groupware system. This suggests an additional benefit of rich embodiment that provides groupware users with information that might not have been previously available.

5.6 Conclusion

The overall results from this study provide evidence that information-rich embodiment is useful to groupware users, and allows for better recognition and characterization. The majority of the participants frequently used some of the variables found on the spaceship embodiments throughout the study in order to recognize other ships and players. The rich embodiments were not required to play Spacewar, but improved the interaction among the participants. Additionally, the results show that although the mappings were simple, they were very effective at expressing the information variables.

The study has also shown that the findings from Chapter 4 do transfer to a real groupware environment. That is, users are able to recall and interpret the information variables that are graphically encoded on an embodiment, even if the embodiments are immersed in groupspace. This demonstrates that complex embodiments with many variables can be interpreted and used successfully.

Overall, the study reveals the performance of rich embodiment at solving problems of recognition and characterization in groupware. This suggests that groupware designers should consider the potential for improved interaction and collaboration by applying richer embodiment. Moreover, the results show that increased richness in groupware can be achieved by increasing awareness among the participants about each other.

Some caution must be taken when formalizing a conclusion from the results of the Spacewar research. The study only focused on a single groupware application, context, and embodiment. Although, we are confident that similar results could be seen in different groupware scenarios, the following chapter examines rich embodiment in a more-traditional groupware environment.

Chapter 6

The Performance of Information-Rich Embodiment in Grouper

The long-term Spacewar study provides strong qualitative data regarding the performance of rich user embodiment. For completeness, a second study was performed in order to examine the performance of a different type of embodiment (a telepointer) in a different task (collaborative sketching).

6.1 Goals

This study was intended to further investigate the questions outlined in the Spacewar study, while examining several other issues. Once again, the main goal was to observe how information-rich embodiment affects a person's ability to recognize and characterize other groupware users. The study was meant to be a follow-up to the previous. Some of the foremost questions to be answered were:

- Is there a variation in performance for different embodiment types (e.g., telepointer vs. avatar)?
- How does rich embodiment perform when a task is more collaborative than competitive?
- Is rich embodiment more helpful when users typically do not know each other?

Overall, this study was meant to address additional questions that were not completely answered by the results of the Spacewar study.

6.2 Study Design

A task was designed in which three participants collaborated to sketch various images on a shared canvas. In order to avoid real-world conversation among the participants during the trials, they were separated into different locations.

A total of 18 participants from various educational backgrounds completed the study in groups of three. There were 8 male and 10 female participants, with an average age of 27 (range from 19 to 38). The study took approximately one hour to complete, including orientation and training, the sketching trials, and the post-study questionnaire and interview. The main methods of collecting the qualitative data were questionnaires, interviews, and system logs. Additionally, the experimenter was present to observe the actions of the participants during their sketching trials.

6.2.1 The Grouper System

The Grouper (*GROUP-sketchER*) sketching system was created in order to further explore the performance of rich embodiment (in a separate context from the study in Chapter 5). The Grouper sketching task was considered more collaborative and required coordination between the participants, whereas the Spacewar task was more competitive. The user embodiment created for the Grouper program was a telepointer.

The Grouper application was built as a simple distributed group-sketching system with basic drawing functionality. The tools include: a draw tool for sketching lines with a one pixel width, a paint tool for creating lines ranging from 1 to 50 pixels in thickness, and an eraser tool with adjustable thickness (see Figure 33). Grouper also includes a ‘new canvas’ tool which completely clear the drawing canvas. When the ‘brush colour’ button is selected, a colour selection window appears and the user can choose the colour they wish to paint or draw with. Additionally, the application includes a spin-box widget that is used to set the stroke size for painting and erasing.

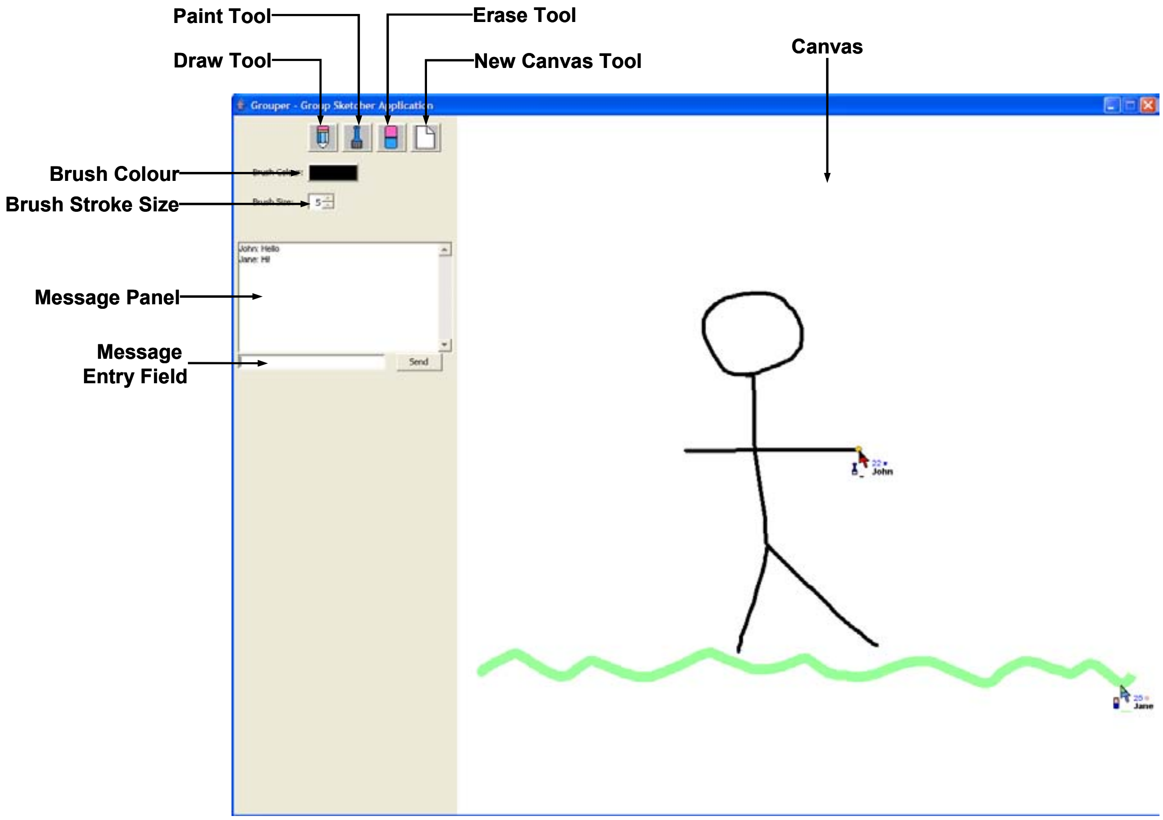


Figure 33. The features of the Grouper System

In order to allow communication among users, Grouper includes a chat panel. The functions of the chat panel are similar to a traditional chat system, with a message pane and a text entry field for messages.

Grouper also includes a user-information panel. The panel displays a set of the information regarding each user (the same variables used in the rich telepointers – see Section 6.2.2). To view the information of all the participants, a user must press the 'Escape' key and the panel appears over top of the drawing canvas (see Figure 34).

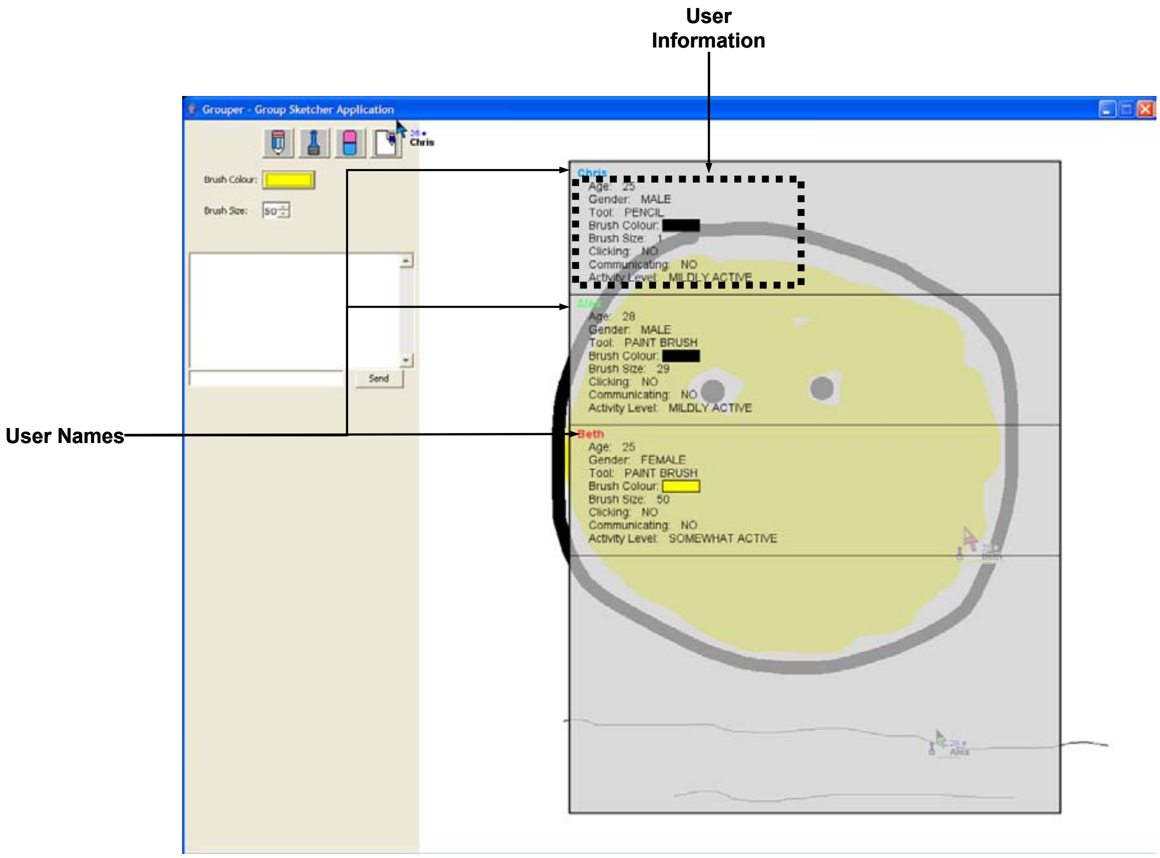


Figure 34. The Grouper user-information panel.

6.2.2 Grouper Embodiment

The embodiments developed for the Grouper application were motivated by the rich telepointers created in the initial feasibility study (see Section 3.2.2). The telepointers in the first study were designed around a hypothetical groupware version of Photoshop. However, since such an application does not exist, the Grouper system was created as a small-scale alternative. It was anticipated that by encoding specific variables on the Grouper telepointers, that users would be able to collaborate more easily and naturally.

Although the feature set of Grouper is small, there are several information variables that are encoded on the telepointers in an attempt to improve awareness. The variables chosen to be mapped on the telepointers are listed in Table 7, and their visual encodings can be seen in Figure 35. Once again, the basic information visualization rules of Mackinlay [34] were taken into account when creating the rich telepointers in the

Grouper system, and the mappings were chosen to be simple, and easy to recognize and understand.

Table 7. Variables, descriptions and visualizations of the Grouper telepointers

Information Variable	**Description**	**Visualization**
Name	The user's name or handle	Text string
Age	The user's personal age	Numerical string
Gender	The gender of the user	Coloured circle (blue for male, pink for female)
User Colour	A colour chosen in order to easily distinguish each telepointer	Telepointer body colour
Brush Colour	The selected colour for painting and drawing	Telepointer tip colour
Stroke Size	The chosen width of stokes when painting	Bar below telepointer (the bar width reflected the pixel with of the stroke size)
Tool	The currently selected tool (e.g. draw, paint, or erase)	Graphical icon
Communication Status	Indication to show when a user is typing a message in the message field	Red waves on either side of the telepointer
Click Status	Indication to show when a user is clicking or dragging with the mouse	Orange circle at the tip of the telepointer (appears only when clicking or dragging)
Activity Status	A measure of how active a user is on the canvas – either drawing, painting, or erasing	The size of the telepointer (the telepointer grows in size as activity level increases, and shrinks as activity level decreases)

Ten information variables are mapped onto the Grouper telepointers. The variables were selected based on their relevance to the sketching task and their ability to improve identification of users. There are several categories of information variables found on the telepointers:

- **Personal:** The personal variables are based on the real-world information of the person controlling the telepointer. These variables include *name*, *age*, and *gender*. A *user colour* is also specified and is shown on the main body of the telepointer and is intended to make a telepointer easier to locate (assuming all telepointers are given a unique colour).

- **Activity:** These variables are based on particular actions that occur in the groupware application. The *click status* variable simply states whether the mouse has been clicked or not. The *activity status* is a measure of the amount of recent actions performed on the Grouper canvas. The more actions (drawing, painting, or erasing) performed on the sketching canvas, the more a user's activity status increases. Conversely, if a user is idle their activity status begins to decrease over time.
- **State:** The state variables in Grouper are based on particular modes or conditions that arise. A user is in a *communication* state once they begin to type a message in the chat panel. The *tool* variable is simply set to whichever tool a user has selected (pen, brush, or eraser). Similarly, the *brush colour* and *stroke size* variables represent the most recent brush colour and brush size that the user has chosen.

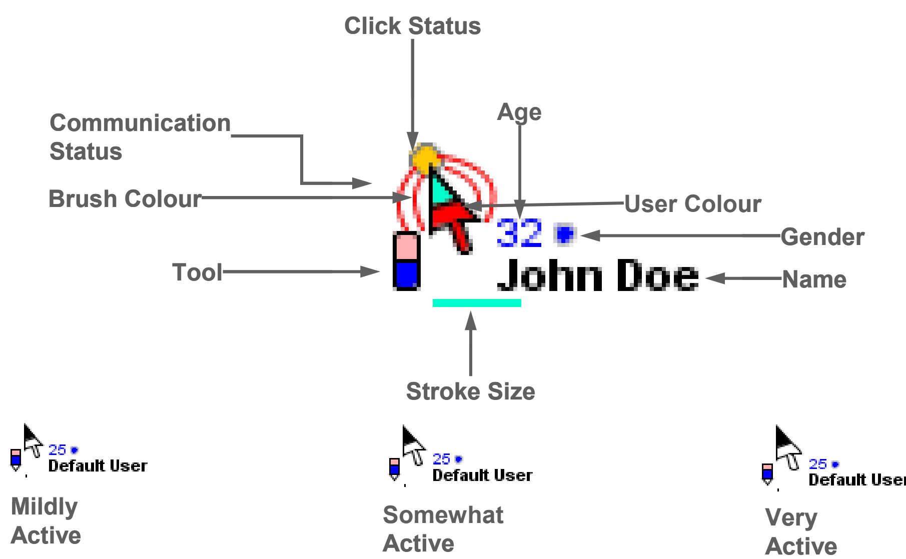


Figure 35. Rich Telepointer Index for Grouper

6.3 Methods

Six groups of three participants each were recruited from the University of Saskatchewan. There were 8 male and 10 female participants, with an average age of 27 (range from 19 to 38). In order to limit verbal communication among the participants and to mask their identities during the trials, the participants were placed into separate rooms.

Prior to beginning the study, each subject was given a demographics questionnaire and asked to complete a simple Ishihara colour blindness test in order to account for any problems with colour-encoded variables on the embodiments. Two of the 18 participants did show signs of colour blindness but they still completed the trials. The results of these particular participants, which deal specifically with colour, were excluded from the overall results analysis.

The experimenter introduced each participant to the Grouper sketching application and its functionality was explained. The participants were then introduced to the information variables displayed on the telepointers. Additionally, the user's personal cursor was adjusted to include their own data – a unique colour was given to each user, as well as their age, gender, and a name. In an attempt to mask identities, each participant chose a name handle from a list. An index with the information mappings was given to the participants for reference during the study. Once the users were familiar with the Grouper application and the information-rich telepointers, they were given a sheet containing four images that they were to sketch in collaboration with the other participants.

The groups were given approximately eight minutes to complete each of the first three sketches together. For the fourth and final sketch, all of the information encoded on the telepointers was disabled, except for the colour coding of each of the telepointers (this was done so that the participants could tell the cursors apart).

Once all the sketches were completed, the participants were asked to fill out a questionnaire regarding the rich telepointers. Following this, a brief group interview was performed (with all three participants) where they were asked questions regarding their experience and use of the telepointers.

6.4 Apparatus

The Grouper application was built using Java and the GT Groupware Toolkit. The sketching application relied heavily on the Java 2D graphics class, and therefore required significant processing power. Thus, three computers with 3GHz processors and graphics cards with 256MB of RAM or higher were used throughout the study. All three of the experiment machines ran Windows XP; however the application was tested and successfully run on a Macintosh.

6.5 Results

The results of the Grouper study are presented and discussed in the following sections. Aspects of recognition and characterization are examined, as well as the overall usefulness of the rich telepointers.

6.5.1 Recognition

It was anticipated that by including rich telepointers in Grouper the ability to recognize other participants would be increased. Of the 18 participants surveyed, 17 answered that the rich telepointers did allow them to better identify the person behind an embodiment. Moreover, only six participants felt that there was no difference in recognition when the sketching task was performed without the rich telepointers. These findings support the theory of improved awareness.

The variable that was cited as the most commonly used for recognition was *name*. However, during the interviews, many of the participants stated that the names were meaningless at the beginning of the trials because a mental model of the users what not yet known. For example, as one user stated: "the names were only good after I got to know the behaviours [of the other participants]." Similar statements show that it took some time before the *name* variable had any significance to the participants. Once a mental model of a person was created, then their displayed name could be associated with that model. This effect is illustrated by the following quote: "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 have an avatar in your head [of that person]." This phenomenon is compelling because the real names of the participants were not displayed. Thus, it appears that the *name* variable was simply the easiest way to correlate the perception of a person. This effect may be due to the fact that humans in the real world are strongly identified or associated by their given names.

Each participant was given a unique telepointer colour (red, green or blue). The telepointer colours provided another way for the participants to tell the cursors apart. It also allowed the users to better keep track of which telepointer was theirs. Interestingly, the name variable was used more frequently than colour to recognize people in Grouper. This may be because it is more intuitive to associate a person by name than by a specific colour.

The responses to the questionnaires show that several participants also used the *age* variable to recognize people in Grouper. From the interviews, it was discovered that the users who used the *age* variable knew at least who one of the other participants was. Since a person's real name was not shown, the *age* variable was the easiest way to determine who a person's real-world companion was.

The ability to recognize other people in Grouper was not as crucial as in Spacewar. Although the participants appreciated the ability to recognize other telepointers or participants, it was not required to complete the sketching trials. Whereas, in Spacewar, interaction with other people is core to the game task so recognition is much more essential.

6.5.2 Characterization

Due to the small scale of the Grouper sketching tasks and the limited time spent using the application (approximately 40 minutes), there was not enough experience to be able to fully characterize other participants. Despite this, the group awareness was definitely improved. This was shown by the approach that the majority of the participant groups used when working on a sketch. Most users would typically look to see which variables were set on the telepointers of their fellow collaborators to get an idea of which part of the sketch the other people were about to start on. Based on this information, a user would then orient themselves in order to begin working on another part of the drawing.

As an example, one of the participants stated: “I used the stroke size and brush colour to see what they [the other participants] are working on and to see what I should be doing.” This behaviour was common among the majority of the groups. Only one of the groups used the chat feature instead to discuss who would complete which portion of the sketch.

Characterization was possible and done frequently in Grouper, but appears less essential when compared to the Spacewar task. This result appears to be a consequence of the Grouper task itself. There are two main reasons why characterization occurred less frequently. First, the Spacewar game was much more competitive and the entire task was built around player interaction. This context makes user information valuable because it was helpful in strategizing. Conversely, the Grouper system did not require as strong an interaction among the participants. More specifically, the sketching task was not dependent on collaboration, and it was possible for a user to work on a drawing without interacting with the other group members. Second, the Spacewar study was more in-depth and involved more users over a much longer period of time. It is assumed that if the Grouper system was used regularly for a long time that characterization would become a more important factor. This is reflected by some of the statements of the participants who commented that if there were more people and the tasks were larger and more complex (e.g., more tools and detailed drawings) that the variables would have become used more frequently. Similarly, the Grouper study lasted only 40 minutes and did not allow enough time for the participants to notice all of the subtleties of their fellow collaborators.

Although characterization was less crucial in Grouper, the awareness among the users was definitely improved. The results show that collaboration was easier due to the rich telepointers. The users were able to avoid replicating the actions or work of their collaborators. This was made possible by interpreting the intentions (based on variables such as the *current tool* or chosen *brush colour*) of other people based on what was shown on their telepointers.

6.5.3 Usefulness

The participants were asked to specify the variables that were useful in the recognition of other group members (see Figure 36). The *name* variable was clearly used by most of the participants for recognition, the other variables are considered to be moderately-useful or unused for recognition.

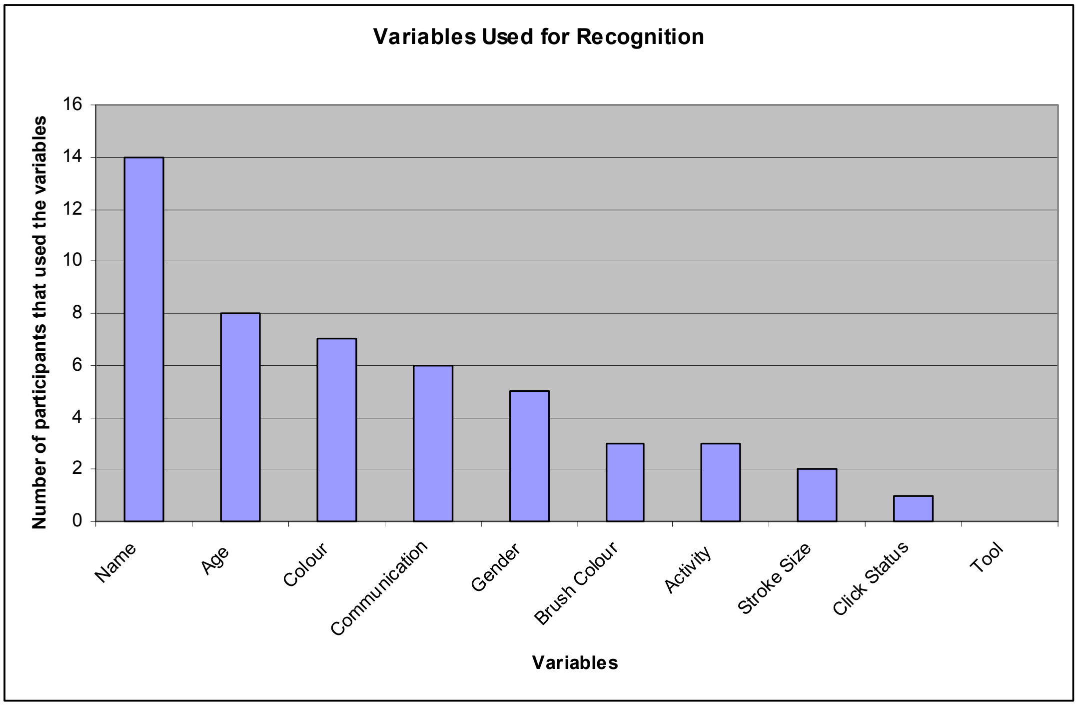


Figure 36. Variables used for recognition in Grouper

Strongly-Useful Variables:

The *name* variable was clearly the most used among the participants (14 out of 18). Many of the participants stated that, although they may not have known the person controlling a telepointer, the *name* variable was the best way to recognize a cursor. During the interviews, several of the participants said that they formed a mental model of each user and associate the model with a name. Based on the questionnaire results, it appears as though a name was the easiest way to locate another group member.

Moderately-Useful Variables:

The moderately-useful variables were considered by five or more participants to be useful in recognition, these include: *age*, *colour*, and *communication*. From the post-study interviews, it is apparent that those who used *age* for recognition relied on the variable to identify one of their friends – since real-world names were not displayed. It is surprising that *communication status* was listed as a variable used in recognition. The communication variable may have been used in parallel with the chat panel to gain a better understanding of who was doing what based on the messages that were sent. Finally, each participants was given a unique telepointer colour (red, green, or blue), and thus it was also considered to be useful in distinguishing among the users.

Least-Useful Variables

The remaining information variables (*gender*, *brush colour*, *stroke size*, *tool*, *click status*, and *activity level*) were rated as useful in recognition by five participants or less. Overall, the fact that these variables were not considered useful is understandable since most of the variables were constantly changing (besides *gender* and *activity status*). Gender only had an effect at the outset of the study when the participants first noticed the sex of their fellow collaborators. And the *activity status* may have been useful for characterizing collaborators but did not help with recognition.

6.5.4 Alternative Information Sources

The information variables displayed on the telepointers were also available on an information panel, as discussed earlier (see Section 6.2.1). A user had to press the 'Escape' key in order to see the summary of all of the group participants. This feature was added to Grouper in order to observe if the participants preferred the information panel as an alternative to the information-rich embodiments.

From the user logs and statements made by the participants, the information panel was only used a handful of times. Analysis of the logs show that only three people activated the panel when the rich telepointer were present, and seven participants used the panel when the rich embodiments were disabled (in the final trial). Moreover, the panel was activated for an average of 2.11 seconds with the rich telepointers, but displayed for over twice that time without the rich embodiments (4.78 seconds). The reasons why the information panel was used infrequently is considered in the analysis and implications section (see Section 6.6).

6.5.5 Other Observations

This section describes some of the findings and observations that resulted from the Grouper study.

The use of Chat

The chat feature was included in the Grouper system in order to allow for communication amongst the participants. The majority of the participant groups used the variables on the telepointers in order to decide which part of the sketch to work on. However, one group in particular relied more heavily on the chat feature in order to divide up the work before beginning a sketch. The three participants would discuss who would begin working on which part of the drawing first. The reason for this may be a result of politeness among the group members and the desire to not interfere with another person's effort.

The fact that five of the six groups used the embodiment variables more frequently to figure out the intentions of their fellow group members is compelling. The advantage of this technique is that it requires less time compared to discussing over the chat system. A user only needed to look at the other telepointers to get an idea of what the other participants were planning, and did not need to wait for a typed response from the collaborators. With this approach, most of the groups were able to start on a sketch almost immediately, and rarely did two participants begin working on the same area of a sketch.

Embodiment Movement

Based on the result of the user observations, it appears as though some of the information mappings were difficult to interpret in some instances. For example, some of the participants stated in the interviews that they did not use the tool icons, shown on the telepointers, because they were difficult to interpret when the telepointers were moving around the screen. This response is somewhat unexpected because the users were able to read the names and ages off the telepointers while they were moving. Therefore, it is possible that the tool variable was a less useful piece of information and was not worth examining. Some of the participants mentioned that Grouper only has three tools, and it was easy to tell what tool a person was using based on the actions they were performing on the canvas.

However, designers of rich embodiment should consider the difficulty users may encounter when attempting to interpret mappings while an embodiment is in motion. For example, a telepointer typically will move more rapidly on the screen compared to an avatar. Some visualizations, such as shape and size, may be more difficult to recognize if an embodiment is moving quickly and often in the workspace. Thus, information variables of greater importance should be mapped appropriately in order to make them easier to interpret while an embodiment is in motion.

Frequency of Interaction

As mentioned earlier, the Grouper study was performed as a follow-up study to the Spacewar experiment. However, from the Grouper results it appears that although rich embodiment was useful, it was not as essential to the task (compared to Spacewar). The reason for this is due to the context of the two applications. Spacewar is competitive and the participants were continually encountering one another. Although the participants needed to work together in the Grouper trials, it was not vital for them to collaborate. The rich telepointers were used at the beginning of each new sketch to determine who was about to start on which area of the drawing. Once each user determined the intentions of their collaborators, there was less need to focus on any of the other telepointers. The information on the telepointers did not become less useful, but they were less important since interaction among the users was less frequent.

Some of the participants stated in the interviews that they saw the potential of the information-rich telepointers in more complex scenarios. For example, if the features and tools were much more robust, or if there were more users during the trials. Additionally, the participants stated that if they collaborated over a longer period of time the information could have been more beneficial. This sentiment is reflected by the following quote: "… as I didn't know anyone, it didn't matter, at least in the short time. If you have been collaborating for three hours then you can start seeing personalities in the cursors."

6.6 Analysis and Implications

The questionnaire and interview results from the Grouper study show that recognition and characterization was possible with the rich telepointers. The *name* variable was the most useful in recognition. However, other variables (such as *brush colour* or *stroke*) allowed the participants to recognize what actions a person was about to perform. This increased awareness was one of the key benefits of applying rich telepointers to Grouper. With the information mappings present, the participants were able to more quickly orient themselves and avoid conflicts in the sketching task.

In the final sketch of the Grouper experiment, all the visualizations were removed from the cursors (except for telepointer colour). The majority of the participants preferred to have the rich telepointers and found recognition much more difficult without them. It was still possible for the users to complete the sketch, but the participants were not able to tell the other group members apart or what actions they were intending to perform.

Interestingly, the ability to get the same encoded information found on the rich telepointers in a data table was not useful to the participants. There are two possible reasons for this result: the effort required, or the importance of the information. First, to gain access to the user information panel, the participants had to press a key and the panel would appear over the canvas. This required an additional step, as opposed to just looking at the telepointers for the same information. Although the panel did cover the sketch canvas, it was slightly transparent so the participants could still see the actions of the other users. Second, as stated earlier, the variables encoded on the telepointers did improve the awareness among the users but it was not required for completing a sketch. Therefore, the participants may not have felt compelled to take the extra steps require to bring up the table with the user information. This result shows one advantage of rich embodiment, that information is displayed directly in the workspace and does not require a conscious effort to access it.

6.7 Conclusion

The results of this experiment strengthen the findings of the Spacewar study (see Chapter 5) by considering a different groupware environment and embodiment type. Analysis shows that recognition and characterization is still possible in a shared work context with rich telepointers. Similarly, this study reveals that the findings from the feasibility study in Chapter 4 are also valid in more traditional groupware environments. This is shown by the fact that the majority of the participants used some of the encoded variables on the Grouper telepointers, and that the information was interpreted properly.

In performing the Grouper study as a follow-up to the Spacewar experiment, the argument for rich embodiment is further supported. The results presented here provide additional evidence for the ability of information-rich embodiment to improve recognition and characterization, in addition to increasing the overall richness of collaboration in groupware.

Chapter 7

Discussion

7.1 Summary of Results

The three studies performed in this research provide a series of results about information-rich embodiments for groupware. The first study examined people's ability to remember and interpret the information encoded on graphical user embodiments. The results of the first study show that:

- People were able to recall an average of 13 out of 15 variables represented on embodiments;
- People could determine the values of the encoded variables on the embodiments with greater than 95% accuracy;
- Users could correctly locate embodiments matching a given criteria 87% of the time.

The second study looked at the performance of rich embodiment in the groupware game Spacewar. The results of the second study show that:

- People used rich embodiment for characterization and recognition of other avatars and players;
- The richness of gameplay was increased with the rich avatars, and allowed players to form better strategies in the game;
- Interpretation of the variables encoded on the embodiments became second nature to the participants;
- The rich embodiments did not clutter the shared space or distract players.

Finally, the third study was performed in order to examine the performance of rich embodiment in a more traditional groupware setting. The results of the third study show that:

- Rich telepointers were also useful to groupware users in the more traditional groupware task;
- People used the rich embodiments to identify collaborators and to maintain awareness in order to better coordinate on the given task.

7.2 Summary of Analysis

Participants in the first study (see Chapter 4) were successful at interpreting and recalling the variables found on the embodiment for three reasons: the attributes were based on well-understood concepts; the relation of the variables to the context; the natural mapping of several of the variables. Overall, the results of the first experiment reveal the potential of rich embodiment. First, by showing that people can recall many more variables from an embodiment than seen in any existing groupware system. Secondly, information that is not always available to groupware users is added to the embodiments.

The Spacewar study (see Chapter 5) shows that the information-rich embodiments were useful and helpful in the task. Not all the information variables were used, but the attributes that were valuable in the game were used frequently by the players. In addition to improving awareness in the groupware application, the information-rich embodiments also helped to enhance the richness of interaction.

The results of the Grouper study (see Chapter 6) further support the findings of the Spacewar experiment. The Grouper study used a more traditional groupware task, and showed that the information-rich telepointers improved awareness among the participants. Additionally, the participants preferred to have the variables displayed on the embodiments rather than a separate information table. The rich embodiments allowed the users to gather information more quickly and effectively.

7.3 Design Guidelines

The main lesson for groupware designers, which can be taken from this research, is that they should include more information on embodiments. Our experiments show that information-rich embodiment is feasible, and that people can and do use them for a variety of purposes. The Spacewar and Grouper studies show that avatars and telepointers can convey far more information than has previously been shown in groupware embodiments. It is anticipated that similar results are possible with other types of embodiment. Increasing the amount of information variables encoded on embodiments has the potential to lead to more natural and enhanced interaction.

Groupware designers should also consider the situations where information-rich embodiment would be useful and effective. There are three possible situations in which rich embodiment may be valuable. First, in cases where group members may not know one another. Here, any information could potentially be valuable, especially in cases with large groups were it is unlikely that people will have any knowledge about their collaborators. Second, when users know who their collaborators are, but not specific characteristics about them. In this situation, experiential, session, and application specific variables would be valuable to express on embodiments. Third, in scenarios were variables may change frequently during a session. Showing the dynamic information (such as current tool, or network delay) would provide better awareness among participants.

The results of this research suggest that increasing the amount of information available to groupware users will provide a much richer environment. Although current groupware is able to support interaction in collaborative tasks, it has a tendency to feel basic or unnatural. It is possible to increase the richness of interaction by providing a more expressive groupware environment. By presenting more information to groupware users, it will be possible for them to filter out the data they require and result in a more engaging and natural experience.

Chapter 8

Conclusion and Future Work

8.1 Summary

Traditional groupware embodiments represent far less information that what is available in face-to-face interaction. This lack of awareness can make it difficult to recognize and characterize other participants. The solution explored in this thesis is to present more information about users by enriching their embodiment.

Information-rich embodiment was tested in three separated studies. The first study showed the ability of users to recall and interpret a large set of information that is graphically encoded on embodiments. The second experiment showed that, in addition to improving characterization and recognition, rich embodiment is valuable for interaction and collaboration in an actual groupware setting – a multiplayer game. The third study further explored the effects that rich embodiment had on awareness in a more traditional groupware context – a shared drawing application.

Overall, information-rich embodiment is feasible and useful to groupware users. The additional information allows for better characterization and recognition among participants. This increased awareness leads to improved interaction and a richer groupware experience.

8.2 Contributions

This thesis has provided evidence that information-rich embodiment is feasible. The experiments show that it is possible to improve the recognition and characterization of other groupware users with richer user representations. Additionally, an approach for designing and creating rich embodiments was also developed. The application of this framework was applied to two separate applications and confirms that rich embodiment is possible in groupware.

8.3 Future Work

The initial experience of developing and building rich embodiment leads to a number of possibilities and issues for future research. A series of open questions and areas requiring additional work are presented in the following sections.

8.3.1 Future Studies

In future, more studies could be performed to examine: the longer-term effects of information-rich embodiment, limits on the number of variables possible, and harder measures on the usage of variables. Questionnaires and interviews were used in both the Grouper and Spacewar studies in order to collect data on the embodiment variables that participants used. The results put some trust in the responses of the participants. Therefore, in future studies harder measures could be achieved by using eye tracking to pinpoint the exact area of an embodiment a user is looking at.

8.3.2 Simplifying Development

In both example systems used in this research, the collection of data and the visualization of information were done manually. A more detailed framework for the creation of rich embodiment needs to be explored. Moreover, the development of a toolkit to simplify the overall construction of rich embodiment for groupware applications would be beneficial. There is the potential to make use of techniques such as shape grammars [32] – which are transformation rules that can be applied to 2D shapes – for easier visual effects. Exploration in this area could lead to a library of effects that designers could utilize when creating information-rich embodiments.

8.3.3 Privacy

It is anticipated that groupware users in a variety of contexts would be willing to share information with others; particularly if these elements would be available in face-to-face interaction. However, although there is the potential for improved interaction if more information is shared, some information may be considered personal. Additionally, there may be situations where groupware users would not want to divulge particular pieces of information. Therefore, we propose the need to investigate privacy issues in more detail, as well as the ability for users to control what information is displayed.

8.3.4 Personalization

As Benford et al. [2] suggest, embodiments should allow for personalization. Customization of avatars is common in many online games. The ability to alter the appearance of an avatar will lead to improved characterization. However, it is important to maintain some consistency among embodiments in a groupware system so that particular elements can still be recognized and interpreted. In the real world, people alter their appearance to express a variety of characteristics. More work is required in order to better understand how rich embodiments should handle this customization. For example, the visualization of some particular variables may need to remain consistent. Moreover, if embodiments are altered drastically and frequently, characterization would become much more difficult.

8.3.5 Improvements in Visualization

The visualizations included in this research involve simple 2D effects. More complex visualizations, such as textures, could provide further possibilities of information mapping. Similarly, the use of space surround embodiments could be utilized to display information using techniques such as traces (e.g., smoke trails behind a damaged ship).

Additionally, information-rich embodiments could be easily transferred into 3D groupware environments. More research is required into aspects that may arise in 3D space, such as the occlusion of information. For example, how to handle cases in which information is visualized on an area of an embodiment that is facing away for the point of view of other users.

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Appendix A – Consent From

UNIVERSITY OF SASKATCHEWAN
INFORMED CONSENT FORM

Research Project:	Rich User Embodiment in Groupware
Investigators:	*Carl Gutwin*, Department of Computer Science (966-8646)
	Tad Stach, Department of Computer Science (966-2327)

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

For this study you will be asked to carry out several trials of a given task.[…] .

At the end of the session, you will be given more information about the purpose and goals of the study, and there will be time for you to ask questions about the research.

The data collected from this study will be used in articles for publication in journals and conference proceedings.

As one way of thanking you for your time, we will be pleased to make available to you a summary of the results of this study once they have been compiled (they will be made available on the HCI web site, hci.usask.ca). This summary will outline the research and discuss our findings and recommendations.

All of the information we collect from you (data logged by the computer, observations made by the experimenters, interview responses, and your questionnaire responses) will be stored so that your name is not associated with it (using an arbitrary participant number). Any write-ups of the data will not include any information that can be linked directly to you. The research materials will be stored with complete security throughout the entire investigation. Do you have any questions about this aspect of the study?

You are free to withdraw from the study at any time without penalty and without losing any advertised benefits. Withdrawal from the study will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed. In addition, you are free to not answer specific items or questions on questionnaires.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

- Dr. Carl Gutwin, Associate Professor — Dept. Computer Science — (306) 966-8646
  gutwin@cs.usask.ca
- Office of Research Services — University of Saskatchewan — (306) 966-4053

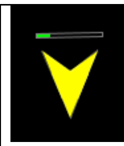
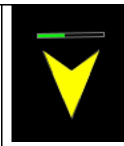
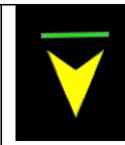
Participant's signature: ____
Date: _____________________
Investigator's signature: ____
Date: _____________________

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Office of Research Services at the University of Saskatchewan.

Appendix B – Experiment 1

Examples of the Indexes

Kill Score

The amount of green fill in the bar located above the ship is a measure of the number of kills the player has scored.						
Kill Score	0	10	20	30	40	50

Experience

The more experienced a player is, the more 'spikes' are added to the ship. This measurement is for overall game play, not the current session.					
Experience	0	1	2	3	4

User Name

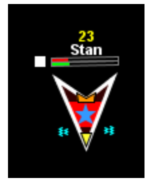
The name string is displayed at the bottom right of the cursor.			
Name	Alice	Bob	Cathy

Foreground Colour

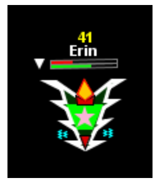
The user's current foreground colour is displayed in the coloured tip of the cursor.				
Foreground Colour	Black	White	Orange	Pink

Example Task Questions

1. Please list all the information variables (and their values) you recognize in the ship and the visualizations that represent them:



2. Please set all of the information variables you recognize in this ship:



Name: ______________________

Gender: ☐Male ☐Female

Age: ______________________

Team: ☐Alpha ☐Delta ☐Epsilon ☐Zeta

Lifetime: 1 2 3 4 5 6 7

Kill Score: 0 10 20 30 40 50

Death Score: 0 10 20 30 40 50

Experience: ☐0 ☐1 ☐2 ☐3 ☐4

Shields: 0 1 2 3 4

Ship Damage: 0 1 2 3 4

Thrust: ☐On ☐Off

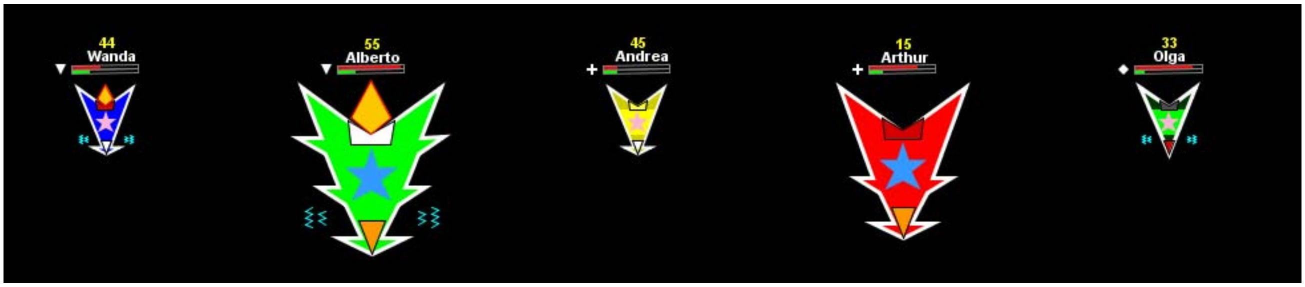
Engine Heat: 0 1 2 3 4

Gun Heat: 0 1 2 3 4

Communication: ☐On ☐Off

Role: ☐Medic ☐Transport ☐Fighter ☐Bomber

3. Imagine you have to choose one of the following ships as a possible opponent to attack. Please select one of the ships and explain your choice.



Example Debriefing Questions

1. Indicate the level of difficulty that you had ***remembering*** each representation used in the spaceship avatar.

Player Name	Low						High
Team	Low						High
Lifetime	Low						High
Kill Score	Low						High
Death Score	Low						High
Experience	Low						High
Gender	Low						High
Shields	Low						High
Age	Low						High
Ship Damage	Low						High
Thrust	Low						High
Engine Heat	Low						High
Gun Heat	Low						High
Communication	Low						High
Role	Low						High

For the representations with low score, explain the reasons for your rating.

For the representation with high scores, explain the reasons for your rating.

Appendix C – Experiment 2

Spacewar Questionnaire

1. Did the variables displayed on the ships allow you to better identify who was the player behind it?
   ☐ YES ☐ NO

   Comments:

---

2. Would you have been able to just as easily identify a person if only the names were displayed?
   ☐ YES ☐ NO

   Comments:

---

3. What variables helped you to recognize someone in the game?

☐ Name	☐ Shield Strength
☐ Gender	☐ Damage
☐ Kill Score	☐ Team
☐ Death Score	☐ Gun Reload
☐ Communication	☐ Experience Level
☐ Engine Heat	☐ Power-Up Level
☐ Gun Heat	

   Comments:

---

4. Please rate how useful each variable was when interacting with others:

   (1= very useful; 5 = not at all)

	1	2	3	4	5
Name					
Gender					
Kill Score					
Death Score					
Communication					
Engine Heat					
Gun Heat					
Shield Strength					
Damage					
Team					
Gun Reload					
Experience Level					
Power-Up Level					

5. For each variable, if you ever used it, please indicate for what purpose:

Variable	Purpose
Name	
Gender	
Kill Score	
Death Score	
Communication	
Engine Heat	
Gun Heat	
Shield Strength	
Damage	
Team	
Gun Reload	
Experience Level	
Power-Up Level	

Appendix D – Experiment 3

Grouper Questionnaire

6. Did the variables displayed on the telepointers (cursors) allow you to better identify who was the person behind it?
☐ YES ☐ NO

Comments:

---

7. Were you able to just as easily identify a person when only the colours were displayed?
☐ YES ☐ NO

Comments:

---

8. What variables helped you to recognize someone in the Grouper application?

☐ Name	☐ Stoke Size
☐ Gender	☐ Tool
☐ Age	☐ Click Status
☐ Colour	☐ Communication Status
☐ Brush Colour	☐ Activity Status

Comments:

---

9. Please rate how useful each variable was when interacting with others:

(1= not at all; 5 = very useful)

	1	**2**	**3**	**4**	**5**
Name					
Gender					
Age					
Colour					
Brush Colour					
Stroke Size					
Tool					
Click Status					
Communication Status					
Activity Status					

10. For each variable, if you ever used it, please indicate for what purpose:

Variable	Purpose
Name	
Gender	
Age	
Colour	
Brush Colour	
Stroke Size	
Tool	
Click Status	
Communication Status	
Activity Status	