# A Guided Exploration Model of Problem-Solving Discovery Learning

by

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Abstract

**A Guided Exploration Model of Problem-Solving Discovery Learning**

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This dissertation concerns development of a model to represent problem-solving discovery learning. The model shows the steps learners must take when content is presented in a form that requires that they discover solutions to problems encountered in pursuing a challenging learning task. Confidence, interest, and learning are increased when learners make use of a minimal knowledge base containing facts and rules that are essential to know to accomplish the task but are difficult or impossible to infer solely from exploring the task environment. Because only facts and rules can be acquired from the knowledge base, learners must discover and correctly sequence the problem solution procedures by reflecting on content acquired from both the task environment and the knowledge base. The model is based on convergent theories of learning, both cognitive and behavioral, and extensive data obtained from eight subjects engaged with an intrinsically motivating, software-based learning task. The software used for the learning task was a popular commercial adventure game with a point-and-click interface. Intrinsic motivation and exploratory learning

are characterized from responses to experience sampling questionnaires and analysis of the video/audio recordings of subjects' interactions with the software. For subjects who solved the game, retention of procedural knowledge was assessed with a comprehensive, written posttest proctored one day and one week following completion of the last data collecting session. Across the eight subjects, a continuum of individual differences was observed. Five of the eight completed the learning task in 7-10 hours and were moderately or strongly motivated, scoring higher than 97% on both posttests. In sharp contrast, the three nonlearners experienced high levels of frustration and boredom and, despite spending between 2.5 and 5 hours on task, made insignificant progress toward the learning objectives. The essential difference in performance between the learning and nonlearning groups, as well as the differences in performance between individuals, was the degree to which subjects understood the guided exploration learning model and applied it to the task.

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## Preface

Late in 1992 I exchanged electronic mail with Professor Gavriel Salomon of Haifa University. Our correspondence addressed some issues concerning the way students learn — issues like engagement with the learning process, mindfulness, and perceptions of mental effort and enjoyment during learning activities. Professor Salomon and I had on several occasions discussed the advantages and shortcomings of computers as instructional devices. Salomon had written about a construct for differences in student perception of task difficulty that varied according to the medium of transmission (television or books) for which he coined the expression, "AIME," or "amount of invested mental effort" (Salomon, 1983). I had been wondering about another possible independent variable and suggested "AEE," for "amount of expected enjoyment." Professor Salomon asked whether I had thought of correlating AEE and AIME (Salomon, personal communication December 18, 1992).

The suggestion to correlate AEE and AIME was intriguing. Results of studies of AIME suggested that students learn more from what they believe to be hard, AEE suggests they may learn more from what they believe they enjoy. The questions I began to ask were: Do students engage in more elaboration when they enjoy something or when they think it is hard? What is the relationship between difficulty and enjoyment?

Lepper, Chabay, and Malone had argued throughout the 1980s, separately and together, that people are motivated by computer games because they expect to have fun, not because they think of them as hard, offering what some consider the theoretical basis for so-called "edutainment" software, which is supposed to offer instruction with the look and feel of recreation — i.e., computer-based entertainment that teaches (Lepper, 1985; Lepper & Chabay, 1985; Lepper & Malone, 1987; Malone, 1980, 1981; Malone & Lepper, 1987). Salomon was suggesting correlating measurements of enjoyment and assessments of mental effort, but Lepper and Malone, along with others investigating intrinsic motivation, had suggested that enjoyment might mediate perceptions of effort. And Csikszentmihalyi (1965, 1975, 1978, 1988a, 1988b, 1988c, 1990) had identified an autotelic experiential state of consciousness that his research subjects had called "flow," in which peak performances are so optimized that they are experienced as effort*less*. I wondered if, instead of an estimate of mental effort, learning itself might be found to be correlated with estimates of enjoyment.

A study that would find greater learning in the presence of both high difficulty and high enjoyment would resolve the conflict between Salomon's finding that students learn more when they report they exert more effort on tasks deemed more difficult and Csikszentmihalyi's finding that people function best when the activity is both difficult and not effortful. I thought perhaps a way could be found to apply some of the motivating attributes of computer games, if they could be found, so that the greater mental effort required for optimal learning could be experienced as effortless by a learner. In the end I decided to adapt methods developed by Csikszentmihalyi and others for quantitative studies to the qualitative analysis of the experience of problem-solving learning when the learning task is to solve a complex computer adventure game.

# Acknowledgments

I am especially grateful to Bill Winn for "lighting the fuse" and keeping the faith. I also want to thank Owen White and Sue Nolen for suggesting key elements of the data-collecting interface, and Mihalyi Csikszentmihalyi for essential methodological guidance. Of course, this project would not have been possible except for the creativity of Will Crowther and Don Woods. Joe Fenton and Jim Drew deserve mention for inventing the Emplant and for extensive personal assistance. Finally, I want to say a special "thank you" to my anonymous subjects for freely contributing their time and mental energies.

For LaVonne

# Chapter 1: Introduction

## Relevance of this Research to Education

Much has been written on the alleged benefits of including elements of computer games in designs of computer-based instruction (Gredler, 1996; Randel et al., 1992). At least two reasons for doing so have been advanced: (1) game-like elements may stimulate the learner to work with the instruction over a longer period of time and with deeper involvement than didactic tutorial or drill-and-practice designs that do not contain such elements (Lepper 1985; Lepper and Chabay 1985; Lepper and Malone 1987; Malone 1980, 1981; Malone and Lepper 1987), and (2) the instruction can be "contextualized," reducing the probability that the acquired knowledge will remain "inert" (Whitehead, 1929) by facilitating construction of a "rich image or mental model of the problem situation" (Bransford, et al. 1990; Cognition and Technology Group at Vanderbilt 1991, 35-36).

This document does not advocate educational computer or video game use and is not about the benefits or detriments of software, or of computers and computer games in schools. Rather, it is about a way of studying how and why some people learn, and other people do not learn when engaged with a learning task that is supposed to be fun. It is about a way of using software as a tool for data generation and the computer as both teaching machine and data collector. The project examines the relationship of learning and motivation to generate and validate a general model of problem-solving learning that is applicable to design of instructional environments, particularly in subject areas for which narrative treatment of instructional content is the norm. Using the game as both a lure for recruiting subjects and a circumscribed exercise in learning that can be observed with remote or semi-remote observational devices and instruments, the research questions ask:

- What are the characteristics of success with this type of learning?
- How effective is this type of learning?

Although Malone (1980, 1981) first outlined the elements of his theory of learning with "intrinsically motivating computer games" nearly two decades ago, and that work has been cited frequently to support claims for the educational superiority of software that embeds instruction within recreational forms, few studies based on Malone's notions of challenge, fantasy, and curiosity have been published (Dempsey, et al., 1993). But the possibilities envisioned by that work and by his and Lepper's subsequent work throughout the 1980s are no less interesting now than they were then (Lepper & Malone, 1987; Malone, 1980, 1981; Malone & Lepper, 1987). In his fourth extended essay on psychology of design, Norman (1993) wrote: ". . . activities for recreation and education are essentially identical. . . [yet] people are typically willing to exert great mental effort upon their recreational but not their educational activities" (p. 32). Norman observed children playing "video" games and noted that the games (p. 38):

- Are not simple
- Can take days or weeks to play
- Require a large amount of knowledge, exploration, and hypothesis testing

- Require problem solving — saving the current state of the game and tentatively exploring novel states, then comparing the results, returning to the saved state when necessary
- Require study and debate among fellow players and the reading of hint books that suggest or explicitly reveal the solutions
- Require reflection

He concludes: "In other words, the games require just the behavior we wish these same children would apply to schoolwork" (p. 38).

Of course, Norman's comments do not accurately characterize what goes on in video game arcades, but they do describe the activities and requirements of successfully negotiating a type of desktop computer game: the "adventure game." Adventure games are dramatic simulations of real or imaginary situations that unfold within complex environments. They can be designed to communicate instructional content while supporting both "experiential" and "reflective" modes of learning (Norman, 1993).

Chapter 3 of this report sketches the details and theoretical foundations of a general model for conceptualizing problem-solving learning both online and offline. The model is based on observation of the learning required to solve a computer-based adventure game that was supplemented with the addition of a "minimal" knowledge base containing clues and essential information. The adventure game used in the project, *King's Quest V,* engages players in every one of the activities observed by Norman.

## Characteristics of the Adventure Game

An adventure game is a collaboration between art and technology. It was never intended to be used as a mechanism for teaching or an instrument of research. However, as an artifact of late 20th Century culture, it and its effects are of interest as objects of study. For this research, I have commandeered one example of the genre to study some aspects of problem-solving learning. The adventure game offers convenience as well as high complexity — a combination rarely found either in the laboratory or in nature.

Adventure games are text-, graphics-, or video-based computer programs that deliver interactive, fictional or nonfictional narrative content. The earliest examples, dating from the 1970s, required the player to interrogate the computer and construct the game's narrative from clues while imagining the temporal and spatial detail, just as one does when reading a novel or short story. Originally written by computer programmers for their own amusement, the early games were played obsessively by adults and often required extensive note taking and map making (Kidder, 1981). Recently produced examples combine interactivity with some elements of the motion picture — sophisticated animation or full-motion video, music, and sound effects. The object of solving an adventure game is to discover a concealed narrative by overcoming roadblocks and resolving the dilemmas one encounters in exploring the environment or "world" represented on the computer screen.

Nelson (1995) characterizes the adventure game as "a crossword at war with a narrative." In Nelson's scheme, "narrative" refers to the global elements — plot, structure, genre — and "crossword" to the local elements —

puzzles and rooms. These interactive environments initially conceal the information that can lead the player to some terminal goal. A series of problems or subgoals, called "puzzles," must be solved, usually in a specific sequence, to reach the terminal goal. The game is an interactive environment in which the choices for correct action under total or partial control of the learner combine to form a narrative.

The adventure game player must find information that can lead the game’s protagonist to the solution through exploring: wandering, looking, touching, trying various objects in one’s "inventory," and "talking" or otherwise interacting with the characters one meets along the way. Dozens of roadblocks must be overcome and dilemmas resolved, often only through great patience, persistence, and ingenuity. After finding the solution to a puzzle, the player may be rewarded with a bit of music and a clever animated sequence, plus control of or access to additional clues, tools (necessary objects and other resources), and / or information, that he or she needs to continue to advance toward the final goal. If the purpose of such a game is instructional, the clues leading to the attainment of the goal may convey the content to be learned. The narrative quality of this genre requires that players acquire and remember a large number of facts, concepts, and rules concerning the game’s imaginary or realistic world and its occupants. It also requires them to make choices among alternative actions, then, through exploration, hypothesis testing, problem solving, study, and reflection, construct a series of possible intermediate solutions that can open the way to the terminal goal. This complexity, and the reflection it requires, are what make the adventure game potentially of greater educational utility than computer or video games that emphasize little more than motor skills, simple memorization, or drill and practice.

Although one or two very successful alternative approaches have been used, the classical adventure game employs an expository style with narration (narrative voice in text or audio) in which characters act, interact with and talk to one another, and in which the player acts in ways that affect the outcomes or consequences of the actions the characters perform. Another important characteristic is the variation of mood across the different settings one encounters — e.g., town, forest, desert, or seashore. These changes are indicated through the graphics, music, and different events and imply different expectations and affordances for acting and solving problems in the different settings.

Olsen (1991, 2-1) describes the designer's approach to building goal hierarchies to create problem-solving challenges:

> The game should constantly make the player ask himself, 'what do I do next?' or 'how do I do that?'. . . For example, the player's final goal might be to release the princess from a magic spell. One smaller goal might be to find the ancient manuscript which lists the ingredients for an antidote to awaken the princess. Other goals could be gathering the necessary ingredients to make the potion. The player might have to find the feather of the giant Roc. Or collect sand from the Kalahari. Or obtain the web from a black widow spider.

Olsen continues with this example to illustrate how puzzles should be layered:

> Take the example of obtaining the feather from a giant Roc. Try to make it more difficult by splitting the task into further small goals. Let's say the player cannot find a feather that has been shed from the bird. She can only pluck one from the bird itself. So she builds a giant trap. But building the trap requires a lot of netting. She has to get this somewhere. Perhaps there is a stand in the bazaar that sells netting. But she has no money. So she has to get a job . . . . Small goals like these make reaching the larger goal more fulfilling (Olsen 1991, 2-2).

An undesirable though functional characteristic of many adventure games is that mistakes are catastrophic — the protagonist / player trips and falls over a cliff or is dispatched by the villain and the game ends. This tradition began with the first adventure game, and is analogous to the "fatal error" sometimes seen when programs encounter unrecoverable bugs or attempt to perform actions that are not allowed by programming rules. There is often no way to recover from a mishap in adventure games, except to "restore" to a point before the error occurred and try again. Sometimes these "deaths" are a result of player error, but more often they are programmed in as a story element or consequence of not solving a puzzle or eliminating a threat. Game "saves" are like bookmarks that allow one to return to a point previous to the point where the fatal error occurred. Repeated "dying" and "restoring" intensifies frustration — which may trigger inquiry behavior if a hint guide is available, and if not, can cause the player to give up. Although some means of providing roadblocks to identify puzzles and intensify frustration is necessary, "killing" the main character is not the only way it can be done. A few games have managed more creative ways of handling error and puzzle identification, like detours or penalties less severe than "death."

Another important characteristic of adventure games is that they afford limited options for action and conversation. Limits are necessary to set boundaries that constrain the imagination, lest it stray too far from the narrative it is trying to discover, and as a way to signal the existence of a puzzle.

## Development of the Adventure Game

The first adventure game was created in a few weekends by programming wizard Will Crowther in Massachusetts in 1976 and enthusiastically elaborated and enhanced by graduate student Don Woods in California a few months later. *Adventure* was unlike any previous computer game and became part of computer culture almost overnight. Within months of its creation, *Adventure* circulated like a chain letter on networks from coast to coast as engineers and hackers worked through breaks and late into the night "going over every variation of every possibly relevant parameter of the situation" (Carroll, 1990, p. 103; Hafner & Lyon, 1996; Kidder, 1981; Levy, 1984; Nelson, 1995). Over the next 20 years, *Adventure* spawned many revisions, versions, and imitations, in addition to launching an entire industry of interactive entertainment (Levy, 1984; Nelson, 1995; Williams, 1996; ).

*Adventure* thrusts the player into an imaginary world where the goal is to find and recover treasure hidden underground in a fantastic cavern. Though the concept is based on the fantasy role-playing game Dungeons and Dragons, the setting for *Adventure's* imaginary tale was drawn from Crowther's vivid mental images of the features of a real subterranean world — part of the most extensive natural system of underground passageways on earth — that Crowther was helping to explore at the time (W. Crowther personal communication November 6, 1996; Hafner & Lyon, 1996; D. Woods personal communication October 12, 1996).

Kidder (1981) writes of his own encounter with *Adventure* late at night in the basement of Westborough at Data General in 1979 (p. 115):

> After you have moved, a message appears on the screen telling you where you are and what you are confronting. You must respond, in two words or less, both to opportunities — treasure or tools lying on the floor of some chamber — and to threats and challenges — the hatchet-hurling dwarf, the snake, the troll who guards the bridge, the dragon. If, for instance, you want to get past the rusty door in one of the chambers, you have to think of what will conquer rust, then you have to remember where it was you saw that pool of oil, then you have to type in step-by-step instructions to get back to that oil, and then, because the computer will let you carry only so many things, you may have to drop one of your tools or treasures — DROP GOLD COINS, you might write — and then type in, TAKE OIL. Of course, you must already be holding a container for the oil. Then you have to retrace your steps back to the rusty door and type, OIL DOOR.

What follows is a brief historical sketch based on several sources, including Hafner and Lyon (1996), Don Woods (prepared statement, personal communication), Levy (1984), and Williams (1996). Will Crowther himself was kind enough to verify, correct, and elaborate much of it (W. Crowther, personal communication November 6, 1996). The alleged case of spontaneous transfer (Park, 1994) was verified in correspondence and a telephone conversation with Beverly Schwartz at her office at Bolt, Beranek, & Neuman (B. Schwartz, personal communication November 17, 1997).

Concerning Crowther's role in the invention of "dynamic routing," a major engineering challenge in the development of the first computer network, Hafner and Lyon (1996) write:

> Crowther's dynamic-routing algorithm was a piece of programming poetry. "It was incredibly minimalistic and worked astoundingly well," [Dave] Walden observed. Crowther was regarded by his colleagues as being within the top fraction of 1 percent of programmers in the world. . . "Most of the rest of us made our livings handling the details resulting from Will's use of his brain," Walden observed.

In addition to his central contribution to the creation of the Internet, Will Crowther was a pioneer in the use of computers in cave cartography. He was in charge of the enormous map of the known portions of Mammoth Cave in central Kentucky during the 1960s and 1970s. In fact, he did all the work himself on an old teletype at his home in Cambridge, Massachusetts. That teletype was attached via a slow modem link to the PDP-1 minicomputer at Bolt, Beranek, and Newman, Inc. (BBN) where Crowther worked (and where he wrote the first Internet packet-switching code). He used the same teletype to teach his two children arithmetic ("It typed out 2 + 3 = and rang the bell if the kids typed 5"), and it was on that teletype machine that they, then five and seven, first played *Adventure* (W. Crowther personal communication November 8, 1996; Hafner & Lyon, 1996).

Though Crowther wrote *Adventure* partly for fun and for something to amuse his two children and a few friends, an important motivation was his interest in natural language processing. In creating *Adventure* he put great effort into deciding which words from the whole of the English language to implement so that people could control the game using just two words at a time. In addition, he wanted to push the possibilities that the technology affords:

> I have at various times made different "adventures." Two stand out. One had hundreds of objects. I made a dump next to the well house, with all sorts of junk. My goal was to implement the semantics of all the concrete nouns I could think of. I particularly remember the problems involved in "cutting a rope." Cut a rope and you have two ropes — everyone knows that. Cut the rope 1000 times and what do you have? Certainly not 1001 ropes. On the other hand, burning something was easy. If you set it afire, it changes into a new thing (which emits light and heat), and then after N ticks changes again into something else (often ashes). This is just an object with three states, just like the plant in the original adventure.

> The second had an elf. To succeed at the elf puzzle, you had to talk to the elf for a while (10-20 utterances) without making him mad. Then he would invite you home for tea, where you could get on with the rest of the game. I didn't do very well at making an elf who was a good conversationalist, but that was the goal. The elf, of course, had emotions and goals and opinions; you had to learn which conversational buttons to push to get his emotions into the "friendly" state. That involved asking (politely) about his family (W. Crowther personal communication November 6, 1996).

One of those who stumbled upon and was captivated by *Adventure* was Scott Adams. Adams was so intrigued that he and his wife Alexis founded a company called Adventure International in Longwood, Florida and began publishing their own adventures — 18 games in all — between 1978 and 1985 (Nelson, 1985; Williams, 1996). In the early eighties a company called Infocom created many more critically acclaimed *Adventure*-style games, the best known being *Zork*. Over the years at least 244 companies have published adventure games with varying degrees of success (Persson, 1998).

The most successful of the enterprises to spring from Crowther & Woods' creation was the software mega-publisher Sierra On-Line. In 1979, Ken Williams, a California-based mainframe programmer, found a version of the game on one of the mainframe computers he was programming and showed it to his wife, Roberta. Like everyone before them, neither Ken nor Roberta had ever seen anything like it. Levy (1984) quotes Roberta Williams:

> I just couldn’t stop. It was compulsive. I started playing it and kept playing it. I had a baby at the time. Chris was eight months old; I totally ignored him. I didn’t want to be bothered. I didn’t want to stop and make dinner.

Discovering the final solution to the game a month later, Roberta wanted more, but could not find other games to pursue that were as satisfying as *Adventure.* So she decided to create her own and to add a new element — graphics. After convincing her husband to handle the coding and figure out how to make their new Apple II render some 70 line drawings to accompany the text descriptions, the Williams’ first adventure game, *Mystery House* was designed, written, illustrated, and coded in about three months (Williams, 1996). As *Adventure* had been based on Dungeons and Dragons, *Mystery House* was inspired by Agatha Christie’s *Ten Little Indians* and the board game "Clue." In May of 1980 the Williams’ invested $200 to place an ad in a small computer magazine in an attempt to sell their new game to other computer hobbyists through mail order from their California home for $24.95 a copy. In the first three months after they placed the ad, May-July of 1980, the couple made over $60,000 from sales through that ad (Levy, 1984, pp. 297-300). *The Wizard and the Princess* followed *Mystery House* later that year, then in 1981 with encouragement and funding from IBM came *King’s Quest I* for the (new) IBM PC, and the most successful commercial computer game series in history was launched.

Published nine years later, *King's Quest V*, the game selected for this study, was the first adventure game to use a "point-and-click" interface and the first product of the Williams' enterprise to sell a half-million copies (Williams, 1996). With its innovative interface, actions in *King's Quest V* are initiated when the player positions one of several action-specific mouse pointers within a three-dimensional, hand-painted scene (Figure 1) and presses ("clicks") a mouse button. In the example shown in Figure 1, selecting the "hand" from the drop-down menu attaches the "hand" to the mouse pointer. Clicking the mouse pointer "hand" in the pool of water causes the animated character to drink from the desert oasis. Actions and pointers include walking, talking, seeing, grasping, pushing, climbing, opening, drinking, etc. Animated characters and objects, extended video sequences, sound effects, and a continuous music track add drama and realism.

> After *King's Quest IV* and *The Colonel's Bequest*, I needed to rethink the basics for *King's Quest V*. The market was changing to where most people didn't want to take the time to learn to type, spell, or figure out just how you talk to a computer via an adventure game. I had to design an icon interface with that future in mind; something that's about as easy to use as it's going to get. On a design note, I preferred working with the no-typing interface because I had more time to think about the plot and puzzles instead of writing all those error messages for people typing things that alternated from the story. Unfortunately it took some time to realize all the

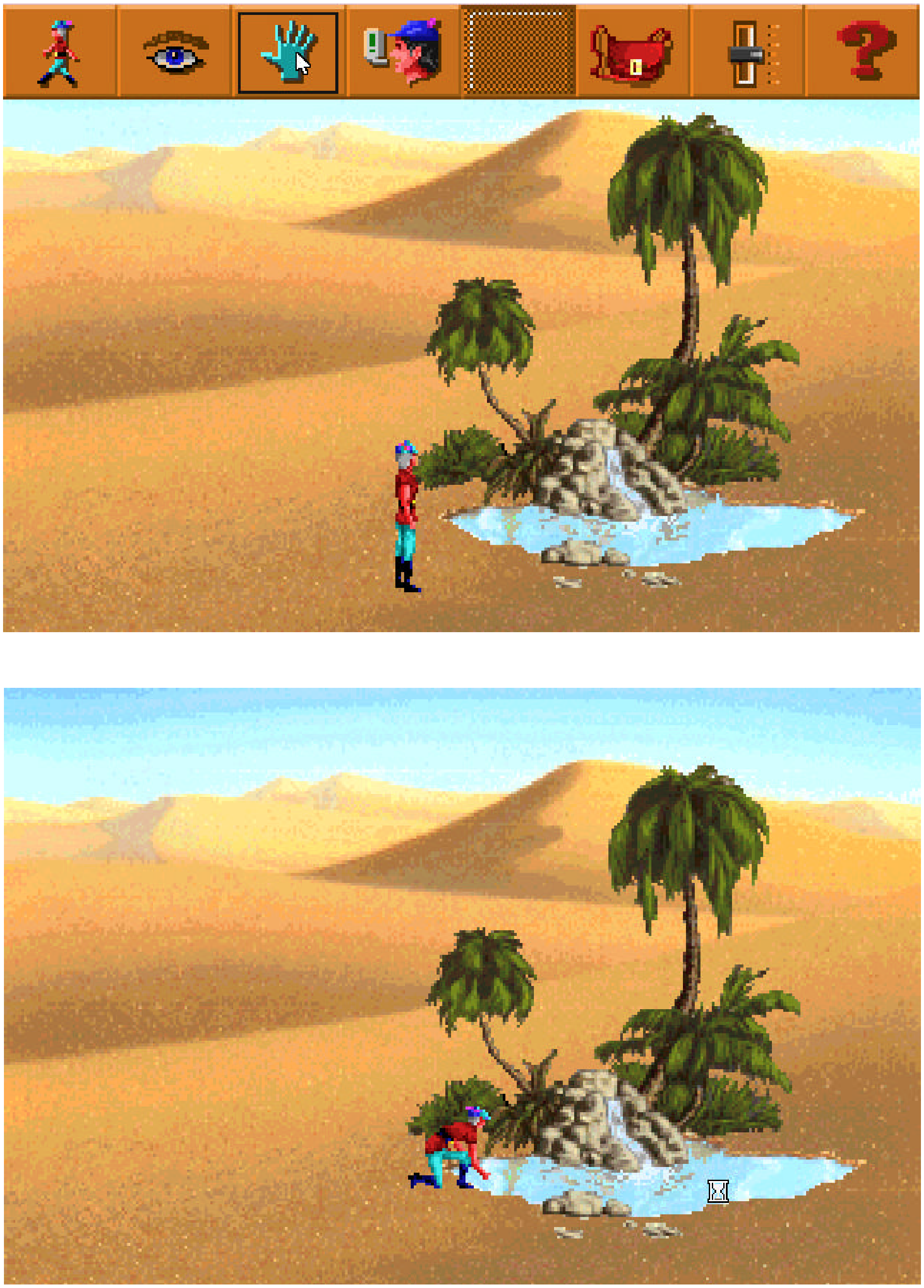

**Figure 1: Selecting the "Hand" to Make the Character Drink.**

> possibilities the new format offered; some players felt icon-based games were less challenging. I kept thinking about this as I wrote *King's Quest VI* (Williams, 1996, p 77).

Figure 2 shows how resources are selected and retrieved from the "inventory" that the protagonist, King Graham of Daventry, carries with him to store objects that he acquires ("grabs") from the environment and then retrieves later for use in solving the various puzzles encountered along the way. When the object is selected in the inventory window, it attaches to the mouse pointer and can then be "clicked" on the object or character that is the recipient of the action — in this case the witch.

About the same time that the Williams' were creating their first game, IBM research scientist John Carroll was shown a version of *Adventure* (Carroll, 1982, 1990; Carroll & Thomas, 1988). Carroll was studying how to train users of the computerized equipment that was beginning to replace typewriters in many offices. He recognized that if the motivational qualities of *Adventure* could be reproduced in a training context, better ways might be found to assist active learning on real (as opposed to fantasy) problem-solving tasks. He wrote, "A computer game like *Adventure* has a conceptual, mazelike learning approach, which I call an exploratory environment, that makes the player *want* to overcome the problems. . . ." (Carroll 1982, p. 49). Carroll realized that exploring an underground cavern, "unearthing" the narrative of an adventure game, and encoding the associative structure of a knowledge domain might involve similar cognitive and motivational processes.


**Figure 2: Using the Mouse to Retrieve an Object From the "Inventory."**

In 1981, Carroll and colleague Lewis undertook a small study that showed that secretaries trained on a word processor using a system of hints like those employed in solving adventure games, instead of the more verbose manuals used at that time, learned more and performed better in less time than those trained with the manuals. He called this instructional approach "guided exploration" (Carroll, 1982, 1990, 1998; Carroll & Rosson, 1987; Carroll, et al., 1985).

**A Case of Learning Transfer?**

Some twenty years after her first experience with *Adventure* and six years after her most recent experience with it, another cave explorer working on the Mammoth Cave project, Beverly Schwartz, had an unexpected opportunity to visit the part of the cave upon which Crowther had based his computer game. Confirmed by Park (M. Park personal communication August 12, 1996) and by Schwartz (B. Schwartz personal communication November 17, 1997) Park, one of the explorers who accompanied Schwartz, wrote (Park, 1994):

> Computer types who grew up exploring *Adventure* don't realize how accurately the game represents passages in Bedquilt Cave. Yes, there is a Hall of the Mountain King and a Two-Pit Room. The entrance is indeed a strong steel grate at the bottom of a twenty-foot depression.
>
> On a survey trip to Bedquilt, a member of my party mentioned she would one day like to go on a trip to Colossal Cave, where she understood the game ADVENTURE was set. No, I said, the game is based on Bedquilt

> Cave and we are going there now. Excitement! Throughout the cave, she kept up a constant narrative, based on her encyclopedic knowledge of the game. In the Complex Room (renamed Swiss Cheese Room in Advent[ure]) she scrambled off in a direction I had never been. "I just had to see Witt's End," she said upon returning. "It was exactly as I expected." When we finished with our work, I let her lead out, which she did flawlessly, again because she had memorized every move in the game. Believe me, the cave is a real maze, and this was an impressive accomplishment for a first-time visitor.

Had spontaneous transfer of learning occurred? According to Schwartz in a telephone interview by this researcher, Schwartz first played *Adventure* on terminals before 1979 at the well-endowed Boston area high school where she was a "computer nerd." She also played the game a few years later on her brother's computer. But she did not visit Bedquilt cave until February of 1991 (B. Schwartz personal communication November, 17, 1997).

Schwartz said the game very accurately reproduces the cave passages from the grate entrance to the Hall of the Mountain King, and that Y2, the Stone Steps, the Hall of Mists, and the Complex Junction are accurately depicted in the game, but that she could not vouch for the accuracy of the maze areas, not having been to them. She is very insistent that her knowledge (recall) of the areas of Bedquilt Cave that correspond to the description in *Adventure* is much more detailed than her knowledge of any other cave or part of a cave.

Schwartz does not claim that she could have found her way around in Bedquilt Cave just from having played *Adventure.* First she needed explorers Park and Osborne to point out the names of the rooms, passages and features in the real cave before she could relate them to the mental map that she had worked out while playing the computer game. Once the association between her mental map and the features of the cave was made, the actual geography of the cave matched the map she had constructed in her mind. She said that when you play *Adventure* you draw maps on large sheets of paper. As you do so you acquire a sense of the spatial relationships. You remember the map you construct, *not the text descriptions* from the game. She could remember the geography of the cave, both because of her "emotional attachment" with the game and because of the mental effort of constructing the maps and associated place names, objects, events, and so forth.

## Selection of the Game for This Research

The adventure game selected for this study had to meet certain criteria to ensure that it could serve as exemplar in the proposed guided exploration learning model. At minimum, the following needed to be answered affirmatively.

- Does the game avoid excessive or unrealistic preoccupation with killing, mutilation, macabre or psychotic fantasies, or other disturbing situations or environments?
- Is the protagonist a force for good and a suitable role model?

- Does the game support reading skills?
- Does the game include an expository video or other introductory material to provide background and introduce the terminal goal? (Needed to test the goal knowledge variable; see the section on treatment in Chapter 4.)

An issue was the choice of medium used to present the explicit, verbal instruction. Although early adventure games were entirely command line-driven, two possibilities exist with current technology. One, audio-based, requires listening skill and the other, text-based, requires reading skill. Regardless of the modalities used — text, audio, or text plus audio — two forms of verbal information are present in most adventure games: (1) commentary or narration, in which the software interface, acting as instructor-narrator "speaks" to the user — analogous to the illustrated lecture or narrative; and (2) dialog between characters who inhabit the story and interact with each other, in relation to which the user is a passive observer — analogous to the speech of characters in a dramatic stage play or motion picture. Verbal information may be presented either as audio speech, as text, or as a combination of text and speech. Among the differences between speech and text that may affect a researcher's conclusions about comprehension and learning is the difference in number of exposures expected with different modalities, and the effect of this expectation on one's confidence that comprehension and learning are taking place. Usually spoken information, whether present in a stage play, film, lecture, or game, is conveyed once and not repeated. Without a visual cue, learning for verbal information is apt to suffer, names will not be remembered, and their spelling will not be learned. In addition, text is often re-read several times before full comprehension is achieved.

Another reason a game that features text and animated graphics accompanied by audio sound effects and music but no audio speech was preferred for this research is that reading skill is more central to education than listening skill, and, for that reason can be more easily studied. While reading is a basic skill, listening is not customarily taught as a specific skill in school. With text as the standard, standardized readability indexes can be used to match subjects' minimum grade level/age with the reading difficulty of the learning task. Another important difference between audio-only and text-only interfaces is speed: one can read printed speech much faster than it can be spoken and precious time is wasted when one must listen repeatedly to the same spoken information when repeating portions of a game. This can add to a learners burden of frustration. The most obvious reason for choosing a game with a text window interface instead of an audio speech interface, of course, was a practical one: the spoken dialog and narration of an audio-based interface would interfere with subjects' think-aloud verbalizations, which are a primary source of data for this study.

Soon after beginning the selection process I faced a new dilemma, however. I had discovered that among ready-made high quality commercial games, few would work for the study, given the criteria and the instructional model I wanted to investigate. Furthermore I had learned that almost none of the few games that I might use would run on my apparatus. I had intended to use an

Amiga computer's pre-emptive multitasking operating system to enable the interventions to interrupt the game at the required intervals to ask subjects about their experiences. I wanted to run the game in one process "window" of the Amiga's operating system and the data-collecting processes in other windows. But when the programmers at Sierra-Online had converted the games I was interested in from the MS-DOS platform to the Amiga platform, they had ignored the Amiga operating system's multitasking rules. While the Amiga versions of the *King's Quest* games will run on the Amiga computers, they take complete possession of the computer's memory, disabling the system's multitasking capability. I spent several weeks during the summer of 1995 in consultation with Amiga users through an e-mail discussion list, and received extensive help from computer science students Thies Wellpott at Carl-von-Ossietzky-Universität and Demetri Dussia at Western Michigan University. Both men wrote and supplied memory reallocation programs and we tried many things. In the end, nothing worked and I was forced to abandon the effort to use a game that would run in a pure Amiga environment.

As no game written for Amiga could be found that met the criteria and would run on the apparatus, I next turned to the emulator created for Amiga computers by Drew and Fenton of Utilities Unlimited for a way of multitasking games written for the Macintosh within the Amiga environment. However, the capabilities of the Utilities Unlimited emulator had been exaggerated in reviews in reputable international publications and full-page advertisements that featured faked screen shots of a product not yet in existence (Drew, 1996). After many weeks of experimentation — adding costly hardware and software enhancements to boost the performance of the Utilities Unlimited emulator and acquiring and testing the software necessary to create and maintain a functional virtual Macintosh within the Amiga — the Macintosh version of Roberta William's *King's Quest V*, was made to run along with the Amiga software within the apparatus.

The game used in this research was therefore not chosen because it is the best or most up-to-date adventure game or design available. The selection was a compromise partly for technical reasons and partly for design reasons. But this is quite the norm for such projects. As Hafner and Lyon (1996) observed, "At its core, all engineering comes down to making tradeoffs between the perfect and the workable" (p. 107).

Both the positive and negative aspects of the final choice ultimately worked to the advantage of the research, however. The negative aspects of the game that produce negative responses in subjects (e.g., excessive "fatal" errors, low resolution graphics, etc.) expose the limits of the design and properly elicit negative cognitive and emotional responses of subjects. The positive elements in the design do the same, eliciting positive cognitive and emotional responses from subjects to the positive qualities of the design.

## Chapter 2: Theoretical Foundations

This chapter reviews the general theoretical territory within which the more specific theoretical roots of the guided exploration learning model discussed in the next chapter are embedded. In contrast to Chapter 3, which describes how learning takes place in a guided exploration learning environment, this chapter outlines the four corners of the theoretical territory inhabited by the model: the human needs for independent action, application of cognitive skill to concrete solutions, structure and guidance, and positive stimulation.

### Instruction as Program Discovery

The idea of "education by machine" is often traced to Sidney Pressey’s work with simple mechanical devices for automated self-instruction, testing, and test scoring (Pressey, 1921, 1926, 1927, 1932). Pressey saw a need for labor-saving devices in response to an increasing use of objective tests in education with their resulting "burden of scoring" which Pressey believed detracted from the teacher’s true function of providing "inspirational and thought-stimulating activities" (Pressey, 1926, p. 374). He presaged much current educational reform rhetoric with his vision of an "industrial revolution in education" (Pressey, 1932).

Pressey’s testing/teaching machines, ancestors of the apparatus built for this project, were autonomous (operated by the learner) and performed the dual function of teaching and recording learner behavior. Prototypes of his earliest machine were exhibited at the annual meetings of the American Psychological

Association in 1924 and 1925. According to Pressey (1926, 1927), the instructional design principles embodied in this technology that set it apart from standard classroom instruction were:

- Automatically scores tests, eliminating mistakes due to human error
- Informs subject of the right answers
- Features an attachment that can reward the subject after a predetermined number of right answers (e.g., with a piece of candy)
- Supports two "modes": testing and teaching
- Supports the Law of Recency (the correct answer is always the last one given)
- Supports the Law of Frequency (the right response occurs most often because it is the only one that leads to the next question)
- Supports the Law of Effect (reinforcement with candy)
- Supports the Law of Exercise (wrong answers require right answers to "compensate")
- Omits a question as soon as the subject has obtained the correct answer twice in succession, preventing overlearning and promoting economy of effort
- Keeps subjects at each question until it is "mastered" (answered correctly on two successive passes) and then takes up the subject’s time no more
- Provides instant feedback with progress evident through "progressive elimination"
- Permits exact adjustment of difficulty to suit the learner

Pressey's anticipated industrial revolution in education did not come soon enough, and by 1932 Pressey regretfully announced his intention of dropping further work on the problems that had preoccupied him and exhausted his resources over the previous eight years (Pressey, 1932). Nevertheless, a few researchers did take up the cause through the next 30 years (Burton, Moore, & Magliaro, 1996, pp. 53-54). The work with teaching machines peaked during the 1960s after Skinner became interested in their relevance to his work with animals.

From the early 1950s through the late 1980s, B. F. Skinner championed and expanded upon Pressey's ideas, extending both Pressey's instructional design principles and the sophistication of the teaching machine concept (Skinner, 1954, 1958, 1968, 1984). The appearance of small computers during the 1970s and 1980s put a more respectable gloss on mechanized instruction, though this displeased Skinner. As he noted (1984, p. 948):

> Computers are now badly misnamed. They were designed to compute, but they are not computing when they are processing words, or displaying Pac-Man, or aiding instruction (unless the instruction is in computing). "Computer" has all the respectability of the white-collar, but let us call things by their right names. Instruction may be "computer aided," and all good instruction must be "interactive," but machines that teach are teaching machines.

Skinner's book, *The Technology of Teaching*, (1968) published the same year as the "summer of love" and the founding of Intel Corporation (Schneiderman, 1986), describes in detail the second generation of teaching machines. Skinner's teaching machines presented instruction in the form of puzzles — blanks to be filled in using prior knowledge, reason, rule discovery, or trial and error. As with adventure games, feedback — the consequence of any choice made by the student — is immediate.

Skinner's contribution was in conceiving of more complex programs that extend the capabilities of the teaching machine well beyond displaying questions and scoring answers on a multiple-choice test and then ejecting candy for right answers. Skinner developed the idea of a learning "program." "The success of such a machine depends on the material used in it" (Skinner, 1958, p. 971). One writes a program by conducting a task analysis of the desired behavior, verbal and nonverbal, so that "specific forms of behavior [can be] evoked and, through differential reinforcement, brought under the control of specific stimuli" (Skinner, 1958, p. 971).

In the 1920s and 1930s, Pressey had written about the instructional benefits of the feedback, self-pacing, and active learner control that his machines provided. Skinner added the concept of minimal instructional units called frames, advocated requiring learner responses that are composed rather than selected, and the incorporation of multiple media. He also identified additional benefits of the technology like adaptability to students with special needs and automatic, formative feedback to the instructional designer.

> When students move through well-constructed programs at their own pace, the so-called problem of motivation is automatically solved . . . It is characteristic of the human species that successful action is automatically reinforced. The fascination of video games is adequate proof. What would industrialists not give to see their workers as absorbed in their work as young people in a video arcade? What would teachers not give to see their students applying themselves with the same eagerness? (For that matter, what would any of us not give to see ourselves as much in love with our work?) But there is no mystery; it is all a matter of the scheduling of reinforcements (Skinner, 1984, pp. 951-952).

## Instruction as Game

The Malone-Lepper theory of intrinsic motivation, developed during the 1980's, attempts to explain a widely observed and acknowledged phenomenon: the extraordinary appeal of computer-based games. Malone's initial theory, and his and Lepper's subsequent extensions of that theory, subsume three classes of theoretical work on intrinsic motivation, each of which developed independently of, but are congruent with, the main features of Malone's theory (Lepper, 1985).

The first of these groups of prior theories views humans as problem solvers and describes intrinsic motivation in terms of innate tendencies to seek solutions to problems. These theories stress concepts like challenge, competence, effectance, and mastery motivation. The qualities influencing motivation are goal structures and the difficulty of accomplishing them, given the skills, knowledge, and personal characteristics of the problem solver. These theories support Malone's notion of *uncertain outcome.*

Another class of theories portrays humans as information processors, focusing on pleasure and curiosity. Pleasure, in this view, derives from such factors as incongruity (novelty), complexity, variability, and discrepancy, as formulated principally by Berlyne (1965). This theme remains largely intact in Malone's formulation of the principle of *curiosity*.

The third group of theories stresses perceived control and self-determination. In this view, humans are primarily beings who seek control over their environments. "Activities evoke intrinsic interest . . . when they provide us with the opportunity to exert control, to determine our own fate, or at least to maintain the perception that we are doing so" (Lepper 1985, p. 5). Implementations of this view in the Malone-Lepper scheme include responsiveness of the environment (interactivity), the endogenous nature of intrinsic fantasy, progressive mastery of layered goals, and the desirability of high levels of choice.

Malone's original work, as detailed in his 1980 doctoral dissertation, asked two questions:

(1) Why are computer games so captivating?

(2) How can the features that make computer games captivating be used to make learning — especially learning with computers — interesting?

Analysis of results of four studies — a survey of game users, two experimental comparisons of effects of different versions of games on players, and an experimental comparison of the effects of eight different conditions (feedback, fantasy, music, and graphic representation) on players' interest — led to Malone's initial formulation of a theory of intrinsically motivating instruction. The emphasis, though, was on what makes computer games interesting, not what makes them educational. The qualities of game interaction Malone found to be motivating (elements of a "fun" experience) were: (a) players understood the games' goals and believed they could achieve them; (b) players reported a sense of control over the task and a feeling of competence; (c) players experienced continuous performance feedback, heightened self-esteem, enhanced sensory and cognitive curiosity, and fantasy involvement. The resulting "comprehensive theory of instructional design" stresses three main categories that describe elements of an enjoyable psychological experience: *challenge, fantasy*, and *curiosity*. The theory's purpose is not to shed light on intrinsic motivation, but to "guide the design of computer-based instructional environments" that stimulate aspects of the user's experience that can are associated with these three categories, which he also calls "kinds of motivation" (Malone, 1980, p. 33).

## Challenge

To motivate goal-oriented action in any type of problem-based adventure, an initial "challenge" is presented. Challenges are invitations to perform what is required to solve a problem. A successful response to such a challenge requires both the motivation to undertake goal-directed action and the motivation to continue acting until the goal is reached.

Challenge is defined as a user's initial uncertainty about the achievement of a goal. The two main components are a goal and uncertain outcome. Malone's studies of computer games identified four ways uncertainty in the attainment of goals can be heightened: varying difficulty level, using multiple level goals (goals within goals), hiding information, and randomness. Removing these elements would, then, decrease uncertainty, therefore challenge.

Motivation researchers have considered the effect of challenge size or difficulty on performance ever since Yerkes and Dodson (1908) reported the use of varying intensities of electric shock on mice to affect their abilities to perform easy and hard visual discrimination tasks. The Yerkes-Dodson Law placed the optimally motivating level of challenge midway between one that is too high, causing excessive stress and resulting in low task performance, and one that is too low, causing boredom or indifference (and low task performance). Attempts to replicate the Yerkes-Dodson work on humans have not been conclusive (Weiner, 1980, p. 136), however optimal challenge also figures prominently in McClelland, Atkinson, Clark, and Lowell's (1953) risk-taking model, and in Atkinson and Litwin's development of this model with studies that used ring-toss and penny pinch games, asking subjects to chose their preferred level of difficulty (Litwin, 1966). For example, in the ring toss, subjects decided how far they would stand from the peg when tossing the ring. When given the opportunity to set the difficulty level of the task for themselves, subjects selected a medium distance, rather than one close up (too easy) or far away (too difficult). They chose a challenge level that was just right — hard enough to avoid boredom, but easy enough to avoid anxiety and to maintain a control over the likelihood of success. Other motivation theorists, especially those interested in computer-based instructional environments, have embraced the principle of optimal challenge as well. Lepper and Chabay wrote (1985, p. 225) that software ". . .should provide activities at an intermediate level of difficulty and a high level of initial uncertainty." Reasserting the Yerkes-Dodson law, Keller and Burkman (1993) call for a challenge level that produces an appropriate expectancy for success:

> If the perceived challenge level is too high, the student is likely to have a low level of persistence, and to quit trying to succeed, even though he or she has the ability to succeed. Conversely, if the perceived challenge level is too low, the student is overconfident and tends not to believe that there is anything new to be learned.

One way to vary the difficulty of the task’s challenge, the method used in the study described in Chapters 4 and 5, is either to offer or impose instruction in the form of hints, additional information, or even complete solutions — in Malone’s terms, to reveal "hidden" information. This instruction could be supplied in the form of printed documents, instructor interventions or prompts, various online interventions, or a searchable knowledge base.

**Fantasy**

For the second category associated with the effects of the games on players Malone defers to the American Heritage Dictionary to define "fantasy" as "mental images of things [physical objects or social situations] not present to the senses or within the actual experience of the person involved" (Malone, 1980, p. 39). His claim is that stimulation of such mental images of things not present to the senses "can make instructional environments more interesting and more educational" (p. 39). Other than this assertion, a rather elaborate definitional distinction between two different ways of relating fantasy and skill, and a reference to Freud's views on sex and aggression, Malone has very little to say about this second element of his theory. Though fantasy can be an element of expository story telling whether the medium is the novel, theatrical production, motion picture, or computer game, and it is certainly an important ingredient in play of all sorts, the mechanism by which fantasy motivates, if it does, has apparently not been identified.

Laurel (1986, 1991) offers a more thoroughgoing analysis of the role of this element. Drawing on Aristotle's *Poetics* for her conceptual framework, Laurel suggests one mechanism for a possible motivational basis of the fantasy element: the "constraints of dramatic probability." The constraints imposed by the element of probability in a dramatic (i.e., fantasy) scenario may simply affect the level of challenge of a scenario-embedded problem-solving task by restricting the possibilities for actions that could lead to the goal. Dramatic probability expresses a causal relationship between who a character is and what happens to him or her. This relationship at once makes the dramatic action believable and limits the possibility for action.

> At the beginning of a play, a number of things are *possible.* As the characters' traits and motivations are revealed and the action unfolds, the possible is formulated into a smaller set of incidents that are shown to be *probable.* As the play moves toward its conclusion, competing lines of probability are eliminated and a single line is demonstrated to be *necessary*. The *plot* functions as the formal control in the orchestration of dramatic probability by determining which lines of probability will be terminated and which will emerge as the necessary outcome (Laurel 1986, 58-59).

It is in this sense that the content of an interactive scenario-based program is neither created nor influenced by the user, but is *discovered* by him or her. But the constraints of dramatic probability maintain consistency in the fantasy world, thereby limiting the number of potential solution paths. What this means is that some, but not all, things are possible; therefore the imaginary world is rule-bound.

### Curiosity

While acknowledging his contributions to work on the topic, Malone added a twist to Berlyne's concepts of complexity and curiosity (Berlyne, 1963, 1965). A learner's curiosity can be aroused if "environments are neither too complicated nor too simple with respect to the learner’s existing knowledge" — if they contain an *optimal level of informational complexity* (Malone, 1980, p. 41). Following Berlyne’s scheme, environments should be novel and surprising, but not incomprehensible. Curiosity can be aroused two ways: through *sensory* or *cognitive* means. Attention can be attracted by "technical events" — changes in patterns of light, sound, or other sensory stimuli (sensory curiosity) — or by a desire to "bring better ’form’ to one’s knowledge structures" (cognitive curiosity), meaning that people seek *completeness, consistency,* and *parsimony* in their cognitive structures (Malone, 1980, p. 42).

## Optimal Learning as Autotelic Experience

The present project grew out of interest in the same research on intrinsic motivation that informed Malone. Psychological theories in that tradition view humans as problem solvers and describe intrinsic motivation in terms of tendencies to seek solutions to problems. The qualities influencing motivation are goals and goal structures and the challenges they represent vis-a-vis the skills, knowledge, and personal characteristics of the problem solver.

Predating Malone’s work by nearly 20 years, Csikszentmihalyi’s theory of optimal experience arose from the same theoretical roots, but had broader application (Csikszentmihalyi, 1975, 1978, 1988a, 1988b, 1990). Though rarely applied to instructional issues, the work of Csikszentmihalyi and colleagues is unique in the way it operationalizes the elements of intrinsically motivated, achievement oriented experience. As such, the theory is highly relevant to problems of learning. Csikszentmihalyi’s work began when he noticed that just about any activity can be experienced as enjoyable, even though it may not normally be considered play. The theory was the result of a search for the elements of intrinsically motivating experience that are independent of the nature of the activity itself. This search arose from observations of male artists and their approaches to their work during the mid-1960s (Csikszentmihalyi, 1965). Later Csikszentmihalyi and one of his students developed an embryonic version of a general model of subjective experience (Csikszentmihalyi & Bennett, 1971). Csikszentmihalyi points out that his interests focused on "*the quality of subjective experience* that made a behavior intrinsically rewarding," rather than the existence of "intrinsically motivated *behavior,*" as others working in motivation psychology like Lepper, Deci, and deCharms had done (Csikszentmihalyi, 1988a, p. 7).

This focus on the quality of enjoyable experience led to a new term for the experience itself. Although the technical term for activities associated with the experience is "autotelic activity" — "having an end or purpose in and not apart from itself" (G. & C. Merriam Co., 1976), "flow" is the term most frequently used by the informants themselves to describe the *experience* that is autotelic (Csikszentmihalyi, 1975, p. 36).

Flow is therefore a quality of one’s subjective experience not dependent on the content of the activities through which one experiences it (Csikszentmihalyi, 1988a, p. 7, 9). It occurs "within sequences of activities that are goal-directed and bounded by rules — activities that require the investment of psychic energy, and that could not be done without the appropriate skills" (Csikszentmihalyi, 1990,

p. 49). Certain activities, like games, sports, and artistic and literary forms are specifically designed to provide this experience. These activities are usually enjoyable, and described as "fun."

Csikszentmihalyi wanted to know what it is that makes an activity intrinsically rewarding, irrespective of whether it is classified as work or play. As he observed, "One fact seemed clear from the beginning: the immersion into enjoyable experience which is typical of play occurs frequently outside of games." So what is it that makes an activity intrinsically rewarding? Csikszentmihalyi recalls when he stumbled upon the first clue (Csikszentmihalyi, 1975, pp. xi-xii):

> One thing struck me as especially intriguing. Despite the fact that almost no one can make either a reputation or a living from painting, the artists studied were almost fanatically devoted to their work; they were at it night and day, and nothing else seemed to matter so much in their lives. Yet as soon as they finished a painting or a sculpture, they seemed to lose all interest in it. Nor were they interested much in each other’s paintings or in great masterpieces. Most artists did not go to museums, did not decorate their homes with art, and seemed to be generally bored or baffled by talk about the aesthetic qualities of the works they or their friends produced. What they did love to do was talk about small technical details, stylistic breakthroughs — the actions, thoughts, and feelings involved in making art . . . .

> Artists provided the clue for the importance of intrinsic motivation. Their acts implied that work can give enjoyment and meaning to life. It was a simple and obvious message, yet full of tantalizing implications. Did these artists enjoy their work because the subject matter was art or because the pattern of actions required by their work was in itself rewarding? In other words, is enjoyment of work unique to creative people doing creative tasks, or can everyone experience it if some set of favorable conditions is met? If everyone can experience such enjoyment, then boring everyday tasks might also be turned into enjoyable and meaningful activities.

In establishing the parameters of enjoyable experience, Csikszentmihalyi and his students began by interviewing people who "spent great amounts of time in strenuous activities for which they got no money and little recognition" — amateur athletes, chess masters, rock climbers, dancers, high school basketball players, and composers of music. The researchers wanted to find out how these people described the activity when it was going particularly well (Csikszentmihalyi, 1988a, p. 7). Reports of these studies contain the first full-blown descriptions of the flow theory (Csikszentmihalyi, 1975). But since that seminal work, the theory has been applied to study of an enormous variety of topics, including play, sports, leisure, recreation, older retired persons, ritual, emotional consequences of risk and competition, Taoist philosophy of Chuang-tzu, television reporting, Japanese motorcycle gangs, elderly Korean immigrants, various European and Asiatic populations, mountain climbers, ocean cruisers, Jesuits, the urban American work environment, solitary ordeals, teenage

Americans, patterns of television-viewing, sociocultural evolution, creativity and cultural evolution, evolution of consciousness, student attitudes and teacher enjoyment, education of gifted children, scholastic achievement of Italian and American students, industrial accidents among factory workers in Hungary, leadership development, consumer behavior, sociological implications of anomie and alienation, working women, work and leisure in traditional societies, juvenile crime in Saudi Arabia, deviance, and advertising. The model has been applied to public school K-6 curricula, student writing projects, physical and occupational therapy, management of public parks, a statewide anti-drug campaign, design and redesign of museums, audience involvement in theater (Csikszentmihalyi, 1988a, pp. 8-14).

What these studies and applications have in common is an interest in explaining or influencing motivational qualities of experience that illuminate the relationship between enjoyment and achievement. "Whenever the quality of human experience is at issue, flow becomes relevant. It helps explain why people enjoy their work and their leisure; it also helps explain why in some circumstances people are bored and frustrated" (Csikszentmihalyi, 1988a, p. 14).

Although an experience of flow has not been widely recognized in educational theory as a desired condition for learning, there is no reason a priori to separate enjoyment from learning. Obviously, a heightened state of motivation during learning is desired, just as it is when participating in the kinds of activities people frequently describe as "fun." As Norman (1993) and others have observed, learning tasks that facilitate the induction of flow states may lead to superior educational outcomes.

As with the theories discussed above (Yerkes-Dodson Law, Lepper & Malone), flow requires optimal balance or equilibrium between a high level of presenting challenge and either a high level of skill or access to the information needed to match a presenting challenge. Csikszentmihalyi writes (1990, p.52):

> In all the activities people in our study reported engaging in, enjoyment comes at a very specific point: whenever the opportunities for action perceived by the individual are equal to his or her capabilities. . . enjoyment appears at the boundary between boredom and anxiety, when the challenges are just balanced with the person's capacity to act.

When a goal of some activity is known but the steps to achieve it are unknown, the initial uncertainty (challenge) is high. The more information one has about the specific steps required to achieve a goal, the less uncertainty one has, and the lower the challenge. This effect of information on performance can be thought of as psychic *negentropy,* the quality of reduced disorder, confusion, and uncertainty — conditions contributing to anxiety (Csikszentmihalyi, 1988b, p. 22; Kubey and Csikszentmihalyi, 1990, p. 4-6). Csikszentmihalyi and Kubey write that "psychic entropy" stems from uncertainty in a goal-oriented task environment. Psychic (or information) entropy is present when our goals are frustrated or uncertain (we do not know how to proceed). Entropy in a system also means a system has less capacity for productive action. Information that reduces uncertainty and confusion, permitting a closer match between the content of experience and one's goals, elevates one's control over one's mental energy, and increases capacity for productive action — hence the desirability of its presence in an optimal learning environment.

**Learning as Guided Exploration**

During the early 1980s, Carroll conducted several studies of instructional methods designed to elicit behavior similar to what he had observed of people solving Crowther and Woods' *Adventure* (Carroll, 1982; Carroll, et al., 1985; Carroll & Thomas, 1988). These studies led to a framework for computer training and documentation called "minimalism." Minimalist instruction was designed to teach word processing and other office skills by helping users to approach the actions they must perform to accomplish a typical task with, say, the word processor in the manner of someone solving the puzzles in *Adventure.* Carroll had encountered a puzzle which he coined "the paradox of sense making" (Carroll, 1990; Carroll & Rosson, 1987).

Citing Suchman (1987) and Winograd and Flores (1986), Carroll argues that people can understand best through observing the consequences of their own actions because they are "situated in a world more real to them than a series of [instructional] steps" He observes: "In a word, *they are too busy learning to make much use of the instruction*" (Carroll, 1990, p. 74). This paradox captures the contradictory demands on active learners in any context. The paradox of sense making is the reason exploration and guidance are *both* necessary in active (activity-based) learning contexts like those characteristic of learning with computers and playing adventure games.

For Carroll and Lewis's first study, Carroll writes (1990, p. 109), ". . . we decided in 1981 to invite someone to learn basic text processing by exploration, to treat document processing as an Adventure, so to speak." In "The Adventure of Getting to Know a Computer" (Carroll, 1982), he wrote, "What I hope to show . . . is that by examining the similarities and differences between the *Adventure* player and the inexperienced user, we can find some insights to use in designing application systems that are easier for the user to learn" (p 49-50).

**Minimalism**

Minimalism is governed by certain still-evolving principles, but most writers on the subject recognize most or all of the following (Carroll & van der Meij, 1998; Draper, 1998; van der Meij & Carroll, 1998):

- Focus on meaningful task goals
- Quick engagement with task activities
- "Incomplete" verbal instruction
- On-demand, random access to instruction
- Organization of instruction in parallel with structure of tasks
- Support for error recovery
- Reliance on synthesis of prior knowledge and application *to* problem solution
- Incorporation of formative evaluation feedback mechanisms

In his criticism of instructional systems design, however, Carroll (1990) mischaracterized the analytic reductionist model of Gagné, Briggs, and Wager (1979) and "the systems approach" as ". . . related only superficially to any serious understanding of human learning, [that] draws most heavily and directly on stimulus-response models of animal conditioning" (p 2-3), in which ". . . instruction is designed with little consideration of the learners and no consideration for the contexts within which learning will occur (p 74) and ". . . has no substantive theory content and no user domain content at all (p. 278). These surprising assertions are easily disputed, as (a) the systematic design of instruction always begins with a learner needs analysis; (b) Gagné's theory, the basis of the instructional design model he, Briggs, and Wager developed, is conditions-based, not systems-based, and (c) Gagné's orientation was not ultimately behaviorist, but cognitivist (though it can be argued that he borrowed from research within both paradigms in support of his taxonomy of learning categories, and that the cognitivist basis of his later work evolved from neobehaviorist beginnings in the early 1960s) (Gagné, 1972; Gagné & Glaser, 1987; Gagné & Smith, 1962; Ragan & Smith, 1996, p 544-549).

In truth, much of Gagné's work stressed the importance of the discovery-oriented problem-solving learning that is fundamental to Carroll's minimalism (Gagné, 1964, 1966, 1972, 1985). Gagné (1964) argued that problem solving is not simply a result or effect of learning, but is itself a special case of learning.

The key point that Carroll missed is that in a *performance* environment like a word processing machine operator encounters in an office, the computer functions as a tool whose purpose is to enable an operator to accomplish certain tasks efficiently — i.e., with the least mental effort and possibility of error. In a *learning* environment the object is to acquire "intellectual skills" (Gagné, 1985). Learning intellectual skills requires mental effort. Here some degree of difficulty (challenge) and effort-full guided exploration that leads to "discovery" of problem solutions, for the reasons specified by Gagné, Anderson, and others, may intensify the encoding of the critical content in long-term memory. The performance of a clerical act may not require encoding specific content or procedures, however, if it can be facilitated through prompting or other performance support methods. Guided exploration is therefore more appropriately applied to learning environments than performance environments, and as the term was coined to name the more general case of the type of learning observed during the process of solving adventure games, adventure games themselves are an ideal testbed for exploring the process of exploratory learning with guidance as a general case.

### Exploration as Instruction

The term guided exploration expresses the relationship between the instruction (or "guide") and the uncertainty of a goal-based task or action to be performed, or approximated, through trial and error. The essence of that description is that neither the guidance nor the exploration is sufficient, but both are necessary. In comparing learning to use a computer with playing *Adventure,* Carroll noticed that the game was more successful at motivating people than the methods he and others were using to teach computer skills, even though what the players of *Adventure* were doing and learning about was very intricate and difficult — actually far more complex than a computer business application (Carroll, 1990, p. 104). This brings to mind Malone's (1981) distinction between software "toys" and software "tools," the difference being one of purpose. In contrast to computer tools that perform cognitive work by reducing the mental effort required of a task, computer toys are programs that are made intentionally difficult to stimulate mental effort by challenging players to overcome seemingly intractable, though interesting and enjoyable, roadblocks. Contrasting traditional step-wise instruction with the way procedures (subtasks) emerge in *Adventure*, Carroll notes that with the latter, goals "emerge from the interaction of the learner and the system" (1990, p. 106):

> In Adventure, the player assumes what might be called strategic control: many aspects of the game must be discovered, often on the basis of subtle hints, and most aspects are presented as open-ended problems to solve. The learner has no other choice but to construct his or her own goals. One learns about the game by discovering the game, by making sense of it.

The central point of this comparison is that whether one is faced with learning a document processing application or playing an adventure game, the problem is the same: *how to make sense of it.*

# Chapter 3: Learning Model

This work began as a study of intrinsic motivation and instructional design. As the project progressed, however, it became clear that it was also a study of problem-solving discovery learning in a more general sense — of how people approach and either succeed or fail with problem-based learning when the learning task is an activity that is supposed to be fun. Solving an adventure game proved an ideal learning task for research, and the computer on which it ran was an efficient data collection environment.

The result of broadening of the scope of the study was the development of a model of, not merely how people learn with adventure games, but optimal problem-solving discovery learning generally, a necessary element of which is guided exploration (Figure 3). The model is "optimal" in two senses: (a) because it optimizes learning, and (b) because it optimizes motivation. The result is an optimal (flow) experience, a main effect of which is the learning of some new intellectual content. Motivation and learning are two parts of a whole. Learning does not occur in the absence of motivation, and motivation does not endure in the absence of learning.

This chapter discusses two aspects of this optimal learning model: (a) the model as a representation of the process by which learning takes place in a discovery oriented problem solving environment and (b) practical and theoretical considerations in design of the knowledge base — the inquiry system / guidance component of the model — that was constructed for this project. The model is explained in terms of the theories of Anderson (1983, 1990, 1993), Berlyne, (1963); Carroll (1982, 1990, 1998), Csikszentmihalyi (1975, 1978, 1988a, 1988b, 1990); Csikszentmihalyi and Bennett (1971); Kubay &

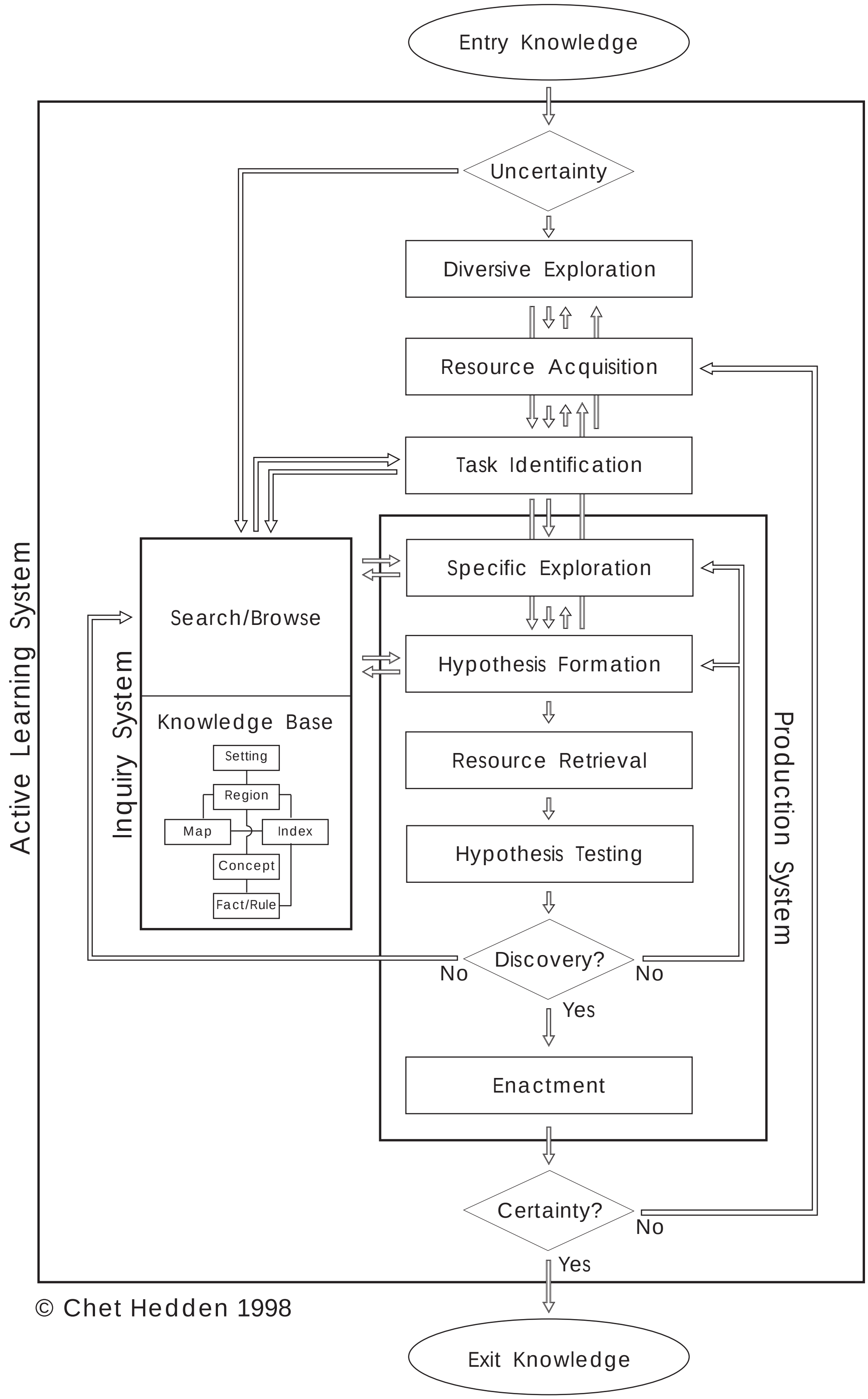


**Figure 3: Guided Exploration Learning Model.**

Csikszentmihalyi, 1990; Gagné (1964, 1966,1985); Gagné and Merrill (1990), Hutt (1976), Laurel (1991), and Petersen (1988). Design of the Inquiry System was guided by the minimalist principles developed by Carroll (1982, 1990, 1998). Please refer to Figure 3 as the elements of the model are discussed in the following sections.

Note that the language from the domains of instructional design and game design overlaps, but some of the terms are different. "Rules" and "facts" in the first domain are "hints" or "clues" in the second. "Procedures" in the first domain are "solutions" in the second. In this document, these terms are used interchangeably to reflect these equivalences. "Problem solving" has the same meaning in both domains.

## Active Learning System

In Figure 3 the outer rectangle defines the boundaries of the Active Learning System (Carroll, 1982; Carroll, et al., 1985; Carroll & Rosson, 1987; van der Meij & Carroll, 1998). The large rectangles within enclose two subsystems, the Production System (Anderson, 1983, 1990, 1993; Gagné, 1964, 1966, 1985), representing the elements of the discovery process, and the Inquiry System, with its minimal online knowledge base containing concepts, rules, and facts, but not procedures. For the research, the instantiated knowledge base was a virtual "deck" similar to Carroll and Lewis's physical deck of Guided Exploration (GE) cards. Carroll's deck of GE cards, first employed in his and Lewis's studies of secretaries learning to use a word processor (Carroll, 1982, 1990; Carroll, et al., 1985), was the prototype of the "minimal manual" (Carroll, 1982, 1990; Carroll, et al., 1985). The current knowledge base differs from Carroll's GE cards, however, in that its content and format are informed by Gagné's (1964, 1966, 1985) recommendations for design of problem-solving discovery learning, and in accord with Anderson's (1983, 1990, 1993) production acquisition learning architecture.

One enters the active learning system without prior knowledge of the content of the learning task, but with general knowledge that can be called upon to help with the learning task. Carroll, et al. (1985) observed repeatedly in their studies of adults learning computer systems, what has become a truism in the world of software publishing, that ". . . learners are *overtly active* in that they seem to prefer to learn by trying things out rather than by reading" (p. 284). Certainly this is axiomatic for adventure game aficionados, who typically refer to any type of solution aid or verbal hint source as a "cheat."

Active learning environments support learner autonomy and overtly active learning styles. They are task-oriented and encourage self-initiated action and exploration of both the task environment and any available source of guidance, although the latter must be relevant to the goals of the activity and designed to support "reading to do, study, and locate" (van der Meij & Carroll, 1998).

## Play and Exploration

At the point of entry to a problem-solving learning environment, the learner faces an unknown experience with an uncertain outcome. "Psychic entropy" — cognitive disorder — characterizes one's experience on the threshold of the unknown (Berlyne, 1963; Csikszentmihalyi, 1988b; Kubay &

Csikszentmihalyi, 1990). So the first steps that one must take are to find a way to reduce that initial uncertainty through one or both of the options available: by exploring the setting itself (the environment within which the adventure takes place) or by exploring the knowledge base, to begin to acquire knowledge of the setting, the situations or circumstances of the characters, and the rules that govern the environment.

Two different stages of exploration are shown in the model to represent different exploration styles and goals. Using Berlyne's (1963) distinction, the first exploratory stage is "diversive" — not directed toward the *solution* of any particular puzzle, but rather toward the *identification* of a "task" or puzzle to solve. The exploration that takes place within the production system rectangle is "specific," as it is directed toward solving and enacting a specific production.

Resources are objects or tools needed to perform some action that is central to the enactment of a puzzle solution or production. All productions require at least one resource. If upon entering the learning system one chooses to explore the setting (the usual approach), one may acquire resources as they appear, or go straight to task identification. Task identification, resource acquisition, and diversive exploration are circular; one can do them in any order. It may be necessary to explore to find a resource after one has identified a task, or it may be possible to acquire a resource, either following the successful enactment of a production or before identifying the task for which the resource is needed. But once a task has been identified, the nature of the exploring within the physical setting becomes focused on hypothesis formation; it changes to purposeful or "specific" exploration (Berlyne, 1963). Whereas the goal of diversive exploration is task identification, the goal of specific exploration is hypothesis formation. Hypothesis formation may involve additional specific exploration and knowledge base search and / or exploration until a hypothesis has formed. When a hypothesis is formed, it is tested immediately for discovery. In Hutt's (1976) view, having identified a task, the learner would shift from investigative exploration (e.g., of an object) to exploratory play, to make use of something to affect outcomes rather than continue to investigate and inquire about the possibilities for action.

If the outcome of the test for discovery is negative, one returns either to (a) the inquiry system for more research, (b) to specific, purposeful exploration until a new hypothesis is formed; alternatively, (c) a new hypothesis may form immediately, from which one may seek confirmation in the knowledge base or the physical setting, or return directly to testing. If the outcome of the test for discovery is positive, the procedure is enacted (produced). A test of homeostatic certainty (negentropy, order) follows the enactment of a production system solution procedure. Failure of the certainty test means the concluding task has not been accomplished, and the process of identifying the next subtask begins. The successful enactment of a production is usually followed by acquisition of a new resource, both as reward and to enable future productions.

It can be argued that the first activity in the sequence of stages in the process of active problem-solving discovery learning that takes place upon entering the active learning system is play. Although play has several meanings and has been defined various ways (Fagan, 1976, 1981; Hutt, 1976; Petersen, 1988; Sylva, et al., 1976), what people do with games is play them.

Csikszentmihalyi’s earliest formulation of a model of subjective experience that defined the experience of flow, was to characterize play:

> Play is action generating action: a unified experience flowing from one moment to the next in contradistinction to our otherwise disjoint "everyday" experiences. (Csikszentmihalyi & Bennett, 1971)

The data from which Csikszentmihalyi and Bennett developed that definition and the model of play (and subsequently of flow) were characteristics of three "traditional" categories of games as universal (cross-cultural), institutionalized play-forms: games of chance, games of strategy, and games of physical skill. Adventure games belong to the second category — those based on exercise of the intellect. In the present learning model, concepts of play and flow converge in a game-like learning task that requires the exercise of intellectual skills and strategies. In the most literal and general sense, therefore, one may characterize problem-solving discovery learning overall as play.

It can also be argued that the first action a problem-solving discovery learner takes, whether the learning environment is a game or something else, is to explore. In fact, play and exploration have a well established association (see discussion below). Sometimes their association is described as convergent and sometimes as divergent. In the model, play and learning converge in the act of exploration.

Adventure games, both by definition and by design, are exploratory environments (Carroll, 1982, 1990). According to the model, one proceeds from uncertainty to exploration to learn about the setting and/or the knowledge base.

Berlyne (1963) defined two kinds of exploration. Of the first kind, "diversive exploration," he said ". . . what in human life goes by such names as 'recreation,' 'entertainment,' or 'seeking a change'" (p. 290). Petersen (1988), whose work focuses on play in young animals and children, considers play to be evidence of an uncertainty of ". . . which forms of behavior to adopt and which actions to perform in order to achieve a certain goal" (Petersen, 1988, p. 17). The uncertainty Petersen is interested in stems from an organism's youth, but is not dissimilar to the uncertainty one faces at the start of any problem-solving activity. Diversive exploration, the first step in "playing" an adventure game, according to most sources, is either synonymous with or a prelude to play.

Others have a different view. Hutt (1976) and Petersen (1988), while admitting that the two are often regarded as synonymous, define exploration and play as separate but sequentially related stages. In Petersen's view, diversive exploration is the prelude to play; whereas both specific and diversive exploration are part of "autotelic exploration," in which an "active search" constitutes a goal in itself.

> . . . we may designate an activity by the terms "play" or "exploration", according to whether the player's interest is directed toward the activity *per se* or toward the result of the activity (Petersen, 1988, p. 23).

In contrast, Hutt's (1976) position would suggest that if one chooses to browse the knowledge base at the beginning of the activity, one would need to make a shift at the stage of task identification from relatively constrained exploratory inquiry to play. Action requires hypothesis formation: "In play the emphasis changes from the question of 'what can *this object* do?' to 'what can *I* do with this object?'" (Hutt, 1976, p. 211). In agreement with Petersen, however, play, for Hutt, does not begin until exploration is complete and hypothesis formation has begun, at which point play becomes a process of outcome testing.

Petersen's (1988) classification, like Berlyne's, recognizes just two types of exploration: "heterotelic" or non-autonomous exploration, in which ". . . exploration has a *pragmatic* and *instrumental* function" (p 22) and "autotelic" or autonomous exploration (search for its own sake). Autotelic exploration, in Petersen's system, subsumes both specific and diversive exploration. Petersen would probably dispute the sequence of the two exploration stages in the model as he writes (1988, p. 22):

> In cases where diversive exploration appears at all, it is always preceded by specific exploration and, depending upon the course of events, it may be mistaken for play.

Other views have been offered. In a quasi-behavioral analysis, for example, White (1959) argued for an intrinsic tendency of organisms to explore that is not one of the primary drives. White could not find a motive for exploratory behavior in "drive orthodoxy," so he concluded that the motivation to explore is hardwired in the brain and harbors a "sober biological purpose" as an expression of the need for competence or effectance and that exploratory behavior produces learning along with a feeling of efficacy — power and control over the environment:

> Considering the slow rate of learning in infancy and the vast amount that has to be learned before there can be an effective level of interaction with surroundings, young animals and children would simply not learn enough unless they worked pretty steadily at the task between episodes of homeostatic crisis. The association of interest with this "work," making it play and fun, is thus somewhat comparable to the association of sexual pleasure with the biological goal of reproduction (p. 329).

**Play and Learning**

Whichever view is correct, evidence that play can be a critical element of problem-solving comes from Birch (1945). In Birch's study, three days of prior experience playing with sticks made the difference between success and failure in the ability of five chimpanzees to solve a banana retrieval problem using a stick as a rake. In a similar study using children 3-5 years of age, a somewhat more complex task (a "game" that required tool making), and groups with three different types of prior experience — "no treatment," "observe principle" and "play," Sylva, Bruner, and Genova (1976) found that subjects who were not shown how to make the tool but were encouraged to play with the materials did as well as those who were shown the solution. Standardized hints were given in all treatments when subjects failed to act or attempted to quit. The study concluded that play-experienced children:

- Engaged in more goal-directed responses
- Progressed from simple to more complex hypotheses and were not frustrated with early failures, but learned from them
- Were more enthusiastic
- Were more productive and organized in their approaches

The authors note that the play subjects had to discover the solution, yet did as well as the subjects who had been given the solution, and speculate whether the application of "general principles to specific problems" (like the rules in the current model's knowledge base) is helpful in promoting discovery. They conclude that the play-experienced subjects did better for three reasons: their actions were self-initiated (a requirement of problem-solving), they employed "serial ordering of the constituent acts involved" (a requirement of tool invention), and they were able to act with less frustration and fear of failure, hence they could benefit from hints and ". . . approach the solution gradually without breaking off" (p. 256).

Finally, a detailed operational theory of play by Fagen (1976) links the findings of the Sylva, Bruner, and Genova study directly with the next component of the learning model — the production system — speculating that (p 98):

> . . . the play experience enabled the children to construct an internal model or description . . . of the objects and of the kinds of actions that could and could not be performed with them. This model would serve as an

economical representation of the information gathered and could be used to make predictions and to generate hypotheses in the course of the solution process, allowing the children to solve the problem in a systematic and purposeful way.

**Resource Acquisition**

Resource acquisition is simply the step whereby one takes some object from the environment into one's possession. Sometimes the resource might be an object lying on the ground or hidden somewhere out of view, like a stick on the ground or a needle in a haystack. Other times the resource may be given to one as a reward for some successful puzzle solution enactment. Resources that have been retained in what is generically referred to as an "inventory," are then available for later use, and where necessary to enact a procedure, the correct resource must be selected just before any test for discovery of a solution procedure or "production rule" (Anderson, 1983, 1990, 1993; Gagné, 1964, 1966, 1985).

**Task Identification**

The purpose of the diversive exploration upon entering the active learning system is to reduce uncertainty (anxiety, entropy) through exploration and / or play. The goal of that stage is to identify a problem or puzzle to solve. This must occur before the production system process kicks in. Identification of tasks or problems to solve is one of the most difficult and often frustrating phases in problem-solving. In the "real world," one may ask "What can I try to get this to work?"  In the imaginary world of an adventure game a player may say "What can I do?" (which means, "What will this game allow me to do?").  In the latter, as well as in complex problem-solving environments like one encounters in the workplace, it may be necessary to identify several tasks during the course of trying to solve one or more of them.  That is, solutions to individual puzzles may not be forthcoming and multiple tasks may be undertaken simultaneously.

> People in this situation see many things going on, but they do not know which of these are relevant to their current concerns.  Indeed, they do not know whether their current concerns are the appropriate concerns for them to have.  The learner reads something in the manual, sees something on the display, and must try to connect the two — to integrate, to interpret (Carroll & Rosson, 1987, p. 81).

## Production System

The heart of the production system is a "production paradox":  the learner's need to act in order to know versus the learner's need to know in order to act (Carroll & Rosson, 1987; van der Meij & Carroll, 1998).  The production paradox, also called "the paradox of sense making" (Carroll, 1990), is the critical issue for those who do not succeed, because this paradox makes both action *and* guidance necessary.  The knowledge available through each must be integrated in the learner's thinking for successful discovery of a production solution.  The purpose of the production system is to enable the discovery and enactment of the procedure that accomplishes the *enterprise task.*

The term "enterprise," although it helps elucidate the production system, does not appear anywhere Figure 3. The production system defines in functional terms a problem-solving task whose objectives are integrated with those of other production systems within a given instructional context. The term "enterprise" was suggested in an article by Gagné and Merrill (1990) that extended well-established instructional design practices to cover complex instruction in which multiple learning objectives must be integrated in the design. As it is used here, the term signifies the complexity of the production system beyond the stages shown in Figure 3. Enterprises are purposive activities that depend for their execution (successful enactment) on a combination of verbal information, intellectual skills, and cognitive strategies (Gagné and Merrill, 1990, p. 25). The production system outlined in the model shown in the figure, along with the component extensions of Gagné and Merrill’s "enterprise schema," is what Gagné and Merrill would call an "enterprise scenario." The schema with scenario and components is shown in Figure 4. Think of the production system in the model as the scenario part of the enterprise schema. Gagné and Merrill write (p. 25):

> An important feature associated with the goal is the enterprise scenario that relates component activities (identifying concepts, carrying out procedures, etc.) to the goal. It is the scenario that provides a basis for the application of the constituent knowledge and skill in the enterprise performance. This entire complex is what is meant by the enterprise schema.

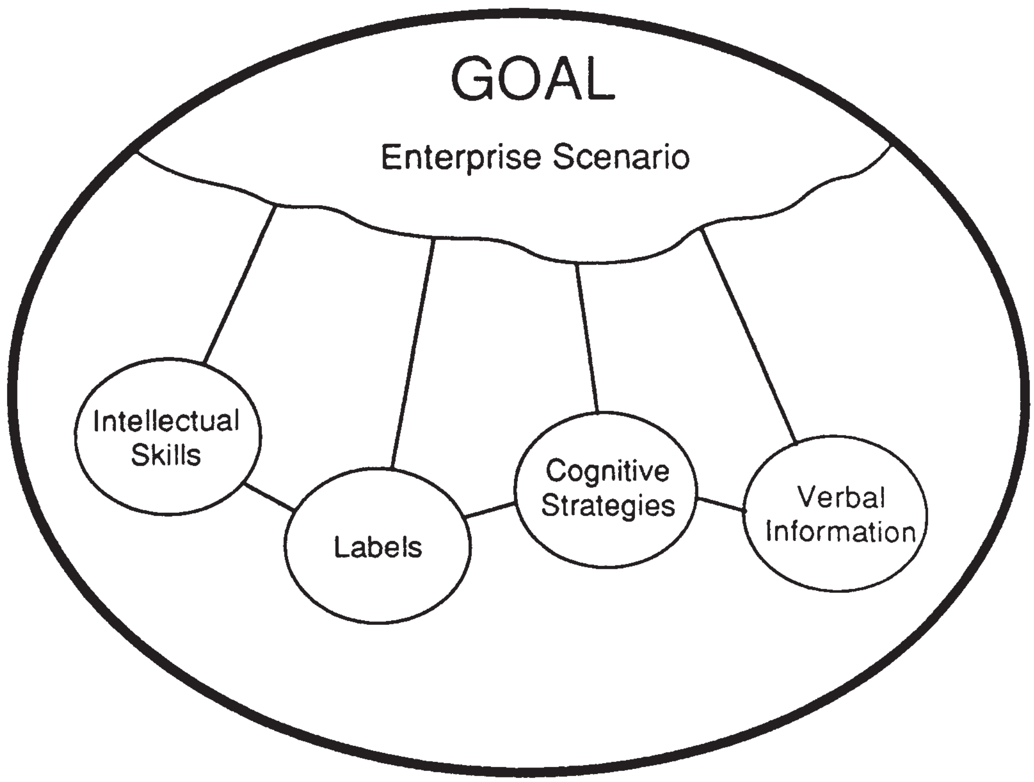


**Figure 4: Enterprise Schema.**

From Gagne & Merril (1990) Integrative goals for instructional designers. *Educational Technology Research and Development, 38(1).*

In effect, Gagné and Merrill have described a mental model like that suggested by Fagen in his reference to the Sylva, Bruner, and Genova study of play (above).

The term "production system" comes from Anderson’s (1983) ACT* ("act-star") theory of cognitive architecture. Although it has been revised several times (Anderson, 1990, 1993, 1996), the original ACT theory, which Anderson subsequently characterized as descriptive of "production-rule theories more generally" (1993, p. vii) is somewhat more accessible than more recent formulations, and its broader descriptive power makes it quite useful for the purpose of understanding the transformation of declarative information extracted from a knowledge base into proceduralized solutions. Glaser (1990) explains the applicability of the ACT* theory to learning in a passage that dovetails nicely with Hutt’s view of the transition from investigative exploration to play (Hutt, 1976, p. 31):

> The major learning mechanism posited by Anderson’s ACT* theory is *knowledge compilation,* which accounts for the transition process that turns declarative knowledge, initially encoded from text or from the teacher’s instruction, into proceduralized, use-oriented knowledge (i.e., converting "knowing what" into "knowing how") . . . .

This is one way of describing the hypothesis formation step in the discovery process that is based on knowledge acquired from the knowledge base. However, Glaser continues:

> The theory holds that effective knowledge of procedures can be acquired only by actually using the declarative knowledge in solving problems.

So discovery requires the additional step of hypothesis testing.  Here is where declarative knowledge becomes operational, exploration becomes play, correctly formulated production rules are enacted and incorrect ones discarded.  In Gagné's words (1985, p. 178):

> Learners are placed (or find themselves) in a problem situation.  They recall previously acquired rules in the attempt to find a "solution."  In carrying out such a thinking process, learners may try a number of hypotheses and test their applicability.  When they find a particular combination of rules that fit the situation, they have not only "solved the problem" but have also learned something new.

Part of the hypothesis testing step may require the use of a tool or other resource that must be selected to initiate the discovery test.

**Resource Retrieval**

Resource retrieval is the step one takes just before testing a hypothesis in which a resource, usually a tool of some sort, is selected from among the items the protagonist has in his or her possession.  Sometimes resources are tried in serial fashion as a way to identify a task or discover a production.  In the adventure game used for the studies one cannot test a hypothesis without first retrieving a previously acquired resource, because all productions require the use of at least one previously acquired resource.

**The Discovery Process**

Gagné’s formulation of the problem solving process as a synthesis of facts and rules into higher-order (production) rules (solution procedures) is also useful here. In fact Gagné (1964, 1966, 1985), Gagné & Merrill (1990), Carroll (1982, 1990, 1998), Carroll, et al. (1985), as well as Anderson (1983), McDaniel and Schlager (1990), and many others agree that discovery learning takes place when a learner creates a higher-order rule, principle (a general rule), or procedure (the expression or enactment of a general rule) from the combination of lower-order rules, facts, concepts, and sometimes procedures. This combination that results in discovery is represented by the production system in the model. A characteristic result of the discovery process is a superior kind of learning. As Gagné writes, "When this happens, the individually constructed higher-order rule is effective in generalizing to many situations and is, at the same time, highly resistant to forgetting" (1985, p. 193).

Gagné argues (1964, pp. 293-294) that problem solving is itself a type of learning. When a problem is solved, a general rule is found (discovered, learned) for handling all similar situations. The discovery of that rule is the acquisition of new knowledge.

**Enactment**

Once formed, the hypothesis must be tested by "enactment" of the procedure (Gagné and Merrill use the term "manifesting"). If the hypothesis is correct, the attempt to perform the procedure will be successful and the task solution will be enacted. In the adventure game, this may mean the successful attainment of access to another portion of the story, the availability of a resource, or the performance of an animated sequence that provides additional information or simply moves the story along. If the hypothesis is incorrect, discovery has not yet occurred, therefore no enactment takes place. This is where the feedback, so critical to the model, both in cognitive and motivational terms, is most salient (Butler & Winne, 1995). The feedback is either positively reinforcing (enactment takes place) or negatively reinforcing (nothing happens).

The term "enactment" is taken from Laurel's closely related work on computers and theater (Laurel, 1991), and stands for a concept congruent with the change from declarative to procedural knowledge and exploration to play in the theories described above. Note that a dramatic presentation is often called a "play." In the full sense of the term as Laurel means it, and in the model, enactment signals the multisensory nature of the presentation that follows discovery in a multimedia adventure game. In drama, enactment is "everything that is seen." In human-computer activity, enactment is "the sensory dimensions of the action being represented: visual, auditory, kinesthetic and tactile, and potentially all others. (From Table 2.1 "The six qualitative elements of structure in drama and in human-computer activity," Laurel, 1991, p. 50.)

The learning model described here is a general model of problem-solving discovery learning. In its application to environments that are not fundamentally expository in nature like adventure games, no obvious scenario or dramatic plotline may seem at first to exist. In everyday problem-solving terms, therefore, the enactment portion of the process is when the lid comes off the jar or the vehicle starts. The model simply requires that one view instances of real-world problem-solving learning as dramatic situations.

## Inquiry System - The *Guide*

> Correct solutions to such problems as these were best achieved in both cases with considerable amounts of 'guidance' . . . . When such guidance was given, a significantly greater number of solutions was achieved than when it was omitted. Learning was thus made more probable (Gagné, 1966, p. 148).

The design of the knowledge base or *Guide* for this project is intended to reflect the theories of discovery learning outlined above, in which knowledge gained from exploring both the task environment and the knowledge base is combined to formulate hypothetical solutions, which are then tested for discovery. This section describes what was done to support that process and why. The complete knowledge base script is included in Appendix A.

**Structural Design**

For purposes of this analysis the following definitions apply (Winn, 1990). A "concept" is the name of a class into which persons, places, or things can be classified on the basis of critical attributes or other criteria. In the knowledge base, concepts are names of persons or creatures, real or mythical; objects, compounds, or natural features; or places. "Facts" are statements that have truth value. In the knowledge base, facts provide little more than background information or the location of a resource. "Rules" express a conditional relationship among two or more concepts. In the knowledge base, rules describe how a thing named by a concept is used or how things or characters act. "Procedures" are actions, motor or cognitive, that consist of a definite sequence of steps. Procedures do not appear in the knowledge base, but must be discovered by learners through process that consists of relating knowledge of facts and rules acquired from the knowledge base to knowledge of possibilities for action acquired from exploring the problem-solving domain (game).

In designing the knowledge base for this project, it was axiomatic that concepts are learned before facts or rules because they are the terms of rule and fact statements. Supported by the reading-level analysis and the reading test, as described in Chapter 3, meanings of concepts that learners must know and manipulate during the learning activity are assumed to be either part of prior knowledge or evident from their description in the game. Concepts like "harpy," "dink," or "ice queen," although not part of the prior knowledge of any research subject, are well enough described in the game that no formal definition was needed. Most of the concepts encompassed by the learning activity — concepts like snake, bear, honeycomb, conch shell, elves, tambourine, hermit, etc. — were presumed to be known to most individuals with 7th grade reading skills. The concepts constitute the third level in the knowledge base hierarchy and are the access points to the facts and rules that constitute the knowledge base content. In addition to their organizing role within the knowledge base, the concept names are "appropriate and stable subsumers" (advance organizers) that help assimilation and retrieval of content within hierarchical cognitive structures, therefore enhancing both learning and retention (Ausubel, 1960). In the knowledge base, fact and rule statements constitute the fourth level in the hierarchy, subsumed by the concepts.

The macro structure of the knowledge base parallels the game: concepts are grouped by geographical region. One selects a region from the links on the top level node, the "cover page," Figure 5. Concepts are grouped within the region in which they are introduced, or for which their influence is most critical. Throughout the *Guide,* concept names are displayed in alphabetical order to facilitate visual search. The buttons for each region on the cover page have a distinctive color, also to aid visual search. Concepts are listed on the region screens (e.g., Figure 6) in columns of no more than seven, so as not to exceed short-term memory chunking limits (Miller, 1956). The region name associated with a fact or rule node appears at the top of each rule or fact node screen (e.g., Figures 7 & 8) to help maintain the learner's orientation within the knowledge base. In the learning hierarchy, rules and facts are "children" of concepts; facts and rules are therefore "siblings." If a rule or fact is responsive to more than one concept, more than one concept button may be linked to it from the region or index nodes.

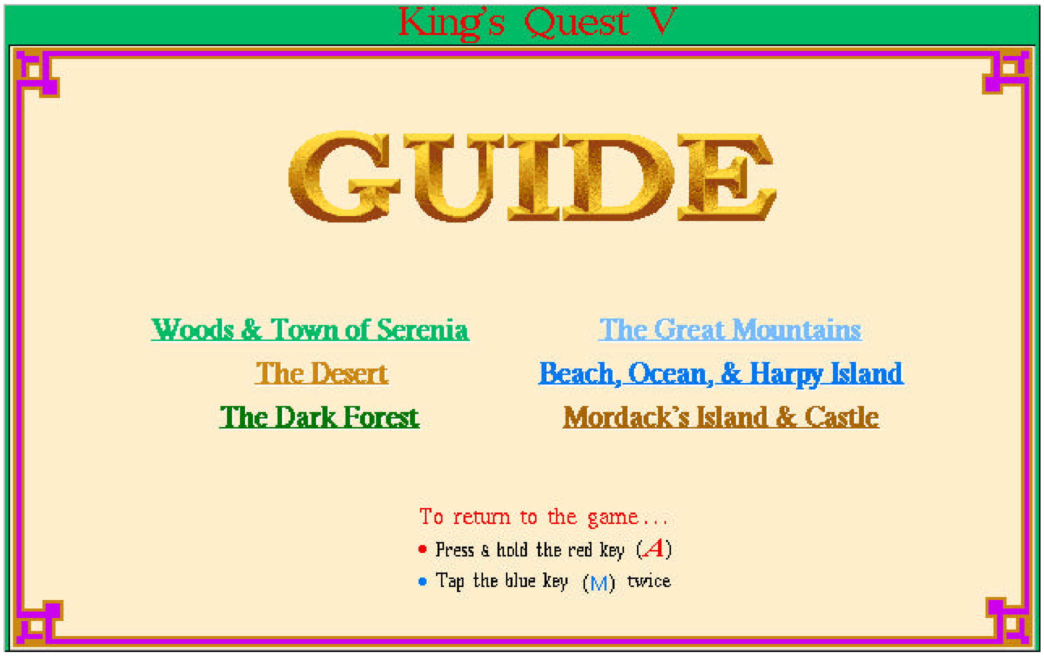


**Figure 5: The *Guide* Cover Page.**


**Figure 6: The Woods & Town of Serenia Region Page.**

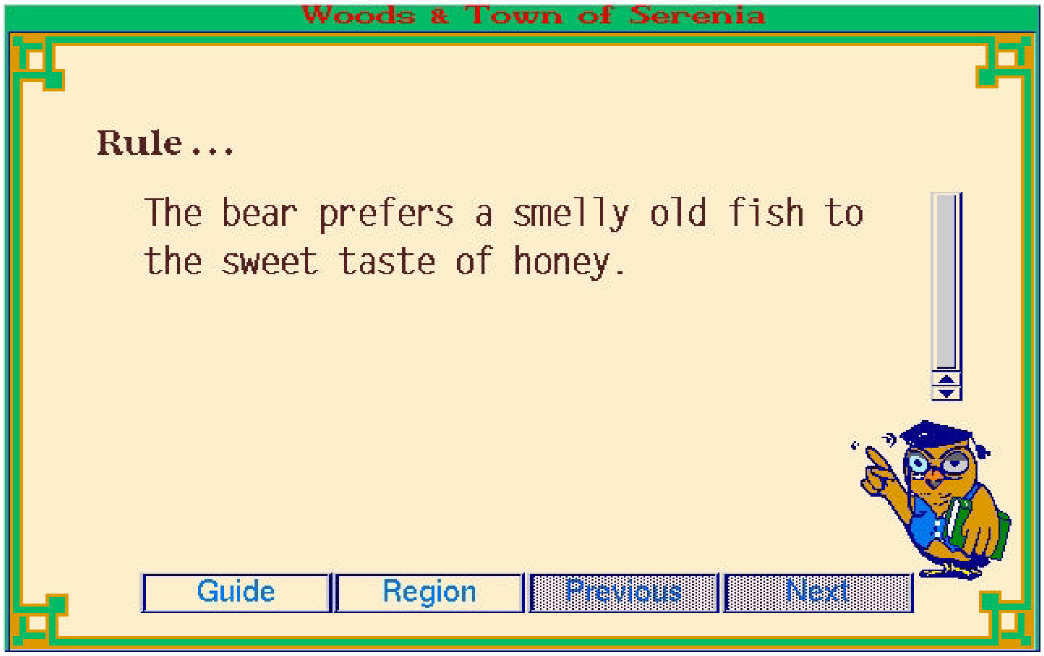


**Figure 7: Knowledge Base Rule Card for Concept "Bear."**

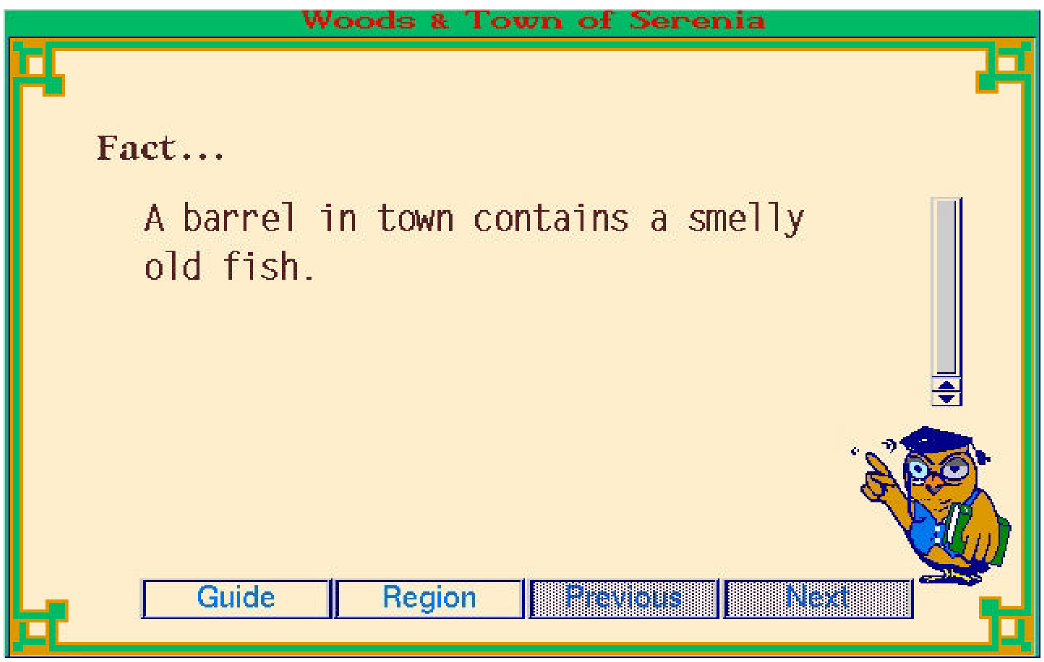


**Figure 8: Knowledge Base Fact Card for Concept, "Fish."**

Multiple rules or facts that are related to a single concept are read sequentially. The order of presentation of facts or rules related to a single concept either observes a learning sequence logic (that certain content should be learned before other content) or parallels the sequence of steps in the procedure (the steps to be performed to enact the solution). For example, although one could argue that the model suggests that the acquisition of information must precede the use information (procedural organization), it is probably best to learn why it might be useful to have a cobbler’s hammer before knowing where and how to acquire one (learning sequence organization). Hence, the rule, "A cobbler’s hammer is an effective tool to break the padlock on a cellar door. . . ." should precede the fact, "A retiring shopkeeper would gladly trade his cobbler’s hammer for a pair of fine shoes made by elves." This is a "learning sequence" because it tells you why you need the resource first and where to get it second. But the rule, "Graham must use Mordack’s machine to transfer power from Mordack’s wand to Crispin’s wand" precedes, "When the transfer of power is complete, Graham must act quickly to remove Crispin’s wand from the machine!" is a "procedural organization" because the rules are linked in the order of execution.

Each map node is linked to a region node and not cross-linked to any other node. Map buttons appear only on the region page for the region associated with the map. However from a map node, one can access the index, help, cover page, and region nodes.

**Search and Navigation**

Two search mechanisms are incorporated into the knowledge base: (a) an alphabetical list or index and (b) a geographical grouping, with concepts as the key search words. Visual scanning is faster and more efficient than "find word"-type electronic search methods for very small information sets. With visual scanning the searcher does not need to know any of the keywords in advance of and in order to initiate the search. Learners may browse the knowledge base from a list or hierarchy without any prior knowledge of its content or semantic structure.

To support visual search, an index listing is available from the menu bar of every node except the cover, help and index nodes. The menu function on the cover is used to quit the knowledge base itself and the menu function on the help and index nodes simply returns one to the node from which the index or help node was accessed. The index contains a single scrolling alphabetized list of concept buttons linked to all the "first-of-the-sequence" fact or rule nodes in the knowledge base. First-of-the-sequence nodes are the entry point to all multiple-node fact/rule sequences. Fact/rule sequences are sequential sets of two or more nodes that contain different facts or rules related to a single concept, some of which, because they are also related to more than one concept, are cross-linked from other concepts. Because only the first-of-the-sequence node is linked directly to any concept button, whether linked to its region node or to the index, fact/rule sequences must be read sequentially. Not all concepts require more than one fact or rule, however. Therefore, a method of signaling the existence of second or third nodes in a sequence was incorporated into the design of the node page buttons. Centered at the bottom of every fact or rule node page are four buttons: (left to right), "Guide" (meaning cover page), "Region" (to which the fact or rule applies), "Previous" (in case one is at a second or third node), and "Next" (meaning next fact or rule in the sequence). The two leftmost buttons (linked to the cover page and to the region to which the fact or rule belongs) are always active. The "Previous" and "Next" buttons are only active if there is a next or previous node linked to them. If either or both of the buttons on the right are not active, they are "ghosted," the conventional way to signify inactive links.

**Support for Indirect Observation**

The guided exploration learning model does require the availability of a library, "guide," or inquiry system and a simulated or real environment or "world" to explore, but it does not specify the medium. The knowledge base may be realized on paper, computer screen, or some other medium. It may consist of searchable (or scannable) text, graphics, sound, or animation. Although paper is most common, both paper (hint books, clue books) and onscreen "cheats," have been used before with adventure games. It was beyond the scope of this project to study differences in the instructional effectiveness of different methods or media, but a choice of medium and the mix of modalities was necessary in planning the research. Relevant instructional design issues include the nature of the software used for creating the instruction; whether tutorial, electronic book, paper book, speech, animation, or video elements are employed; how graphics like maps and diagrams are accessed and displayed;

speed of access; access method (keys, mouse, touch screen, or book); screen / page design; and whether the instruction is solicited or unsolicited and context sensitive or context free.

The decision to use online text and graphics in a rather ordinary button-link interface with a hierarchical structure was made for one reason only: to enable the capture of knowledge base use data. It is virtually impossible to record data on a subject's use of a paper document — i.e., how and when they read or access what information and why — but when what subjects read is online, a subject's use of the knowledge base is captured on video along with the rest of the video and think-aloud data. The observer of the data can therefore describe, to whatever degree of detail that is necessary, exactly how, when, and why a subject used the knowledge base. Because the display of text is limited to four lines, and each screen displays just one fact or rule, it is also possible to observe exactly what information is accessed, and to quantify the time and the number of repetitions involved in accessing a single fact or rule.

**Instructional Design Philosophy and Rationale**

A guided exploration learning activity or environment is supported by an instructional knowledge base that enables problem solution hypothesis formation and discovery learning. These environments can be highly motivating for those who perform well. Different ways of designing the instruction may affect not only the quality and extent of the learning, but the strength of the motivation. The model and the theoretical principles that define it call for learners to generate the solution procedure for each puzzle themselves by selecting, sequencing, and applying facts, rules, and concepts learned from both the knowledge base and the environment itself. Formulating a procedure (generating a solution) requires selection and sequencing of the incomplete information. Gagné advises (1985, p. 178):

> Guidance may vary in amount or completeness, always stopping short of describing the solution. As a minimum, guidance of thinking informs the learner of the goal of the activity, the general form of the solution; this amount of guidance appears to be required if learning is to occur at all. Greater amounts have the effect of limiting the range of hypotheses entertained by the learner in achieving solution. . . .
>
> Problem solving occurs when the instructions provided the learner do not include a verbally stated "solution" but require the construction of such a solution "on one's own." When this happens, the individually constructed higher-order rule is effective in generalizing to many situations and is, at the same time, highly resistant to forgetting.

Productions are the connection between declarative knowledge and behavior. They occur when a correct hypothesis or higher-order rule tests positive for discovery (it enacts, producing learning). A positive test for discovery amounts to a "proof" of the production rule. Productions demonstrate procedural knowledge, knowledge about how to do things. Production rules are rules in the formal sense: i.e., they are "if-then, condition-action pairs" (Anderson, 1993, p. 4) in which the "if" term specifies the condition and the "then" part of the rule specifies "what to do in that circumstance" (Anderson, 1993,p 4). Production rules are the hypotheses to be tested for discovery through enactment. The object of the production system is the formulation and testing of the (hypothetical) production rule, and the path of if-then links from task identification to enactment may be long and indirect.

To see how this works, please refer to Figures 6, 7, and 8 (above) and Figure 9 (next page). Figure 6 shows the knowledge base (*Guide*) region page that lists the concepts, "bear" and "fish." When subjects click these concept buttons, they access the instruction associated with each concept — a rule governing the general preferences of bears (at least in the imaginary world of the game), and a fact relevant to fish — actually a particular fish in the game (Figures 7 & 8). When encountering an agitated bear in the game the subject must formulate the higher-order production rule hypothesis: "*If* bears prefer fish to honey, and *if* I get a fish from the barrel in town and give it to the bear, *then* the bear may leave the bees (and me) alone." Testing this hypothesis with action (Figure 9) enacts the procedure. Because the enactment confirms that this is the correct higher-order production rule (one that will be remembered and correctly recalled later on the posttest), an unanticipated and highly reinforcing reward (feedback) may follow — acquisition of a new resource (Figure 10) that will be needed much later (Figure 11). In Figure 11, the learner discovers an ingenious use for residue from the honeycomb resource acquired from the bees to enable new possibilities for action — the repair of a sailboat with which to embark upon the high seas.

**Figure 9: Enactment: Rescuing the Bees by Tossing a Fish to the Bear.**

**Figure 10: Post-Production Resource Acquisition (Honeycomb).**


**Figure 11: Enactment: Use of Resource (Beeswax) to Patch a Leaky Boat.**

Figures 12-16 on the following pages illustrate the varied, yet critical role of "resources" in the formulation of production rules and the enactment of productions in *King's Quest V*. The resources that are needed must be acquired in separate and sometimes unrelated actions before they can be used. The enactments shown in Figures 12-16 illustrate the range of production rules that must be discovered, and the resources that are needed: a rope to climb an ice wall, a pie to blind and confuse a yeti, a locket to charm and befriend a princess, peas to trip and knock out a monster, and knowledge of the enemy's magic to outwit him. By applying a general problem-solving learning model to the complex sequence of steps that must be performed for King Graham of Daventry to successfully defeat the wizard and recover the imprisoned members of his family, learners "discover the curriculum." But most of these solutions are not likely to be discovered without the assistance of a knowledge base constructed on minimalist principles. The five elements of minimalism and their implementation in the design of the online knowledge base for this study are from Carroll and van der Meij (Carroll, et al., 1985; Carroll, 1998; van der Meij & Carroll, 1998):

- *Action Orientation.* The knowledge base encourages and supports exploration.
- *Task Orientation.* Organization of the declarative knowledge in the knowledge base duplicates the organization of the task environment.
- *Incomplete Information.* Facts and rules are stated in short, pithy, epigrammatic "riddles" or broad generalities.

**Figure 12: Enactment: Use of Resource (Rope) to Climb the Frozen Cliff.**


**Figure 13: Enactment: Use of Resource (Pie) to Defeat the MountainYeti.**

**Figure 14: Enactment: Use of Resource (Locket) to Befriend a Princess.**


**Figure 15: Enactment: Use of Resource (Peas) to Defeat the Blue Beast.**

**Figure 16: Final Enactment: Use of Resource (Knowledge of Magic Spells) to Defeat the Wizard.** *Screen Images Copyright 1990 Sierra On-Line, Inc. and its licensors. All Rights Reserved.*

- *Modularity and Random Access.* Hierarchical and alphabetical search tools support reading in any order (context insensitive).
- *Safety.* Knowledge base supports error recovery as a source of stimuli for new hypotheses when hypotheses fail. Helps set player up for a new start after restoring game.

Information needed to solve a problem or a game should be solicited by problem solvers voluntarily and be completely under their control. The player should be able to control both the level of challenge and his or her learning rate by seeking or not seeking help. Content disconnected from context encourages the student to mindfully select, sequence, compile, and retrieve applicable elements from the whole of the knowledge base.

Leutner (1993) compared the instructional effectiveness (retention) of several ways of making concepts, facts, rules, and principles of a simulated domain, including "permanently available background information" or "non-adaptive instructional support" (a knowledge base); "adaptive advice" (context-sensitive instruction); and "pretutorial" (a tutorial before entering the simulation) explicit. His findings support the principle (Carroll 1982, 1990, 1998; van der Meij & Carroll, 1998) that information should be randomly available on demand and not context sensitive. Concerning context sensitivity, Leutner concludes:

> Background information on system variables seems to be especially useful when the learner, after reading it the first time, can at any time refer to it and use it to solve specific problem situations. Contrary to that, adaptive

> advice and pretutorial information demand less personal initiative because they are automatically supplied by the system and the student cannot consult the information exactly when required for solving a certain problem situation (Leutner, 1993, p. 129).

Concerning the desirability of user control of the availability of the information, Leutner concludes: "For exploratory learning and problem solving it seems essential to have the appropriate amount of relevant information at the appropriate point in time, namely whenever necessary" (p 115).

An ability to freely consult an instructional knowledge base of some form is a requirement for optimal learning. The instructional component or knowledge base may contain information from any knowledge domain that can be portrayed in an adventure game (Keegan, 1995). Within the active learning system the game functions both as motivation engine and assessment mechanism (pass/fail system). Although learning performance is ultimately assessed by means of a student’s success with the game, and the student’s goal may be nothing more than to succeed with the game, the instructional designer’s goal is for the student to master the content of the curriculum unit, recognizing that the content is distributed between the game itself and the knowledge base/guidance system. The designer knows that the student must master the game to demonstrate mastery of the curriculum unit, so it is also a goal of the designer to ensure that the student will solve the game. In software-based guided exploration problem-solving discovery learning, therefore, the game functions as performance enhancement to the main task of learning the content of the curriculum unit, rather than the reverse.

Assembling or compiling knowledge is a two-step process by which declarative knowledge is "proceduralized" (Anderson, 1983). When proceduralization occurs during problem-solving activity like adventure game play, it enables the sequencing of productions that enact the solution. With only declarative representations in the knowledge base, the subject is required to undertake for himself or herself the knowledge compilation needed to produce the solution performance (by which success is assessed through positive or negative consequential feedback). One should expect that the act of compiling procedures by selecting, synthesizing, sequencing, and applying facts, concepts, and rules for oneself would result in deeper processing and better understanding and retention.

# Chapter 4: Method

The claim that motivating attributes are embedded in computer games comes from both software publishers and theorists. The argument is that people are motivated to play computer games because of attributes of the games themselves, rather than because of peer pressure, fear of failure, or some extrinsic reward for doing so like recognition, fortune, or achievement. It is further claimed that the juxtaposition of entertainment and informational or instructional content can aid learners by taking the drudgery out of the mental tasks normally required in learning. Much evidence does support the idea that people learn better when they are motivated because of an intrinsic interest in the learning task.

If such claims are true, what are the attributes of software games that could be appropriated to motivate learners? Csikszentmihalyi’s observation that led to the search for factors underlying autotelic activities came from the world of fine art (Csikszentmihalyi, 1975, xii):

> Slowly it became obvious that something in the activity of painting itself kept them going. The process of making their products was so enjoyable that they were ready to sacrifice a great deal for the chance of continuing to do so. There was something about the physical activities of stretching canvas on wooden frames, of squeezing tubes of paint or kneading clay, of splashing colors on a blank surface; the cognitive activity of choosing a problem to work on, of defining a subject, of experimenting with new combinations of form, color, light, and space; the emotional impact of

> recognizing one's past, present, and future concerns in the emerging work. All these aspects of the artistic process added up to a structured experience which was almost addictive in its fascination.

This "structured experience," made up of sensory (physical), and cognitive and emotional (psychological) factors, consumes all of an artist's energy and attention. The activity is autotelic. Similar involvement is believed to be possible in some learning contexts, especially when they offer multimodal sensory stimulation (color, graphics, motion, music, speech, sound effects). In other words, much of the toil of learning may simply arise from the lack of adequate stimulation offered by traditional media and instructional methods: "To change a boring situation into one that provides its own rewards does not require money or physical energy; it can be achieved through *symbolic restructuring of information* (Csikszentmihalyi, 1975, xiii; emphasis added).

The basic question for educational software designers, then, is: How can the informational content of an educational environment be symbolically restructured to motivate learning? Is it possible to turn on motivation in users through deliberate application of software design principles and plans derived from the study of games, so as to increase learning? Do computer games induce flow states like those experienced by the artists in Csikszentmihalyi's studies? According to Csikszentmihalyi, the critical factor in activities that are conducive to flow is *design* — design of activities that (1990, 72):

1. Have rules that require the learning of skills
2. Set up goals and provide feedback
3. Make control possible
4. Facilitate concentration and involvement by making the activity as distinct as possible from the "paramount reality" of everyday existence.

As a starting point designers need to know the nature of the effects of the games on players and what aspects of game design are responsible for which effects.

It appears from anecdotal evidence and casual observation, however, that even if a subject is motivated initially while attempting to perform a task as complex as solving an adventure game, his or her motivation is short lived unless help in the form of instruction or performance support is available. Without access to the knowledge needed to avoid the many dead-ends and pitfalls, progress seems impossible and initial motivation quickly turns into frustration, anxiety, apathy, boredom, or even anger or panic (i.e., "thrashing"). These disincentives to continue defeat the purpose for which the game exists and players quit, usually for good, taking the sense of having failed with them.

In the early stages of thinking about and preparing for this research it was thought that results would show that when subjects (a) have knowledge of an adventure game's goal and (b) have access to the information needed to solve the puzzles posed by the game, motivation to work on solving the adventure game would be maintained or intensified. Under such conditions, data from records of time in contact with the task, mid-stream experience sampling questionnaires, continuous recordings of think-aloud protocols, and video recordings of terminal activity would show evidence of states of flow during adventure game play, which might warrant the claim that such games are intrinsically motivating. It was predicted that without both knowledge of the goal and access to the instruction, subjects would experience anxiety, apathy, or boredom, as reflected in the think-aloud protocols and video recordings, and on the experience sampling questionnaires.

## Questions

The main objective of the eight studies described below were to observe and measure (a) the psychological factors in voluntary engagement and/or disengagement with the activity and (b) content-related learning in relation to the psychological factors. A secondary objective was to record and measure differences in motivation before and after the introduction of a knowledge base containing the essential facts and rules needed to discover the game's puzzle solution procedures.

Questions addressed three areas: (1) motivation, operationalized using measures of flow; (2) use of the knowledge base and its and the game's reciprocal roles in the discovery process; and (3) content learning and retention. The study asked:

- What are the factors that determine success or failure in complex problem-solving learning environments like adventure games?
- How effective is a guidance-enhanced computer-based adventure game as a learning environment?

Using the apparatus described below, subjects self-collected continuous video/audio, think-aloud, and experience-sampling data on their experiences while they worked on the adventure game *King's Quest V*. As subjects worked on solving the adventure game, the screen image showing the subjects' manipulations of the interface through the mouse and keyboard, the music and sound effects output by the program, and the subjects' think-aloud protocols were recorded on video tape. At random intervals of between 48 to 74 minutes, subjects responded to a series of Likert-type questions that appeared onscreen and queried them on the nature of their experience while working on the game. Following successfully solving the game, retention was assessed using a conventional paper and pencil recall posttest. The learning objectives measured were the procedures required to enact the solutions to each of the 20 major productions that must be performed to complete the learning task (solving the adventure game).

## Definitions

### Experience Sampling Method

With the Experience Sampling Method (ESM) (Csikszentmihalyi, 1975, 1988a, 1988b; Csikszentmihalyi & Csikszentmihalyi, 1988; Fave & Massimini, 1988; Kubey & Csikszentmihalyi, 1990; Massimini & Carli, 1988), subjects are asked to answer a series of questions on an instrument called an Experience Sampling Form (ESF) while engaged with any activity of interest to researchers. The ESFs most often used have been refined over many trials with different populations during the past 20 years. The most common method samples subjects' experiences over several days or weeks. Subjects are supplied with a stack of paper ESFs and an electronic pager, with which they can be signaled at random intervals from a central location. When the "beeper" sounds, subjects stop what they are doing and fill out the two-page form. Juxtaposing questionnaire and experience is deemed more reliable than retrospective measures. For examples of these instruments see Csikszentmihalyi & Csikszentmihalyi (1988, pp. 255-258), Fave & Massimini (1988, p. 195), and Kubey & Csikszentmihalyi (1990, pp. 54-55, 225-237).

**Autonomy Support**

To collect the data for this study, a special instrumented workstation was constructed to enable subjects to operate in a context that was as autonomous and independent of the researcher's influence on the activity as possible. Throughout the data-collecting sessions, the software, not the researcher, interacts with the subject. Data collection is therefore a natural and integral part of the activity. The intent of this approach is to minimize or eliminate investigator effects, which are of special concern when studying intrinsic motivation. Studies that examine subject responses to threats and deadlines show that restrictions on time and possibilities for action undermine intrinsic motivation. See, for example, Amabile, DeJong, & Lepper (1976) and Deci & Cascio (1972). Studies of lack of subject choice and control over what to do, and when and how to do it, also apply. Swann & Pittman (1977) and Zuckerman, Porac, Lathin, Smith, & Deci, (1978) found that when subjects are given choices both of what puzzles to solve and the amount of time to devote to solving the puzzles, intrinsic motivation is enhanced. Hence it is desirable in studies of intrinsic motivation that subjects be permitted to determine the extent and direction of their effort and involvement.

While an observer must be present at some point in the process, feelings of autonomy and control are likely to be reduced when subjects are aware that their performance is being scrutinized. Studies of subject reaction to the mere presence of the investigator (Deci & Ryan, 1987); in-person surveillance (Pittman, Davey, Alafat, Wetherill, & Kramer, 1980); and evaluation (Benware & Deci, 1984; Harackiewicz, et. al., 1984; Maehr & Stallings, 1972; and Smith, 1974) have demonstrated this. The apparatus and associated procedures are intended to minimize or eliminate the undesirable effects of such perceived researcher control on motivation by fully integrating subjects' data-collection activities within the main activity of working with the game.

The automated data collector ensures an autonomy-supportive context for research subjects in the following ways:

- No *unnatural* time limits are imposed on subjects. Parents, spouses, biological needs, telephone calls, or competing interests or responsibilities will naturally intrude upon the time available for the activity. Yet the subject is free to not interact with the system at all. Data collecting concludes when the subject either completes the learning task or drops out.

- The investigator does not intrude upon the data collection process except when called by the subject, or if some extraordinary event calls for it (like when the software malfunctions), so the negative effects of in-person surveillance are reduced or eliminated.
- No other specific aspect of the subject's interaction with the software under study is interfered with by the conditions of the research. Subjects are free to interact with the system in a natural manner.

### Data — Continuous

The richest source of data on subject interaction with the computer, the game, the onscreen instruments, the knowledge base, and any other aspect of the activity under investigation, is the videocassette recording that simultaneously and synchronously captures video output from the computer, audio output from the computer, and verbal input (think-aloud speech) from the subject.

While systematic analysis of think-aloud protocols was done before the invention of tape recorders by note-taking real-time observers (Watson, 1920), modern recording devices permit detailed analysis of think-aloud protocols with no time constraints. Audio tape recordings can be audited in real time or speeded up or slowed down, and, to some extent, scanned. Audio tape can also be electronically indexed to mark significant portions of a recording. Video tape can likewise be indexed and speeded up or slowed down. Unlike audio, video can be frozen or advanced one frame at a time. Video can also be scanned visually, both backward and forward, for relatively quick, if linear, search. Observational records like video recordings can be reviewed repeatedly by multiple observers. The material can be reworked as many times as desired and used in follow-up studies or studies that ask questions unrelated to the questions that originally prompted the collection of the data.

Transcription of verbal data to text from audio, although tedious, makes possible the detailed examination and manipulation of verbal data. With a word processor one can search through the transcribed text to find particular material, or to locate a particular point in the data stream. One can also use the transcript to locate points in the video, to better understand the context of the cognition or behavior. One may crossreference these points in the transcript using the VCR's counter to describe their locations. The transcribed protocol can be searched for a match with the audio portion of the video tape. Text loaded into a word processor can be searched much more quickly than audio or video tape. Text loaded into a qualitative analysis program can be manipulated and studied at a level of detail that would be impractical or impossible using the raw audio data alone.

Despite the advantages mentioned above, the analysis of verbal data in text form without the video/audio context and accompaniment is far less informative than the combination of the verbal protocols with the video and nonverbal audio. While the advantage of a text transcript is that it is easy to search or scan for words or other units of meaning, and to extract examples for reporting, the disadvantage is that there is nothing in the transcribed and abstracted verbal data to show what a subject is reacting to (an image, action, or audio event) or how the protocols were expressed (e.g., voice inflection, tone, and pacing).

## Data — Questionnaire

Because this study focused on a single activity that extended intermittently over several days or weeks, but was expected to involve a total of less than a dozen hours, somewhat novel flow sampling and analysis techniques were employed. Instead of paper and pencil forms, a shorter electronic version of the ESF, the Experience Sampling Questionnaire (ESQ), was created that appears on the computer screen at random intervals of 48-75 minutes. Also, a shorter Retrospective Questionnaire (RQ) was built into the system that appears each time the system is shut down in the normal way. ESQs and RQs display a random sequence of single-item screens. Randomly varying the interval between ESQs reduces the likelihood that subjects will anticipate, consciously or unconsciously, the appearance of an ESQ. Random sequencing of the questionnaire items also eliminates question order effects. When answering an ESQ or RQ questionnaire item, subjects use the mouse pointer to position an arrow along a scale to indicate a choice and then click a continuation button. When the continuation button is activated, the output from the current item adds a new line in the subject's data file and the next question appears onscreen. A separate file that contains the data for all ESQs and RQs, with each response identified and numbered sequentially, is created for each subject. Each line in the output file contains the following data for one questionnaire item:

- Line number
- Date and time
- Subject ID code

- Session number
- Questionnaire sequence number
- Item number (in random sequence)
- Subject’s selection (a value)
- Value calculated from selection value to plot directly on subjective experience model

The method is robust and keeps track of these administrative details even when the system "crashes" and restarts.

## Apparatus and Instruments

The apparatus developed for this research is an instrumented semi-mobile multimedia workstation that collects data in semi-controlled, naturalistic settings. In its present form, the system is self-contained and under software control from the moment the power is switched on. The subject is required only to remember to turn on the master switch to initiate a session. All other actions required of subjects in the startup and shut-down sequences are prompted by the software. The apparatus can run games and other software within a pre-emptive multitasking environment. Animated graphics and synthetic speech guide the user through the procedures for starting up and shutting down the system. Online ESQs, activated at preset but variable intervals during game play, sample the subject’s experience *in situ*. As with the online knowledge base described above, the ESQ screens — each containing a single question — can pre-empt the process running in the foreground — i.e., the game. RQs run at the conclusion of each session. Advantages of such a system for research are:

- Anonymity of researcher
- Autonomy of subject
- Replicability of research procedures
- Randomization of sampling instruments

The automated data collection process helps assure procedural consistency across sessions and subjects. The complete apparatus "kit" has three component assemblies: hardware, software, and "formware" (supporting documents).

**Hardware**

The workstation itself (Figure 17) was built with consumer level electronic components. In its "roving" mode, the data collecting apparatus emulates an Apple Quadra 900 desktop computer by means of Emplant (Electronic Micro-Processor Level Amiga Native Task) hardware inside an Amiga 3000 desktop computer, accelerated by means of a 40Mhz WarpEngine (which adds a 68040-level processor and 32MB of RAM to the original 86030 processor and 16MB of RAM). A Picasso II graphics display card and a high resolution color monitor complete the emulation package.

During data collection, digital video output is transcoded at broadcast standard (RS170A) to the analog Super-VHS NTSC format and recorded synchronously with the mixed audio signals from the computer and the speech input from the microphone using a Super-VHS video cassette recorder (Panasonic PV-S4366). An external Super-VHS video scan converter (Advanced

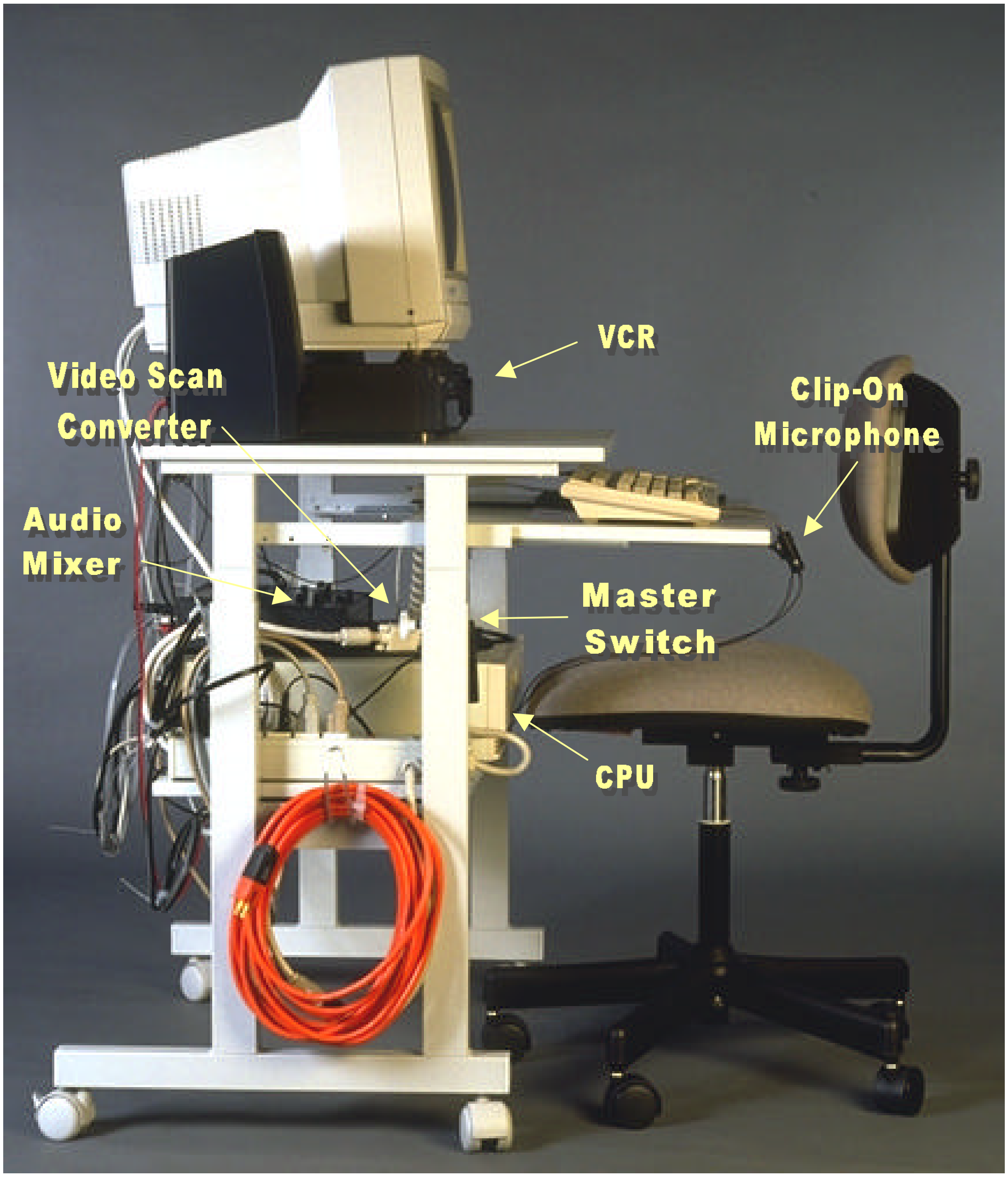


**Figure 17: Data Collection Apparatus Hardware Assembly.**

Digital Systems TV Superscan 2) splits the signal from the computer's video output, sending an RGB signal to the workstation monitor and a Y/C (Super-VHS) video signal to the VCR. The video scan converter synchronizes the computer's and the VCR's scan rates, enabling the analog VCR to record the computer's digital video output. Each videocassette can record 6 hours of video/audio and think-aloud data with T120 tape (8 hours with T160 tape).

The Super-VHS format provides both superior video quality, with its 400 lines of resolution and separate luminance and chrominance controls, and superior audio quality through its dual 1/8" stereo sound tracks. High quality edited copies of data requested on the Super-VHS can also still be made in standard VHS format for presentation on the more common VHS devices. More importantly, however, the Super-VHS format permits recording at the slowest recording speed — "super-long play" (SLP) — with good resolution. Fast-forward and rewind scans during data analysis are therefore three times faster than those possible with VHS recorded at the fastest speed (SP). When "docked," the hardware rover is capable of a variety of audio, video, and digital in-out operations that share analog and digital data among several computer platforms (Amiga, Macintosh, MS-DOS, Windows 2.0, Windows 95) and input-output devices and media (video tape, audio tape, floppy disk, fixed disk, paper, and overhead transparencies). Figure 18 shows the cross-platform, digital/analog, multimedia data flow and processing capabilities of the system.

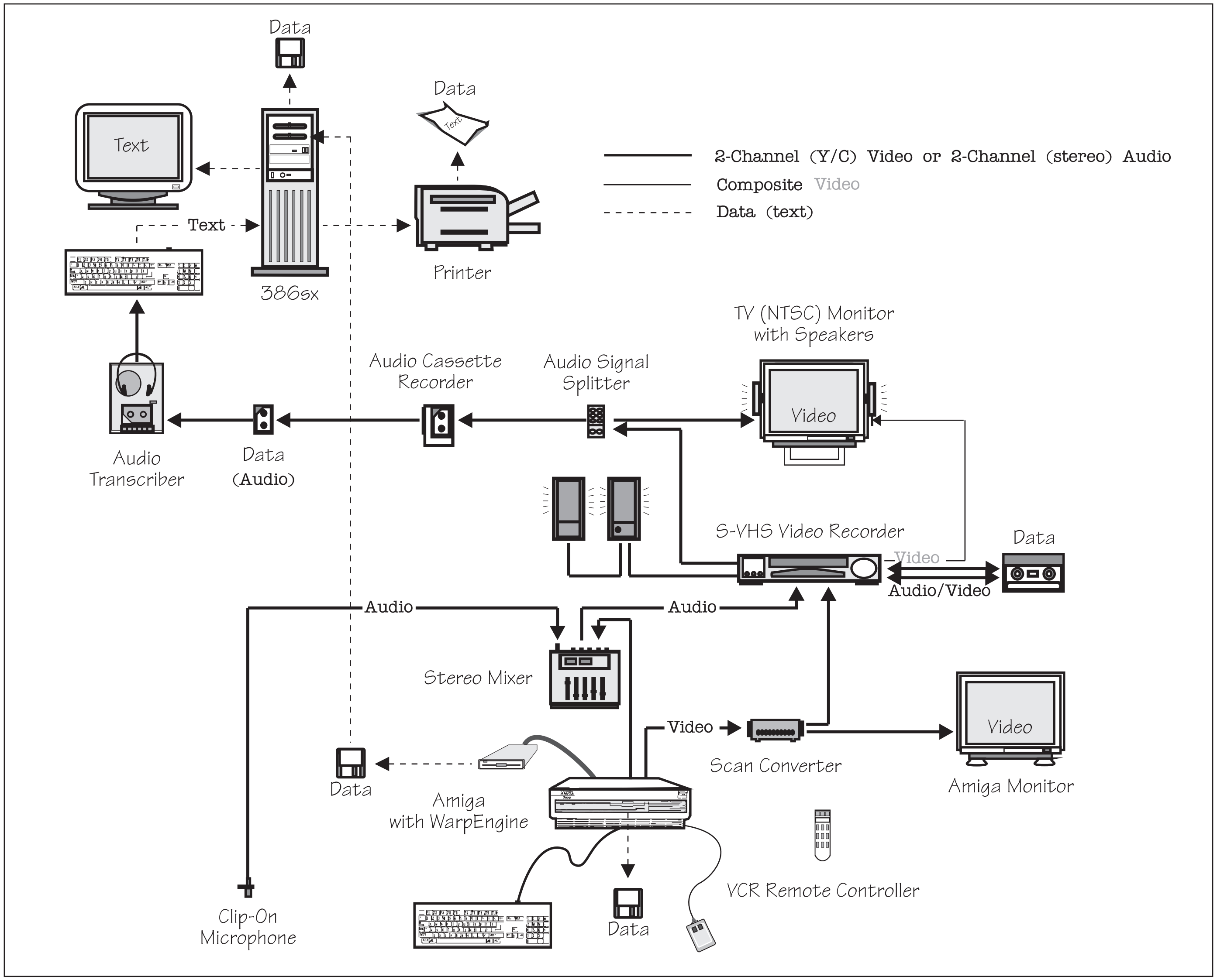


**Figure 18: Hardware Components Data Flow.**

**Software**

The computer is equipped with software that, once activated by turning on the system's master switch, provides structure in the data collection session while delivering and sustaining the learning activity itself. The data collection process is therefore embedded within and integrated with the task. As with Skinner's teaching machines, the subject / learner interacts principally with the program, not the researcher / teacher, during learning and data collection.

Inovatronic's CanDo!3.0 object-oriented multimedia authoring program was used for the major portion of the programming, which included the interactive operating instructions, knowledge base, ESQs, RQs, reminders, timers, change of treatment conditions, emulation startup sequences, and the interactive tutorial. Multimedia elements (graphics, animations, sound effects, and synthetic speech) were created with external programs and linked through icons and requesters with CanDo!3.0. CanDo! scripts can be written that control some operating system processes from within CanDo! Because CanDo! is an authoring program, researchers need not be "programmers," in the strict sense of the term, to use this technology. With most authoring software, useful applications can be created that incorporate computer-generated graphics and animation; text in different fonts, sizes, colors and formats; digitized (recorded) and synthetic (computer generated) sound and music; synthetic speech; interactive text windows, dialog boxes, menus, and selection lists; data entry and display fields; "gadgets" like radio buttons, sliders, knobs, buttons, and scroll bars; and full-motion video sequences. Control structures such as branching, looping, calls to subroutines, and so forth, are also supported and may be launched by researcher-defined variables. Constants, variables, and functions, as well as four types of values — integers, reals, strings, and arguments — are supported, and digital data can be saved to and retrieved from disk.

The concept at work here is that of layering the different simultaneously running processes. The stimulus software, whether a game, word processor, or something else, runs most of the time as a foreground process (task) displayed on the monitor while the research interventions run as separate processes in the background. When programmed to do so, a background process may preempt a foreground process to elicit a response from a subject, issue a directive, or change a condition.

An issue that arises when switching between simultaneously running programs or platforms is whether when first opening a program module it will be launched on its own "custom screen" or a "public screen." This is an issue because it affects what happens when one directs the computer to switch active programs, which is actually a command to switch *screens.* A "screen," as distinct from a "window," is the display area available for use by a program, and on which a window is located. If the screen is larger than the monitor display area, it may be possible for the monitor display area to scan or scroll around over the screen area, for example to display large maps. The dimensions of the screen are a function of the amount of display energy (information) available to the system and they vary with the resolution selected.

Screens can be switched in several ways on the Amiga. The "ScreenTo FRONT" command moves a current screen to the front of the "stack" of screens. A user can cycle through all open screens by bringing the deepest or rear-most screen in the stack to the front (top of the stack) with a *Left Amiga-M* combination keystroke. The system-level public screen is called the "Desktop" on the Macintosh and the "Workbench" on the Amiga. A public screen is a screen that can be shared by more than one program. A "custom" screen is a screen that is the exclusive property of the program that opened it.

Ideally, when running two parallel processes — a Quadra 900 emulation and a Cando!3.0-based knowledge base, for example — one wants subjects to switch smoothly between the programs running on these screens without having also to cycle past unwanted screens that may have opened and remained open when some other background program was launched, like the Amiga Workbench itself or a terminate-and-stay-resident (TSR) utility. Although these are details, it is best to avoid the intrusion of unwanted screens between the two primary ones when switching screens. Fortunately there is a way to minimize, if not eliminate, the problem.

The solution is to open all of the timer modules on the Amiga Workbench screen. The Workbench cannot be closed in any case, so it makes sense to open the timers there. When multiple programs are opened on a public screen, only the last one opened is displayed. This is like a stack within a stack, with only the top layer of "inner stack" visible. Next, the *Guide* (knowledge base) opens on a private screen (behind the Workbench and timers), and lastly the Macintosh emulation opens, also on a private screen, and is automatically "pushed" to the foreground. This arrangement means that only three screens are open most of the time, with the emulation in front, the *Guide* at the bottom, and the Workbench in the middle. The exception to this arrangement is when one of the timers launches a new process on a private screen — say an ESQ — and pushes it to the front. During such intervals 4 screens are open. The presence of the Workbench with its hidden timers in the stack means that when subjects flip screens to access the *Guide,* bringing it to the front and pushing the emulation into second place, the Workbench moves to the bottom. When subjects want to flip back to the game, the Workbench moves to the front first so they must repeat the keystroke action a second time to bring up the game. To make that extra step as unobtrusive as possible, the top-level timer on the Workbench displays a simple graphic with the message, "Returning to Game," that reminds subjects to hit the key combination a second time to reach the game.

The three sequential booting patterns during start-up are shown in Figure 19. Figure 19 should be read from left to right, top to bottom, going in, and right to left, top to bottom backing out. The boxes represent the separate program modules. The order of loading affects the ordering of the screens within the stack. The start-up routine follows alternate paths depending on the step in the data-collection process. The first time subjects boot the machine the software follows sequence 1, which takes them directly to the game. The second time they boot the machine (after being instructed by the system to do so), they take a detour through the *Guide* tutorial, sequence 2. In about 10-minutes they are taught, with synthetic speech, animated graphics, dummy screens, and practice exercises, everything they need to know to make use of the *Guide.* This was done to automate the change in treatment conditions. Finally, all subsequent boot-ups launch a screen from which subjects choose to review or bypass a repetition of the automated lesson on the *Guide.* If they choose

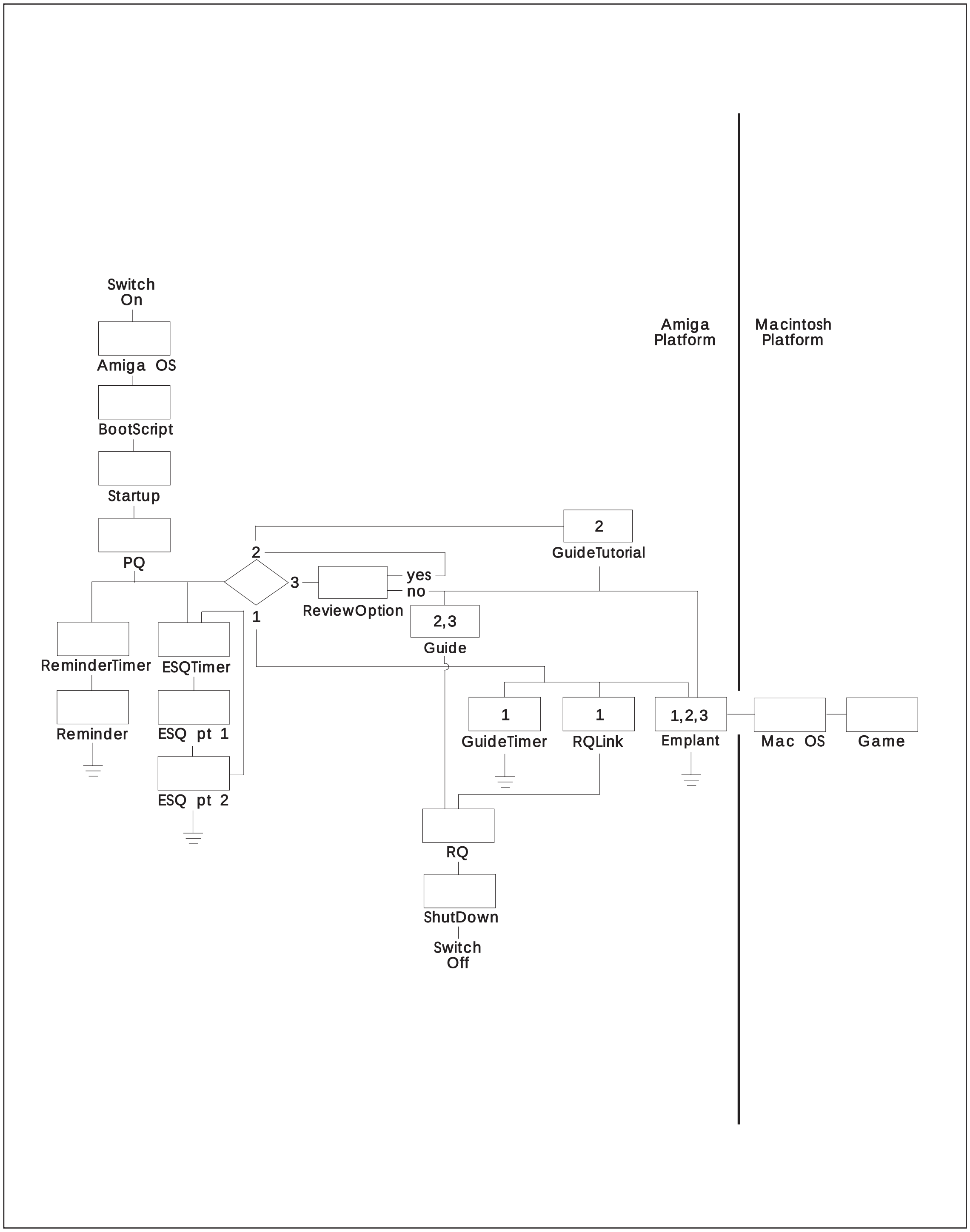


**Figure 19: Software Interface Program Module Flow.**

sequence 2, they repeat the tutorial. If they select sequence 3, they bypass the tutorial and return directly to the game (with the always *Guide* available to them). Once the *Guide* has been introduced, it is always available from within the game by using the *Left Amiga-M* keystroke combination to flip between foreground and background screens. The intention is that the interactive procedures and decisions required of subjects right from the start contribute to their sense of autonomy vis-a-vis the task.

**Operating Instructions**

The operating instructions guide subjects interactively through the steps involved in starting and stopping the videocassette recorder (VCR) and turning the clip-on microphone on and off (see Figures 21-23). All of the other components of the apparatus assembly are preset and operate automatically when the master switch (Figure 20) is on. There are two sets of instructions, one for the start-up procedure and one for the shut-down procedure. The start-up instructions run following boot-up when a subject turns on the master switch, and the shut-down instructions run after the RQ is completed during system shut-down, guiding the subject right through to turning off the master switch. Separate screens that use animated callouts (moving text and graphics) and the data collector’s synthetic voice guide subjects’ actions. Realistic screen images show the state of the buttons, switches, knobs, and status indicators on the VCR. The interactive presentation shows and tells what to do and waits for confirmation that a given action is complete. Confirmation is given by clicking on the text, "Click me when done". Subjects are addressed either by text ("Please


**Figure 20: Hardware User Interface.**


**Figure 21: Animated Interactive Operating Instruction Example 1.**


**Figure 22: Animated Interactive Operating Instruction Example 2.**


**Figure 23: Animated Interactive Operating Instruction Example 3.**

confirm the presence of a cassette," or robot-like speech ("The VCR is now turned on. Please start recording. . . Thank you. Now please attach the microphone to your shirt collar and turn on the switch.") When all steps are complete, the program launches the background process, the emulation, and the game. When the subject quits the game, the shut-down instructions begin automatically, waiting for subject confirmation after each step. The final instruction is a screen that says: "Please turn off the master switch now."

This minimal subject responsibility for hardware operation is necessary because the VCR, which when plugged in is always in "standby mode," and the electret microphone, which is battery operated, cannot be powered on or off with the single switch that activates the rest of the data collector. Limited subject responsibility for operating the apparatus is also consistent with the objective of preserving the subject's sense of autonomy and control during data collection.

### ***Guide* Tutor**

Part of the preparation for this research involved the creation of an online knowledge base or *Guide* to be used by subjects in solving the game (described in Chapter 3). Because the design called for "*Guide*-unavailable" and "*Guide*-available" treatments to be applied to all subjects (see Treatments, below), it was necessary to devise a way to make the change from the unavailable to the available condition, as well as to instruct the subject in the *Guide's* use after it became available, preferably without investigator intervention so as not to intrude upon subject autonomy. Training in use of the *Guide* could not be included in the initial training, when subjects are first introduced to the data collector and procedures, so as not to influence the baseline performance data collected under the *Guide*-unavailable condition. The solution was to create an automatic intervention and computer-based training module to provide interactive, online instruction in which the computer's synthetic voice, verbally and by example, talks and walks subjects through what they need to know to use the *Guide.* The use of synthetic speech as the primary verbal delivery modality was unique, but was preferable to requiring subjects to read the lengthy descriptions as text. Using "voice" with animated graphics and dummy *Guide* pages that allowed limited practice is consistent with minimalist theory. It was hoped that no instructor intervention would be required to introduce the *Guide* and explain its functions and use. This method was used to introduce and describe the navigational characteristics of the *Guide* in all cases, including those for which no *Guide*-unavailable treatment condition was imposed (those in the "*Guide*-always-available" group formed part way through the data-collection trials). This ensured that all subjects were given identical instruction in the use of the *Guide,* so that inconsistencies in *Guide* use orientation would not affect the data.

### Online Questionnaires

The *online* Experience Sampling and Retrospective Questionnaires (ESQs and RQs) used in this study (Figures 24-25; Appendixes C & D) are adaptations of the published instruments, which were developed for use in environments far different from computer games (Csikszentmihalyi & Csikszentmihalyi, 1988, pp. 255-258; Fave & Massimini, 1988, p. 195; Kubey & Csikszentmihalyi, 1990,


**Figure 24: Part 1 Experience Sampling Questionnaire (ESQ) Item.**

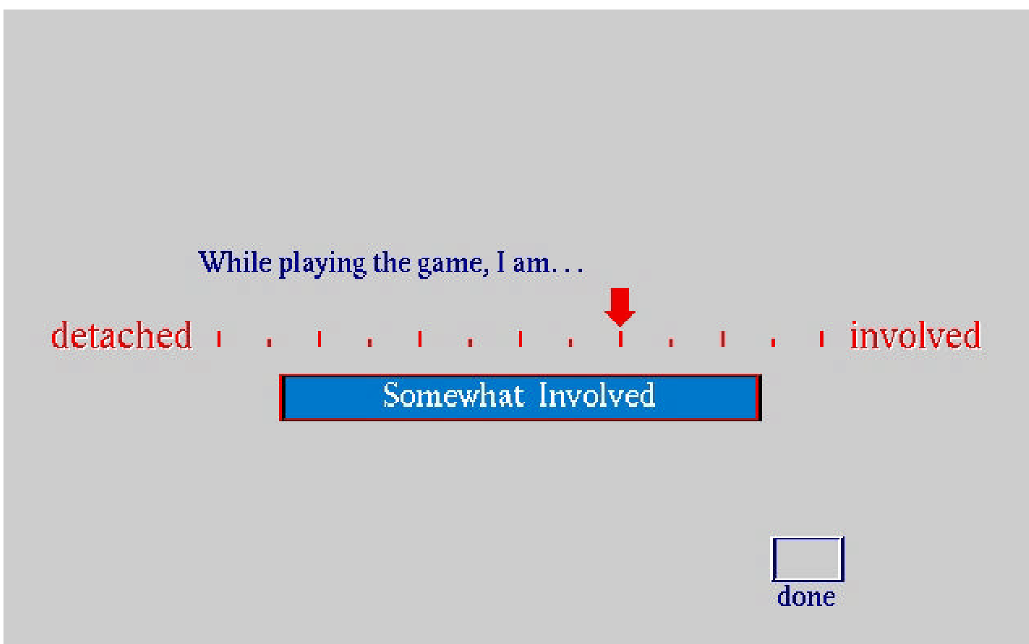


**Figure 25: Part 2 Experience Sampling Questionnaire (ESQ) Item.**

pp. 54-55, 225-237). For Part 1 of the ESQ, by sliding the arrow along the scale with the mouse pointer, subjects record self-report data on ten critical attributes and nonattributes of flow — apathy, anxiety, challenge (goal knowledge), skill (information access), concentration, self awareness, boredom, activity choice, enjoyment, and control. Responses on Part 2 of the ESQs, in which subjects rate their moods, indicate the presence and intensity of elements that characterize the subject's motivational state operationalized as flow. Part 2 is a semantic differential instrument with which subjects rate their involvement, happiness, cheerfulness, excitement, clarity, relaxation, confidence, and alertness. Data from both parts of each ESQ were summarized and characterized directly from the ESQ and RQ data worksheets (see Appendix E).

Three to four minutes are required to complete the 22 items contained in each online ESQ (Parts 1 and 2), yet, because the ESQs are integral to the interface and do not require a significant shift from one medium (e.g., computer to paper), input device (e.g., mouse to pencil or pen), or task (interacting with computer) to another medium, the ESQs had no noticeable effect either on continuity of the subject's activity or his or her state of mind. The sequence of ESQ screens was launched by the timers running on the Amiga Workbench public screen behind the Macintosh emulation, and the order of presentation of the questions was randomly varied to avoid question-order response effects.

**Supporting Documents**

Besides the hardware and software components of the apparatus, several paper documents were required: the Spellbreaker/Shut-Down and Restart

Instructions; a one-page reading test; and a portfolio containing three training checklists, an informational brochure, and two copies each of the participant and parent/guardian consent forms.

**Spellbreaker/Shut-Down and Restart Instructions**

The Spellbreaker/Shut-Down and Restart Instructions reference is a double-sided, 8-1/2 x 11-inch page enclosed in a clear plastic envelope that slips under the workstation keyboard and can be pulled out when needed for reference (Figure 20). One side of this document contains the characters and the abstract symbols that must be matched when a "spell" requester appears in the game. The Spellbreaker is the decoder for unlocking the random copy protection scheme built into the game. The other side contains explicit instructions for shutting the system off when it is necessary to reboot the computer. Normally those instructions are only used when restarting at the conclusion of the *Guide*-unavailable treatment period, or if subjects forget how to quit the game and initiate the shut-down instructions.

**Reading Test**

For purposes of reaching conclusions about the effectiveness of adventure games as instructional vehicles, it is necessary to measure subjects' learning. For such measurement to be meaningful, it is necessary to be reasonably sure subjects have the prerequisite skills needed to undertake the learning. One way to assure this is to provide training in the skills specific to the hardware and software interfaces the subjects will be manipulating. Because the text windows in the game and the knowledge base are the sole sources of the verbally transmitted information that must be learned and / or responded to, one also must be certain subjects are able to read text of the same difficulty as the text in the game and the knowledge base. For the subjects' responses on the questionnaires to be believable, subjects must also be able to understand the terms that refer to the elements of experience that they are asked to rate. One way to increase the likelihood that subjects have the required skills is to ask them to read something of the same difficulty as the dialog and commentary within the game, the knowledge base, and the experience sampling instruments. A measure of the reading difficulty of those items was therefore made using a standard reading difficulty formula (see discussion under Data Collection, below). A one-page reading test (Appendix F) was then prepared from text taken from the game of the same or greater difficulty as those elements. Subjects were asked to read the test page out loud as evidence of their qualifications for participating in the study.

This served as a rough screening and procedure and provided no evidence of comprehension. Working through the "Terms in Questionnaires" checklist in the subject's packet and practice in answering one complete ESQ and one complete RQ during the training and orientation period provided additional assurance that subjects possessed the minimum conceptual knowledge, and introspective abilities.

**Subject's Portfolio**

At the first meeting between researcher and subject, subjects were given a colorful packet containing the orientation/training checklists (3), a brochure describing the project, copies of the required parental consent and subject assent forms, and one or more appointment cards. This is a convenient way to protect, organize, and transport the essential paper documents the subject needs. Subjects can take completed training checklists home and use them to review the training between sessions.

**Researcher's Manual**

An important tool for the researcher is quick reference source of key information for use during the data collection sessions. A Researcher's Manual was therefore prepared to provide a central location for all critical documents that could be used as a reference while working with subjects. The Researcher's Manual is an 8-1/2 x 11-inch comb-bound booklet consisting of eight tabbed sections. The sections contain the following documents:

1. Subject ID code key and essential subject contact information forms (name, parent, phone, e-mail, street address), and other basic information (ID code, gender, age, ethnicity, highest education, occupation, marital status)
2. Posttest answer key
3. Subject portfolio documents (3 training checklists, consent and assent forms)
4. Software configuration set-up procedures for the training mode
5. Software configuration set-up procedures for goal-aware subjects

6. Software configuration set-up procedures for goal-unaware subjects
7. Table summarizing software timer settings for training, data-collecting and demonstration operating modes
8. All supporting documents (list of supporting documents, brochure, reading test, Spellbreaker, and Shut-Down and Restart instructions)

**Posttest**

An unstructured short-answer or completion (recall) posttest (Tuckman, 1988) was given to each subject completing the learning task after a delay of 24 hours and one week. The test measured the subjects' retention of the procedural learning necessary to complete the task — what subjects must know, above and beyond the skill they must have to play the game if they are to accomplish the goal of solving the game. It was expected that if subjects are successful in learning what is required to solve the game, they will show both high motivation in the data and a high learning score on the posttest. Note that knowledge of "how to play the game," concerning which subjects must be trained as well, but that is relevant only to establishment of a performance baseline, is distinct from the "content" of the game itself. What is of interest is what subjects have discovered and enacted through exploring the facts, concepts, and rules of which the imaginary world in which the story unfolds is composed.

**Identifying Learning Objectives**

As examples of written tests of recall of adventure game content were unknown, it was necessary to invent a method for constructing one. The process involved three steps, similar to those one might follow in evaluating the content and objectives of a more traditional curriculum unit.

Step 1: The researcher played through the game, taking the most direct route possible to its conclusion, and recording everything on videocassette. This took about one hour and 45 minutes, and included three "restore" operations with short repetitions that were due to player error, and three restore operations that were due to random events (e.g., the appearance of Mordack's cat before the blue beast). The total time also included one complete system lockup and restart.

Step 2: The researcher viewed the videocassette recording and simultaneously wrote down everything required to solve the game (excluding the six restores and one system restart). The result was a list of 120 action-steps required to "beat" the game.

Step 3: The researcher performed a detailed task analysis to derive a list of the 20 enterprises (major productions) and the steps (procedures) that enable them (Table 1). Groups of steps were organized around a single problem or activity whose goal the steps, when performed in the correct sequence (the procedure), would enact. Each of the 20 major productions was defined by: a list of the required *action steps,* correctly sequenced; a list of the *tools or resources* needed; and a list of the *rewards received or acquired* in the process of solving it. The resources relate the completion of one activity to future actions enabled by the enactment of the current enterprise solution.

**Table 1: Task (Enterprise) List by Enabling Objective**

**RESCUE THE BEES**

**RESCUE THE ANTS**

**GET GOLD COIN & BRASS BOTTLE**

**DISPOSE OF WITCH**

**RECOVER STOLEN ARTICLES FROM FOREST**

**ESCAPE FROM FOREST**

**RETURN STOLEN ARTICLES**

**RESCUE THE RAT**

**COLLECT ESSENTIALS FROM TOWN**

**ESCAPE FROM COUNTRY INN**

**CHASE RATTLESNAKE AWAY**

**TRAVERSE FROZEN HEIGHTS**

**ESCAPE FROM ICE KINGDOM**

**SAIL TO HARPY ISLAND**

**GET HELP FROM A HERMIT**

**SNEAK INTO WIZARD’S CASTLE**

**STOP BLUE BEAST ATTACKS**

**SILENCE TATTLETALE CAT**

**EXPLORE THE UPSTAIRS**

**FIGHT THE WIZARD**

Step 4: The researcher verified the accuracy, completeness, and comprehensiveness of the task analysis by comparing the content to be examined with the content of the learning task through a second review of the videocassette recording.

### Design

The two posttests were identical, consisting of 50 write-in items presented sequentially and grouped by enterprise and region. The organization of the test matches the organization of the setting and the sequence in which the enterprises are solved. This was done to permit testing subjects who completed just part of the activity. Each item in the test either asked for a procedure (2 items), a concept (16 items), a combination of procedure and concept (31 items), or a location (1 item). Unstructured questions asked for specific actions or names in the form "what," "how," or "why." Six items were of the sentence completion type. The test questions were structured in a consistent format around a single enterprise: a sentence or two in bold type sets up the scene for each of the 20 enterprises and between one and six questions related to the episode follow. The posttest is included in Appendix F.

### Validity and Reliability

All questions on the posttests ask for knowledge that the subject can only learn through interaction with the software. In that sense there exists perfect correspondence between test questions and learning objectives. The test had high reliability in that all but one subject answered all questions correctly except one: the single "location" question. The source of invalidity for the location question was probably an indistinct graphic combined with an unfamiliar concept (a hanging incense burner that looks like a lamp). All missed items, including the latter, were trivial, and no one failed to correctly recall and describe a puzzle.

## Subjects

Subjects were four female and four male volunteers of European descent between the ages of 12 and 43 whose reading skills (assessed with the reading test described above) equaled or exceeded 7th grade. The minimum reading level was established by an analysis of the reading grade level of the text elements within the game, the online knowledge base, and the research instruments. Gender was equalized to reflect the ratio of males and females in the population as a whole, but no analysis of gender differences was attempted. As it turned out, gender was unevenly distributed with respect to age: the females were 13, 27, 35, and 43 years of age and the males were 12, 12, 13, and 32.

Although gender and reading ability were factors in selection, no other factor was controlled, including age, computer or video game experience, or ethnicity. Ethnic diversity was expected in the sample but no special effort was made to recruit an ethnically diverse sample and only Caucasians volunteered. No one who did not meet the reading requirement volunteered. Subjects were not paid or compensated, although meals and transportation were provided.

## Treatments

The first volunteers recruited were assigned randomly to two treatment groups. One group, the goal-aware group, was given background information and explicitly told about the overall goal of the game — i.e., what needs to be accomplished to "beat" the game. Subjects in this group viewed a 10-minute expository animation that introduced the characters, set the scene, and established the protagonist’s (and the subject’s) goal for the learning task. Subjects assigned to the goal-unaware group were turned loose to explore the game without benefit of seeing the 10-minute expository video. This manipulation was intended to measure the effect of goal knowledge on motivation. Knowledge of a goal toward which one is working is believed to be a necessary condition of flow (Csikszentmihalyi, 1975) and goal setting (task identification) is a key element of problem-solving discovery learning model described in Chapter 3. It was thought that interest, performance, or motivation might vary depending on whether one had knowledge of the ultimate goal of the game.

It was also the researcher’s intention to apply an additional manipulation to *all* subjects to measure the effect availability of the inquiry system (knowledge base). The variable in this treatment was availability or non-availability of access to the inquiry system. It was predicted that subjects would neither perform well nor be motivated without access to the inquiry system — that use of the knowledge base would be a *necessity* for success with the learning task. This is consistent with the model and was supported by the results. In the first condition, all subjects would work on the game without access to or knowledge of the existence of a knowledge base. They would do that for a predetermined interval long enough to establish a performance baseline. At the end of that time the treatment would change, and data would show that change had occurred, as well as the nature of the change. It was thought that applying both conditions to every subject would help control for individual differences. Care was taken to ensure that no one anticipated the appearance of the *Guide.* After a suitable interval — long enough to elicit negative affect (some of which was quite painful to observe) — subjects were instructed by the software to shut down and restart the computer. When the system was restarted according to the instructions, the initialization process branched to the *Guide* tutorial and the *Guide* was explained interactively, then loaded into the stack of screens as explained above for use in solving the game. After that, each time the game was initialized the *Guide's* cover screen was presented and the apparatus's synthetic voice reminded subjects to, "Remember to use the *Guide.*"

A subject's tolerance of the *Guide*-unavailable condition appeared to vary from individual to individual, a topic to be discussed in Chapter 5. However, the length of the initial treatment period could not be varied, so an arbitrary interval of 90 minutes was set initially. When 90 minutes appeared to be too long for comfort, but at the same time long enough to generate plenty of negative affect data for the study, the length of the *Guide*-unavailable condition was reduced to 80 minutes. It had been expected that subjects without access to the knowledge base would become discouraged and lose interest in the game. To establish this, it seemed necessary to allow them to exhibit the signs of discouragement and loss of motivation. It had also been expected that when subjects were shown the *Guide* a change would occur and be evident in the data. What was critical was that the treatment change not come before clear evidence of frustration, anxiety, helplessness, boredom, apathy, and so forth could be captured, or so late that the subjects' interest in the game would be irretrievably lost. At least one and preferably two ESQs in addition to the think-aloud and observational data was assumed to be needed to establish the undesirable effects under the no-*Guide* treatment.

## Data Collection

### Setting

The decision where to conduct the data collection presented a dilemma. The original plan was to place the apparatus in subjects' homes to maximize subject control and autonomy. But in reality, letting subjects voluntarily conduct research without any supervision or any researcher involvement in the process entails too many risks. Some structure in the environment is needed. Yet, the artificiality of an institutional setting like a lab or office in a school or university might discourage long-term, distraction-free task engagement. It would also have been difficult to arrange long-term, distraction-free conditions in any public setting. So it was necessary to work out a compromise. The compromise was to partition a corner of the researcher's home where the equipment and subject could be comfortably situated in relative isolation from the researcher, yet within earshot, should researcher be needed for troubleshooting, and to handle unforeseen contingencies like equipment failure. The relative locations of the researcher's office and the subject's work area are shown on the plan in

Figure 26. Both the kitchen and bathroom were easily accessible from the data-collecting area, which was partially partitioned from household traffic with a room divider. Subjects were equipped with a wireless pager to summon the researcher, and the researcher could also listen to subject's verbalizations through a two-way intercom linking the two work areas. The latter was used to remind subjects to continue thinking out loud.

In addition to the wireless pager for calling the researcher, and the Spellbreaker (the game's copy protection scheme decoder described above), subjects were provided some plain white 8-1/2x11-inch sheets of paper and a pencil to be used for taking notes offline.

**Reading Grade Level**

As explained above, (Reading Test), it was necessary to assess the difficulty of all text elements that subjects must read. A standard readability index was used to make that assessment. Although they have limitations when applied to technical and business communication or when used to simplify documents, guide revision, or improve writing (Bruce, Rubin, & Starr, 1981; Drury, 1985; Plung, 1981; Shelby, 1992) for the purpose of assessing reading difficulty of text intended for general audiences, readability indexes are based on reasonable premises and appear to work fairly well. Research cited by Clariana and Bond has shown that reading from computer screens is more difficult than from paper (Clariana & Bond, 1993, p 256), but their comparison of seven readability indexes indicated that the Flesch-Kincaid, Gunning's Fog, and Automated Readability Index (ARI) formulas "provided the best estimate of reading grade level of

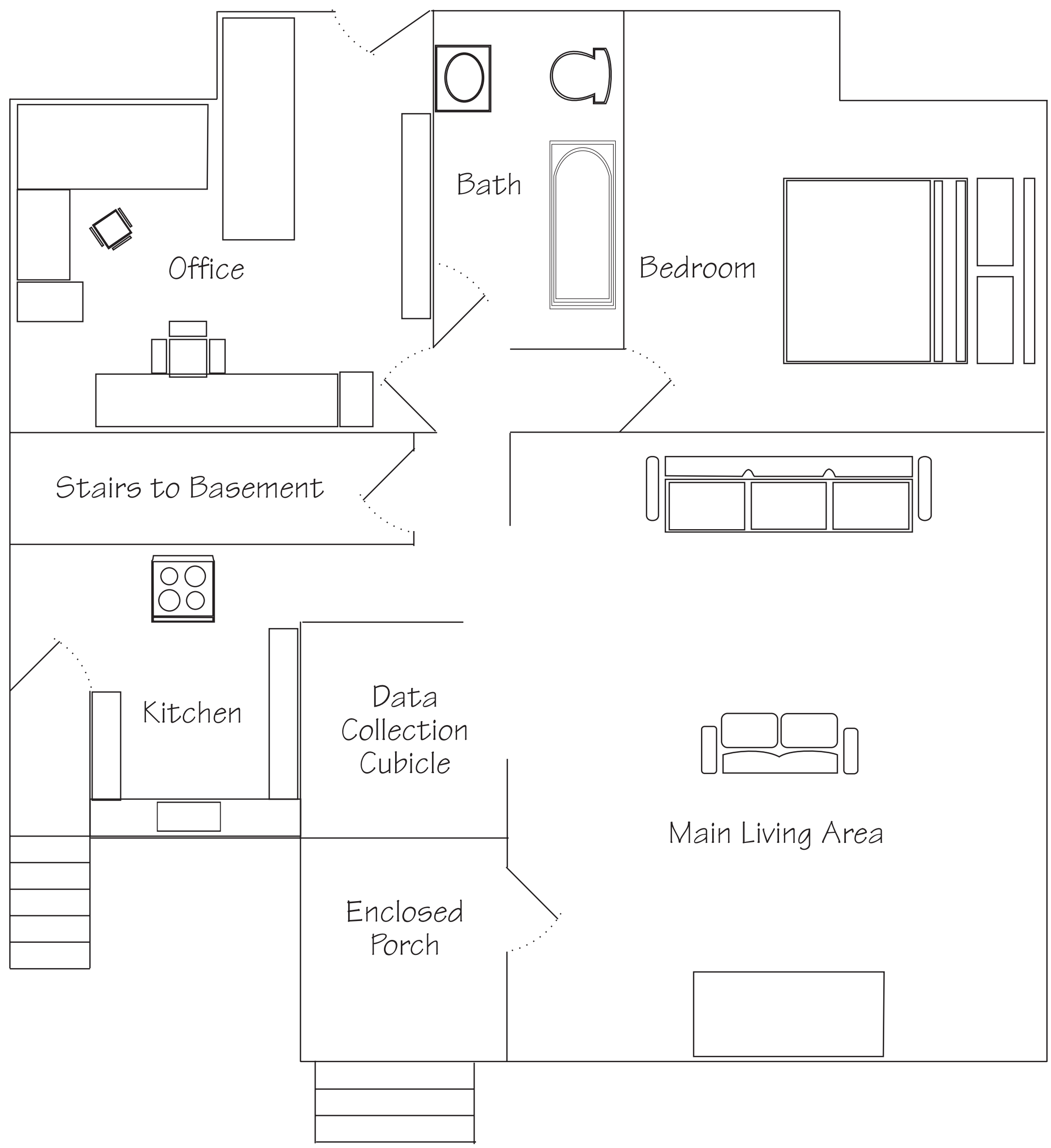


**Figure 26: Data Collection Setting.**

computer-based text" when compared to standardized reading difficulty test scores of fifth and sixth grade students (p. 255). The software used for analysis of the online text in the present study calculates and displays statistics and scores for three readability formulas, two of which were among the top three in the Clariana and Bond study.

The simultaneous calculation of three readability indexes makes for reasonable certainty in the estimates, though for simplicity, results of the Flesch calculations of grade level (Table 2) were the most useful. A reading level of 7th grade for the reading required of subjects in this study was determined from calculations based on the Flesch formula with the computer program *Proper Grammar*, which runs in the Amiga environment. Because these calculations were performed by a computer, it was possible to apply them to all of the non-game text and nearly all of the game-based text.

The text in the game is extensive because the dialog animations, the narrative voice, and each of the control icons return text windows. To extract the text from the game, the researcher "played through" every part of the game, clicking on everything and reading the text off the screen into a cassette recorder. The recorded text was transcribed to disk and the result imported to *Proper Grammar*. This method captured more than 90% of the text from the game, which is a generous sample for analysis. The remaining verbal elements with which subjects must interact — the *Guide* and questionnaire text, and the *Guide* tutor's synthetic speech — everything except the game itself — were stripped of formatting codes and imported as plain text (ASCII) to *Proper Grammar* for analysis.

**Table 2: Composite of Tables from Flesch, R. (1974), *The Art of Readable Writing***

| *Description of Style* | *Average Sentence Length* | *Average No. of Syll. Per 100 Wds.* | *Reading Ease Score* | *Estimated Reading Grade* | *Estimated School Grades Completed* | *Estimated Percent of US Adults* |
|---|---|---|---|---|---|---|
| Very Easy | 8 or less | 123 or less | 90 to 100 | 5th | 4th | 93% |
| Easy | 11 | 131 | 80 to 90 | 6th | 5th | 91% |
| Fairly Easy | 14 | 139 | 70 to 80 | 7th | 6th | 88% |
| Standard | 17 | 147 | 60 to 70 | 8th & 9th | 7th or 8th | 83% |
| Fairly Difficult | 21 | 155 | 50 to 60 | 10th to 12th | Some High School | 54% |
| Difficult | 25 | 167 | 30 to 50 | 13th to 16th | high school / some college | 33% |
| Very Difficult | 20 or more | 192 or more | 0 to 30 | college graduate | college | 45% |

Results of the analysis are summarized in Table 3. In the table, compare the score for the reading test used to qualify subjects with the different sections of the game, the knowledge base, the posttest, and the questionnaires, noting that the reading test grade level exceeds all but one of the estimates.

## Software Setup

Identification codes and treatment variables are configured uniquely for each subject within the software on both computer platforms. The timers that launch the research interventions must be set to different intervals for the training and data-collection modes. Intervals between interventions, like the reminder to talk out loud and the experience sampling questionnaire, are shorter for the training activity than for the data-collection activity. Access to the *Guide* intervention is omitted from the training set-up, as the study requires that subjects must be unaware of the existence of the *Guide* until it is introduced after the baseline psychological states and behavioral data have been recorded. Steps in configuring the apparatus for demonstration, training, goal-aware, and goal-unaware operating modes are kept in the Researcher's Manual.

## Orientation and Training

Although the software is designed to ensure procedural compliance and sampling consistency across subjects and sessions with minimal need for the researcher to be present, subjects must be adequately trained in the experimental procedures to prevent loss of data during data collection. They must be warned against turning off switches except when directed by the computer and

**Table 3: Results of Reading Grade Level Analysis.**

| Source of Text | Current Grade |
|---|---|
| Game | |
| Animations | |
| Cassima | 6.22 |
| Elves | 5.76 |
| Hermit | 5.94 |
| Ice Queen | 6.95 |
| Mushka | 6.14 |
| Introduction | 5.87 |
| Talk Icon (animated dialog) | 5.92 |
| Hand Icon | 6.08 |
| Eye Icon | 8.02 |
| Knowledge Base | 7.20 |
| Reading Test | 7.48 |
| Posttest | 6.81 |
| Tutor (synthetic speech) | 6.43 |
| ESQ Part 1 | 5.97 |
| ESQ Part 2 | 5.90 |
| RQ | 5.56 |

admonished never to change the knobs, or volume controls on the VCR, or speakers. They must also understand what to do when they stop working to take breaks, respond to interruptions, or rest. They must adhere strictly to the online operating instructions when beginning and ending a data-collecting session.

Unless these requirements are made clear, a subject may thoughtlessly switch the microphone off when pausing the program to take a break and then forget to turn it on again. The rule of thumb is, for breaks of longer than 30 minutes, subjects should quit the game and follow the system shut-down procedures as directed by the Software. Breaks of 30 minutes or less do not require shutting the equipment off. The microphone must be left on whenever the apparatus is in use, but subjects should state for the recording that they are taking a break.

It is essential to ensure adequate training in "thinking out loud," with both practice and feedback. Subjects should be told that thinking out loud is like explaining to someone, *using words in a normal tone of voice,* what one is thinking. Several minutes of taped practice were included in the training to give the subject an opportunity to become comfortable with the idea of constant verbalization. Following think-aloud practice, subject and researcher reviewed the video tape together to determine the adequacy (volume and clarity) of the subject's voice. It was hoped that this feedback would remove any uncertainty the subject might have about the nature of what the data look like, thereby increasing the likelihood of a high-quality recording. In reality, however, subjects varied widely in their ability to produce clear, well enunciated think-aloud recordings, even though their practice recordings were nearly always satisfactory.

Care also needed to be taken to be sure subjects understand the meanings of the terms in the questionnaires, and that they receive adequate practice in the operating procedures, all aspects of the game interface, and the data collection procedures.

Because of these performance requirements and the need for consistency in the training, a routine was followed at the initial visit by the subject. The steps in the orientation session are spelled out on three checklists that subjects receive in their portfolios and take home with them: (a) the Orientation/Training Agenda, (b) the Participant Skills Checklist, and (c) the Terms in Questionnaires checklist. These documents were intended both to guide the orientation and to serve as reminders for subjects between sessions, which were usually a week or more apart.

In the first part of the training, subjects are given a brief tour of the main floor of the house. Then subject and researcher sit down at a table away from the apparatus to discuss the project and the subject's rights and responsibilities. When the project had been explained and questions answered, subjects read the one-page reading test.

In the second phase of the training, the researcher briefly explains the components of the data collector and how they function. Then subjects turn on the master switch and wait for the computer to initialize. When ready, the computer displays the first screen of the startup instructions. The subject then follows the onscreen instructions with minimal assistance from the researcher. When the game appears, the researcher introduces each of the elements of the game interface, following the format of the Participant Skills Checklist — the menus, icons, and navigation techniques — with the subject at the controls. At this time the software is configured for the training mode, which means that interventions like the think-aloud reminders and ESQs arrive more often than they do during data-collection. When all of the elements of the game interface have been explained and tried, and one Experience Sampling Questionnaire has been completed, subjects are left alone to practice playing the game and thinking out loud for approximately five minutes.

After the practice period, subjects are guided through the shut-down procedures, working through the items on the Retrospective Questionnaire. If subjects have questions about the meanings of any of the terms on either questionnaire, they usually become evident during this phase of the training. Following the complete system shut down, researcher and subject review the video tape of the subject's think-aloud practice to critique the results.

The orientation lasts approximately one hour. When the training is complete and necessary forms signed, subjects take a 20 minute break while the researcher configures the software for the first session.

## Data Analysis

### Convergence and Redundancy

Several kinds of data were collected and analyzed:

- Duration (length of time subject is logged on or engaged with the apparatus), used to calculate learning rate as a measure of control
- Video-plus-audio recordings of all terminal output (screen and speakers) analyzed in combination with the think-aloud verbalizations
- Responses to 14 experience-sampling Likert-type self-ratings repeated in randomly varying sequences at intervals during subject interaction with the computer game, reduced to means and plotted as overall experience points on the Subjective Experience Model (SEM) to show changes during the activity
- Responses to a seven-item semantic differential self-characterization, analyzed to show changes during the activity
- Responses to a seven-item retrospective questionnaire (six are Likert and one is an open-ended verbal assessment) reduced to means and analyzed as with the Likert-type items above
- Results of two delayed recall posttests.

One reason for collecting and analyzing multiple types of data is to compensate for defects in the data from failures during data collection. For example, subjects might turn off the microphone, stuff it in a fold of their clothing, or refuse to verbalize, or the equipment could malfunction several times between ESQ cycles, effectively eliminating questionnaire responses from the data set. In such cases, data may have been collected in another form or in sufficient quantity to permit characterizing the subject's performance and/or experiences with the imperfect data. This is particularly important in small *N* studies in which the relative size of each subject's contribution is greater than in large *N* studies.

A more important reason for collecting and analyzing multiple data types is to increase confidence in one's conclusions through data convergence: "bracketing" or "triangulation" (Mark & Shotland, 1987; Yin, 1994). Triangulation asserts that methodological error across multiple methods cancels out because it is uncorrelated while the variance accumulates and converges on the single right answer. Bracketing suggests that methodological error may not cancel out, but and that results offer a range of answers, among which lies the correct answer (Mark & Shotland, 1987). On the other hand, the "complementary purposes" model allows that the different methods or data types may measure or estimate different aspects of a phenomenon or task. Several variations of the complementary purposes model are discussed by Mark & Shotland. Whether bracketing, triangulation, or complementary purposes are at work, when the responses on Parts 1 and 2 of the Experience Sampling Questionnaire (ESQ), the Retrospective Questionnaire (RQ), and the think-aloud protocols converge, one has high confidence in one's conclusions. When they do not, as with two of the cases studied here, one must conclude either that convergence has not occurred, or else that results are not consistent enough to warrant precise conclusions.

## Learning Rate as a Measure of Control

One way to evaluate performance is to look at the progress a subject makes with respect to time. This is an objective measure that tells something about the degree of control a subject has over the learning task, on the assumption that faster learners have greater control over the task. A convenient unit to use in such a comparison is the same unit used in the construction of the posttest: the "enterprise," of which there are 20. Because the longest time for any subject in this study to complete all 20 units (100%) was slightly over 10 hours, a reasonable standard for comparing learning rates across subjects would be 10 percent per hour. All subjects can be evaluated on the basis of the percent of the learning (number of units completed) per hour. A subject who completed 100 percent of the task (20 units) in 10 hours, learned at the rate of 10 percent per hour. A subject who completed 5 percent of the learning (4 units) in 5 hours, and then quit, learned at the rate of one percent (1%) per hour, showing only 1/10th the control of the first subject. This measure was used to corroborate (triangulate) the ESQ and RQ self-assessments of the element of control with actual performance, on the assumption that faster learners demonstrate greater control than slower learners.

## Questionnaire Data Reduction

Online questionnaire data was output by CanDo!3.0 to ASCII text files in a directory on the Amiga’s internal hard drive. Using the AmigaDOS CrossDOS utility, these data were then copied to an MS-D0S-formatted high density floppy disk. The floppy disk was then inserted into a drive of a 386sx IBM-compatible

PC and the files viewed onscreen and formatted for printing with XyWrite III+, a text-based word processor. A separate file was created for each subject that contains the data for all ESQs and RQs completed. Each line in the output file contains the data for one questionnaire item as follows:

- Line number
- Date and time
- Subject ID code
- Session number
- Questionnaire sequence number
- Item number (random order)
- Subject's selection (value)
- Value calculated from selection value to plot on the SEM

The conversion of the subject's questionnaire response to the value to plot on the SEM is performed by the software from the value returned from the slider position selected by the subject for the ESQ or RQ item. Characterization of the subject's experience consists of manually plotting points for the converted values from the subject's responses on an SEM template using the mouse in a drawing program. Subject responses on the ESQ Part 1 item 10-point scales are converted using the Part 1 ESQ Matrix to a value on the SEM scales. In this manner, it is possible to plot directly on the model a composite point representing the overall experience of the subject with respect to the SEM at the time the ESQ or RQ was completed. Please refer to the scoresheets and matrices in Appendix E for the process described below. The procedure is as follows:

1. The Part 1 ESQ Scoresheet is used to convert subject answers on the ESQ to values. On the Scoresheet, some of the values increase from left to right and some decrease. This is because, although subjects evaluate all questions in a single direction, from "1" on the left to "10" on the right, answers are evaluated in relation to flow. For example, if a subject rates the question on the "control" dimension as "very much," he or she receives a high score because people in flow states experience a high sense of control; but a subject who rates an "anxiety" question as "not at all," will also receive a high score, because people in flow states experience low anxiety.
2. The Part 1 ESQ Matrix is used to convert the value for each item on the ESQ Scoresheet to a new number that matches the scales on the SEM. The value from the Scoresheet is found on the top scale of the Matrix and the corresponding intersection of that value with the item listed in the column on the left is marked (e.g., circled).
3. The numbers on the bottom scale of the Matrix (-5 to 5), that correspond to those on the top scale, indicate the coordinate plotting points for the elements represented in the SEM.
4. The "overall experience" or mean point in the examples is plotted from a single value. It is the same on both scales, so it is always centered on a diagonally ascending line. That value is calculated by averaging all of the values summed from the bottom scale on the Matrix (the sum of the scores divided by 14, the number of questions on the ESQ). The result is the value of the point on the model representing the "average experience" reported by the subject on one ESQ.

If ESQ data such as these are collected on average every 60 minutes, one could expect to construct similar plots for about eight ESQs per subject, (assuming subjects take eight hours to complete the game). The actual number will be less because most subjects do not remain on task continuously and the software timers are reset each time the system is restarted. The differences between these individual data points represent changes in subjects' experiences over time that one might expect to see reflected in, or to corroborate, events in the video and audio recordings.

Similar procedures were followed for the RQs, using the Retrospective Questionnaire Scoresheet and Retrospective Questionnaire Matrix. ESQs and RQs were combined on the plots to show the overall experience for each subject.

## Limitations

Subjects do not always perform to expectations. Some subject-related issues that can affect data collection are:

- Subjects may not be willing to devote the necessary time and effort to the task.
- When studying flow, subjects must be willing to perform without external inducements or rewards.
- Subjects must be willing to perform in a "stranger's" home.
- Because only one subject can be studied at a time, all sessions must be by appointment.

- Because few people have a large enough block of free time to solve the game in a single sitting, the sessions must often be separated by a week or more.
- Some subjects may not be able to produce a satisfactory recording. To produce a quality recording, subjects must not mumble, mutter, or whimper as a substitute for thinking out loud; they must speak clearly in words. Better than showing subjects a sample of their own recording might be to show them an exemplary performance by another subject.

# Chapter 5: Results

This chapter discusses the following data and their analysis:

- Composited and interpreted responses from experience-sampling and retrospective questionnaires
- Selected portions of video/audio think-aloud recordings
- Retrospective summaries
- Offline notes
- Learning rates
- Posttest scores

Table 4 shows contact dates, intervals, times-on-task, and learning rates for the eight subjects. Table 4 can be used to extract several types of information. It can be used to compare subjects' estimated time commitment for each session against the actual contact times. The table also shows the dates and intervals of all data collecting and testing contacts, the total time each subject was in contact with the learning task, and individual learning rates. One can also see the overall lapsed time between the first data-collection session and the last posttest for each subject. Contact periods ranged from a little over a week to five and a half weeks.

The five subjects who completed the task did so in times that ranged from seven hours six minutes to ten hours ten minutes, with learning rates much higher than those achieved by the non-finishers. Two posttests were given to the five subjects. Results, presented in Table 5 show a ceiling effect for retention of

**Table 4: Data Collection/Posttest Intervals, Time on Task (TOT), and Learning Rates.**

| | Data Collection Dates | TOT Estimates (PQ responses) | TOT Actual | LR | TOT Totals | Posttest Dates |
|---|---|---|---|---|---|---|
| A1 | 1/17/98 } 2wks<br>1/31/98 } 1wk<br>2/7/98 | "An hour and a half"<br>"An hour and a half"<br>"Three hours" | 3:40<br>3:05<br>3:24 | 9.84%/hr. | 10:10 | 2/8/98<br>2/15/98 |
| U1 | 1/22/98 | Not recorded, but she later indicated she planned 3 hours | 3:45 | N/A | 3:45 | N/A |
| A2 | 1/25/98 | "At least two hours" | 2:58 | N/A | 2:58 | N/A |
| U2 | 1/19/98<br>1/26/98 } 1wk | "About and hour"<br>"Two to three hours" | 3:03<br>4:25 | 13.36%/hr. | 7:29 | 1/27/98<br>2/2/98 |
| A3 | 1/23/98<br>1/30/98 } 1wk | "About two hours"<br>"Until 2:30, which is three hours" | 1:50<br>3:11 | 2.00%/hr. | 5:01 | N/A |
| U3 | 2/19/98<br>2/20/98 } 2days | "I don't know, but a long time"<br>"At least two hours" | 2:27<br>6:25 | 11.28%/hr. | 8:52 | 2/21/98<br>2/28/98 |
| A4 | 2/5/98<br>3/7/98 } 4wks+2 | "One and a half to two hours"<br>"About 6 hours" | 1:43<br>5:22 | 14.08%/hr. | 7:06 | 3/8/98<br>3/15/98 |
| U4 | 2/13/98<br>2/16/98 } 3days | "About an hour and a half"<br>"About an hour" | 4:30<br>5:21 | 10.14%/hr. | 9:52 | 2/17/98<br>2/23/98 |

**Table 5: Posttest Results.**

| | Posttest #1 | | Posttest #2 | |
|---|---|---|---|---|
| | Correct | Incorrect | Correct | Incorrect |
| A1 | 49 (98%) | #17 (-1.0 wrong location) | 49 (98%) | #17 (-1.0 wrong location) |
| A4 | 50 (100%) | | 50 (100%) | |
| U2 | 47.5 (95%) | #4 (- 0.5 concept missing)<br>#12 (-1.0 concept & procedure missing)<br>#18 (- 0.5 procedure missing)<br>#20 (- 0.5 partial procedure) | 50 (100%) | |
| U3 | 49.5 (99%) | #13 (- 0.5 partial procedure) | 50 (100%) | |
| U4 | 48 (96%) | #14 (-1.0 two concepts missing)<br>#17 (-1.0 wrong location) | 48.5 (97%) | #14 (- 0.5 one concept missing)<br>#17 (-1.0 wrong location) |

conceptual and procedural learning. Test scores for all subjects either remained the same or increased slightly on the second test taken one week and one day following the session during which they solved the game.

The conjunction of difficulty with a sense that one is in control is an indication of flow. Those who accomplished the most in the least time, making the fewest mistakes while keeping repetition to a minimum, exhibited the greatest degree of control. A useful measure for comparing learning performances and evaluating control is the "learning rate as a measure of control," (LR). This is the percentage of the total learning achieved (defined by dividing the number of task subtask units into 100) divided by the time on task. For this calculation, each of the 20 subtasks or enterprises represent 5% of the total learning. Subjects must accomplish at least one subtask for the LR to be calculated, because the measure is not sensitive to actions below the level of one subtask. This is a useful way to compare the performances of subjects with different total times on task. The results of this measure are shown in Table 4.

Table 6 shows the means for each subject's questionnaires. These data were used to plot the questionnaire responses on the Subjective Experience Models (SEMs, Figures 27, 29, 30, 31, 33, 35, 37, 38) that accompany the descriptions of results of individual subjects that follow.

## Subjects

Subjects are designated by a code consisting of a letter and number. The letter identifies their group (A = goal-aware; U = goal-unaware) and the number indicates the sequence in which subjects first committed to participate in the

**Table 6: Questionnaire Data Summary.**

| Session | | Instrument | Means (OE) |
|---|---|---|---|
| A1 | 1 | *Guide* unavailable | |
| | | ESQ1 | -0.14 |
| | | RQ1 | 0.33 |
| | | *Guide* available | |
| | | ESQ2 | 2.79 |
| | | RQ2 | 1.83 |
| | 2 | ESQ3 | 3.64 |
| | | ESQ4 | 1.00 |
| | | RQ3 | 2.33 |
| | 3 | ESQ5 | 2.86 |
| | | ESQ6 | 3.00 |
| | | RQ4 | 3.67 |
| | | Total Mean | 2.13 |
| | | ESQs | 2.19 |
| | | RQs | 2.04 |
| | | *Guide* unavailable | 0.1 |
| | | *Guide* available | 2.64 |
| U1 | 1 | *Guide* unavailable | |
| | | ESQ1 | 0.43 |
| | | RQ1 | 1.17 |
| | 2 | *Guide* available | |
| | | ESQ2 | 3.00 |
| | | ESQ3 | 1.86 |
| | | RQ2 | 0.67 |
| | | Total Mean | 1.43 |
| | | ESQs | 1.76 |
| | | RQs | 0.92 |
| | | *Guide* unavailable | 0.8 |
| | | *Guide* available | 1.84 |

| Session | | Instrument | Means (OE) |
|---|---|---|---|
| A2 | 1 | *Guide* unavailable | |
| | | ESQ1 | -0.43 |
| | | RQ1 | -0.50 |
| | 2 | *Guide* available | |
| | | ESQ2 | -1.07 |
| | | RQ2 | 0.67 |
| | | Total Mean | -0.33 |
| | | ESQs | -0.75 |
| | | RQs | 0.9 |
| | | *Guide* unavailable | -0.47 |
| | | *Guide* available | -0.4 |
| U2 | 1 | *Guide* unavailable | |
| | | ESQ1 | 4.36 |
| | | RQ1 | 3.84 |
| | 2 | *Guide* available | |
| | | ESQ2 | 4.36 |
| | | RQ2 | 3.84 |
| | 3 | ESQ3 | 4.50 |
| | | ESQ4 | 4.50 |
| | | ESQ5 | 4.50 |
| | | ESQ6 (after win) | 4.36 |
| | | RQ3 | 4.50 |
| | | Total Mean | 4.31 |
| | | ESQs | 4.43 |
| | | RQs | 4.06 |
| | | *Guide* unavailable | 4.1 |
| | | *Guide* available | 4.37 |

**Table 6 (Continued).**

| Session | | Instrument | Means (OE) |
|---|---|---|---|
| A3 | 1 | *Guide* unavailable | |
| | | ESQ1 | 0.07 |
| | | RQ1 | 1.00 |
| | 2 | *Guide* available | |
| | | RQ2 | 1.17 |
| | 3 | ESQ2 (*Guide* only) | 3.14 |
| | | ESQ3 | 1.21 |
| | | RQ3 | 0.33 |
| | | Total Mean | 1.15 |
| | | ESQs | 1.47 |
| | | RQs | 0.83 |
| | | *Guide* unavailable | 0.54 |
| | | *Guide* available | 1.46 |
| U3 | 1 | *Guide* available | |
| | | ESQ1 | 3.50 |
| | | ESQ2 | 4.90 |
| | | RQ1 | 3.83 |
| | 2 | ESQ3 | 4.50 |
| | | *ESQ4 | 1.14* |
| | | RQ2 | 4.50 |
| | | ESQ5 | 4.64 |
| | | ESQ6 | 4.57 |
| | | RQ3 | 4.00 |
| | | Total Mean | 3.95 |
| | | ESQs | 3.88 |
| | | RQs | 4.11 |

| Session | | Instrument | Means (OE) |
|---|---|---|---|
| A4 | 1 | *Guide* available | |
| | | ESQ1 | 2.00 |
| | | RQ1 | 2.17 |
| | 2 | ESQ2 | 1.29 |
| | | ESQ3(after win) | 3.71 |
| | | RQ2(after win) | 2.83 |
| | | Total Mean | 2.40 |
| | | ESQs | 2.33 |
| | | RQs | 2.50 |
| U4 | 1 | *Guide* available | |
| | | ESQ1 | 2.64 |
| | | ESQ2 | 4.64 |
| | | ESQ3 | 4.29 |
| | | RQ1 (incomplete) | —.— |
| | 2 | ESQ4 | 4.29 |
| | | ESQ5 | 4.36 |
| | | ESQ6 | 5.00 |
| | | ESQ7 | 4.90 |
| | | *RQ2 | 3.34/4.67* |
| | | Total Mean | 4.35* |
| | | ESQs | 4.30 |
| | | RQs | 3.34 |

study. Because contact with subjects extended over several weeks, and data-collecting and testing sessions were scheduled at varying intervals, the ID code does not indicate sequence of sessions or contacts except the initial contact. In other words, subject code numbers indicate the approximate order in which subjects volunteered, and in which they were assigned either to the "A" or "U" group, but does not indicate the order in which subsequent contacts occurred.

### A1

A1 was a 13 year-old male in the 8th grade with "action game" experience, but no adventure game experience. He was interested in science and had been a participant in a software evaluation that Microsoft had conducted at his school. He arrived at the research site around mid-morning on three Saturdays over a 3-week period, usually tired from the previous day's skiing and late return from the mountains. His reason for volunteering for the study was "to get some computer time." Because A1 experienced extreme levels of frustration before its introduction, he was enthusiastic about the possibilities the *Guide* afforded initially, but overall he expressed ambivalence about continuing through the sequence of three visits required for him to solve the game. He later mentioned that he had never played a computer game through to mastery, so he had had little confidence from the beginning that he would be able to do so this time.

#### Questionnaires

A1's questionnaire output is shown on the SEM in Figure 27. Table 6, Questionnaire Data Summary, and the SEM provide the most succinct picture of A1's overall self reports. The mean ESQ and RQ points shown on the SEM are

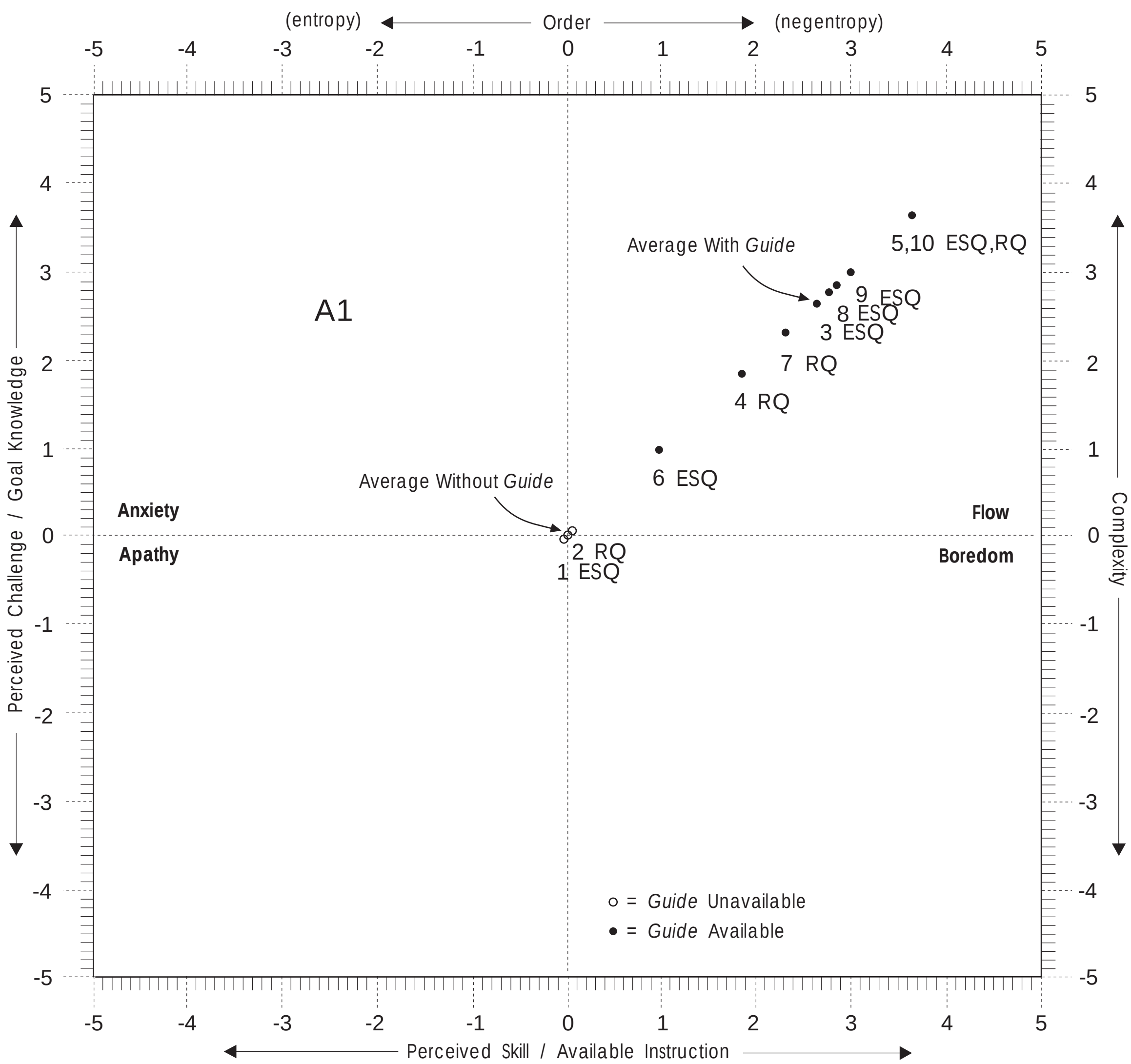


**Figure 27: Overall Experience for A1.**

plotted from the data in Table 6. The points show the subject's overall experience (OE) as recorded for each questionnaire, calculated by averaging the converted values on the questionnaire worksheets (Appendix E). The points are numbered to show the sequence of questionnaires and to show how the subject's responses varied over time. The numbers refer to the order in which the questionnaires were completed, irrespective of questionnaire type. Also identified are the means for the subject's reported experience before and after the introduction of the *Guide.* A1's questionnaire results show an absence of measurable experience of any of the qualities of the four quadrants of the SEM (at the "subject mean") before the introduction of the *Guide* and a definite increase in the direction of flow after the introduction of the *Guide.*

A1 responded to 160 items on 10 questionnaires (six ESQs and four RQs) during the 10 hours he worked on the game over a three-week period. In the first hour and 44 minutes before the introduction of the *Guide,* he experienced very high levels of frustration, evident from both the video / audio recordings and responses on the first ESQ and RQ. On the 10-point scale for the first Part 1 ESQ, after one hour and 22 minutes of play, especially significant were his ratings for skill / information access (5), enjoyment (4), control (2), boredom (8), and difficulty concentrating (7). Desire to win was high (9). High desire combined with high boredom, low enjoyment, and low control suggest extreme frustration. This is corroborated in the video / TA data:

TA Sample 1 Lapsed Time to Start of Sample: 1:21:38

So, see if I can work my way around him. Okay. One. Two. Three. Four. Aw, come on! Oh, probably still there, of course. Zap! Go on in. Maybe it let me out this time. Aah, man! Okay. [Think-aloud stops while A1 answers ESQ 1.] (sighs) Ugh. Man, I'm confused. It's like a game that is meant to be made so you can't even win, huh? I'm so much more used to games that are so straight-forward. Tried everything I could think of with the snake. Been everywhere. Witches on top, scorpion on the side, desert on the side, village won't let me get through, can't find the pathways up above that. There's nothing to do. Na-na, na-na. Dang! Don't want to go in there? (yawn) Man. Man! Man, I've already been here. Let's see. Try going over here to the left again. (sigh) Watch me search for things I don't even . . . there's nothing in. Search through it again. (chuckle) Aah. Well, fine! See what what's his name says, here. (sigh) Just know I'm missing some obvious thing. Let's see here. (sigh) The owl guy seems to think I need to go into this bakehouse again. I have no money. Wish I could just jack something (chuckle). (sigh) Come on. Okay, here we go. (yawn) Okay, I'm going to work my way around the edge. See if I can find a way out of this stuff. Oh, yeah. Just see how far I can go out. (sigh) Feel like I'm trapped in this area. Doesn't seem to want to let me go anywhere. Wherever I go I die or get captured, or whatever. Uuh!

On Part 2 of ESQ 1 (scale of 6) A1 reported "very bored," "quite confused and drowsy," "somewhat anxious and irritable," yet at the same time "quite involved." This subject endured both high motivation in terms of involvement and desire to win in combination with anxiety, irritation, boredom, drowsiness, and confusion for one and three quarters of an hour.

When the *Guide* became available, however, A1's affect and performance both showed a marked change:

TA Sample 2 Lapsed Time to Start of Sample: 1:54:05

Finally got . . . I got the *Guide* now, and all that stuff. I want to say I've played it before now, right? So I don't have to watch the whole movie. (he restores game) Now I want to check out the guide and see what that thing looks like. "Desert." "Map." This is helpful. Okay, I'm turning back into za game. Uuh, Guide's going to be a big help . . . . Okay, look around here so I don't get lost. Oh, that's where that dang scorpion is. Oh, "scorpion territory," I get it. Just writing down some of the things, here. Okay. Mark down a couple things here. That's why it's paused. Okay, I'm heading down towards the skeleton, after having mapped out the thing a little bit. One more down and then one to the right. Darn, forgot to count (chuckle). Oh well, it's either to the right here . . . I'll check on it. Oh, it's not to the oasis. Should be to the right, now. If it's not there, it's . . . the oasis isn't there. Okay, I'm the . . . I'm a in danger (chuckle). [A1 breaks for lunch] . . . .Time to resume my intrepid studies into the human mind. Okay. So, where do I want to go from here? Well, let's see here. "Staff"? "Bandits." "Gold coin." Geeze! Can't believe what I've missed!

On the second Part 1 ESQ at two hours and 53 minutes, a marked change occurred from the first ESQ ($M$ = -0.14 to $M$ = 2.79), supported by evidence from the video / audio recordings. On the 10-point scale for the second ESQ, responses showed evidence of high involvement (9), skill / information access (8), enjoyment (8), control (7), and low anxiety (4), boredom (4), and difficulty concentrating (1). Desire to win was still high (9). High desire combined with low boredom, high enjoyment, and high control suggest flow. This is corroborated in the video / TA data.

On Part 2 of ESQ 2 (scale of 6) A1 was still "quite involved," but also "quite clear," "somewhat cheerful," "somewhat excited," and "somewhat confident." He was now performing at a much higher level, and the data show an ability to handle greater complexity. The following excerpt from A1's think-aloud data illustrates the complexity of judgment and task identification, management, and sequencing that successful subjects must engage in. Contrast this example both with the first sample from the *Guide*-unavailable treatment and with a parallel example from the subjects, U1, A2, and A3. Each of the latter, for different reasons, showed an inability to match the level of control shown here.

<u>TA Sample 3</u>    Lapsed Time to Start of Sample: 4:13:38

There we go. Wah-hoo! Yes! Huh. Feel dumb? I could have put the cloak on the whole time? Or the amulet? (sigh) There we go. Now that I'm wearing the . . . yeah, that's good. Now who is this guy? Who is this toymaker that can't do anything? Who's the new guy? Yeah, I know.

Gotta get out. Okay. There's the cobbler. Huh. Well, let's see. What's the other thing? I just remembered it. Oh, yeah, the pie. Go try getting that and see if that works with anybody. See if the rat . . . old shoe. Okay, I'm going to walk inside here. What is that? Oh. See if I can get that pie from the baker. Hello. Hello. There we go. Ooh, custard pie! See if I can do anything with the custard pie now (chuckle). No idea what. Getting that shoe ready constantly, because I know I'm supposed to get that rat, or something . . . that cat or rat . . . but I don't see him come out again. I saw him come out once, but that was it. Okay. This game is weird, because it actually involves some thinking — but . . . but, other games you just . . . you basically man the controls and it's all timing — because you think about each move. Oh, wrong place. I know I have to get the marionette before I finish this place. I'm going to go the cobbler's. Get the hammer, which I don't know how to get. Daddy wants custard pie (chuckle). Aw, well. Okey-doke. Now that I'm wearing that amulet, maybe I'll go try the witch place again. Save game. "Save." "Replace." Okay, now I'm going to go and check out that witch again. Forgot to put on the amulet last time. Didn't realize that was an option. Thought you just had it. Okay, I'm just walking along, heading up to the scary forest. (whistles) Oh, good . . . Almost got eaten by the rattlesnake. Whoops, wrong way. Oh well, maybe I can go this way, too. There we go. Make sure that amulet's on. I want to go see if I get killed again. Hopefully not. Who knows, though. Hmm . . . get fried by that witch sooner or later, probably. Well, hasn't come yet. Yes! Here we go, yes. (chuckle) Hey,

> excuse me. Heads up . . . let me through. Is there anything that'll work? How do I know you're not that dumb? Yes! Awe . . . I'm slick! Oh, oh. What was . . . what happened? Ha, ha, ha, ha! Sucker! Yes, I am good! Save. Replace. Ah, (sigh) much better.

The final RQ from this subject's data set (RQ4), which followed his successful completion of the learning task after 10 hours and 10 minutes, has a mean flow value of 3.67 on the SEM. On the 10-point scale, he reported extreme comfort (9), enjoyment (8), and difficulty (9), and low boredom (3) and anxiety (3).

**Guided Discovery**

A1 understood and correctly applied the learning model, switching appropriately between the game and the *Guide.* The only exceptions were several extended periods where, despite extreme frustration, he remained stalled as a result of failing to notice until very far into the game that the "Next" button at the bottom of some of the fact and rule cards in the *Guide* could lead to additional information related to the topic. This oversight limited his ability to benefit fully from use of the inquiry system during task identification and hypothesis formation. On one additional occasion unrelated to the use of the *Guide,* he overlooked an obvious path out of the area between the Crystal Cave and the junction leading to the Ice Palace that was guarded by one of the Ice Queen's sentries, spending many minutes engaged in a desperate "thrashing" (frantic mouse clicking and resource cycling) from which, when he finally realized this oversight, he had difficulty recovering emotionally.

**RQ Summaries**

Question seven on the Retrospective Questionnaire asks subjects to answer out loud, "What do you think of this game?" The answers are of special interest because they are extemporaneous summaries of the subject's experience in her or his own words. The first and last subject summary statements are quoted here in full:

> First                    Lapsed Time From Start of Game: 1:43:02
>
> I think this game can be very confusing, but when you find out what something is, or you figure out a new way to do something or discover a secret about it, or something like that, it's very satisfying.

> Last                    Lapsed Time From Start of Game: 10:09:10
>
> Very interesting game. A lot more satisfaction when beating this than, like, an action game. With an action game there's a lot more quick little spurts of beating a guy and having fun with that, but this . . . when you actually beat the whole thing, its a lot more satisfying.

These assessments indicate that the subject worked hard for his rewards and that they were intrinsic and cognitive / affective rather than extrinsic or a result of the exercise of psychomotor manipulations. These assessments of the experience are consistent with the experience of flow at least some of the time during the activity.

### Offline Notes

A1 made occasional use of offline notes. Notice in Figure 28 how his navigational notations for the castle Labyrinth evolved from a facsimile of the online map to a simplified list of turns.

### Learning Rate

A1 finished the game in 10 hours, 10 minutes, in three sessions spread over three weeks, the longest completion time. His LR was 9.84% per hour. His greatest source of frustration was a result of either the absence of the knowledge base (in the first treatment condition) or his incomplete use of the knowledge base (see below). Except for his failure to notice a critical navigational button in the *Guide,* both his learning performance and motivation would probably have been greater.

### Posttest

A1 scored 49 out of 50 correct on both tests, missing the same item on both tests. Question 17 asks for the location of the "small key," for which the correct answer is "in the hanging incense burner." He incorrectly answered "I think it was in the chest" (test 1), and "in the chest" (test 2). The chest actually contained a spinning wheel.

Although the tests were intended to assess retention of specific procedures that were "discovered" through the hard work of trial and error exploration, task identification, hypothesis formation, and hypothesis testing, as well as relevant

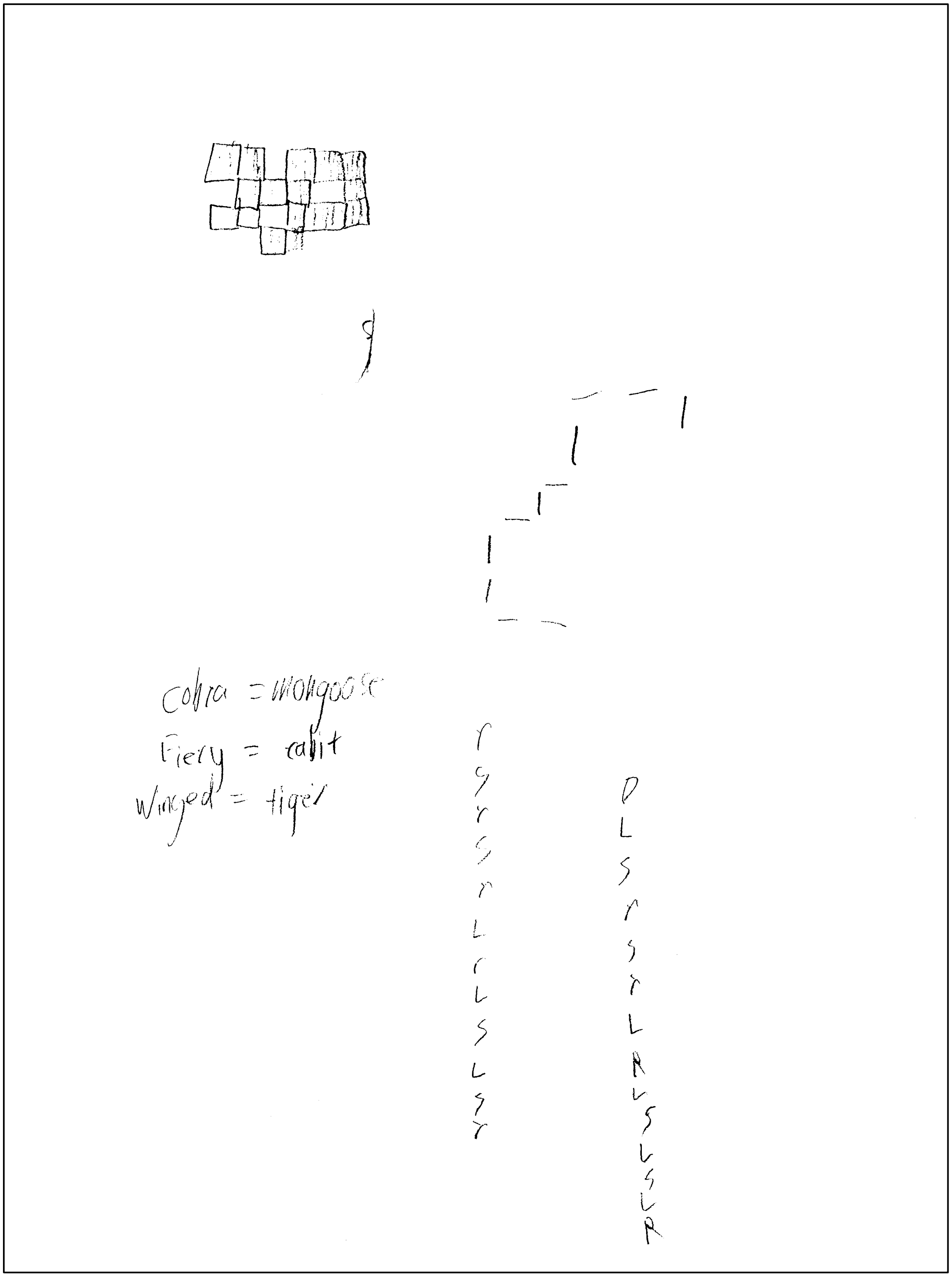


**Figure 28: A1's Offline Notes**

concepts, A1 occasionally went beyond the criterion learning. Question 3 asks, "What did Graham do to rescue the ants?" and question 7 asks, "What did Graham do to save the rat from the murderous cat? Both questions can be answered "He threw the shoe. . ." or "He threw the stick. . ." because either the stick or the shoe will work in both situations. A1's answer to both questions was the same: "He threw either the stick or the shoe." A1 was, therefore, not reporting what he had done, but was stating the rule that applies equally to predatory cats and dogs.

On other occasions, A1 elaborated the consequences or benefits of the criterion procedure. Question 14 asks, "Why did Graham want to get inside the temple in the desert?" The criterion answer was "to retrieve a gold coin and brass bottle." A1's answer, in addition to naming the two resource concepts, "gold coin" and "brass bottle," names the two portions of the procedure for disposing of the witch to which the two resources apply:

> "Because inside there were a brass bottle which had a genie to imprison the witch. He also got a gold coin to exchange for an amulet at Madam Mushka's."

**U1**

U1 was a 35 year-old single female with a BA in social work. She was self employed as a house cleaner and had some business computer experience but no computer game experience. She had never been a participant in a research project, but volunteered because a friend showed her a brochure, suggesting she might like it. She volunteered at least partially as a favor to the friend. U1's preferred time for working on the project was weekday evenings after work. Because of her difficulty scheduling time, 10 days lapsed between the orientation and training session and her first data-collection session. From the beginning, U1 seemed unable to make sense of the task — to understand what she was supposed to do. She was intrigued by the game, but did not want to invest more than three hours of her time in the data-collection phase of the project. Her interest appeared limited to helping the researcher by providing "enough data" for his study. U1 gave the poorest performance of the eight subjects, acquiring but a single resource in approximately three hours of play. She did not appear to understand the function of the knowledge base or how to apply the learning model, and wandered the desert without checking the map.

**Questionnaires**

U1's questionnaire output is shown on the SEM in Figure 29. Table 6, Questionnaire Data Summary, and the SEM provide the most succinct picture of U1's overall self reports. The mean ESQ and RQ points shown on the SEM are plotted from the data in Table 6. The points show the subject's overall experience (OE) as recorded for each questionnaire, calculated by averaging the converted values on the questionnaire worksheets (Appendix E). The points are numbered to show the sequence of questionnaires and to show how the subject's responses varied over time. The numbers refer to the order in which the questionnaires were completed, irrespective of questionnaire type. Also identified are the means for the subject's reported experience before and after the introduction of the *Guide.*

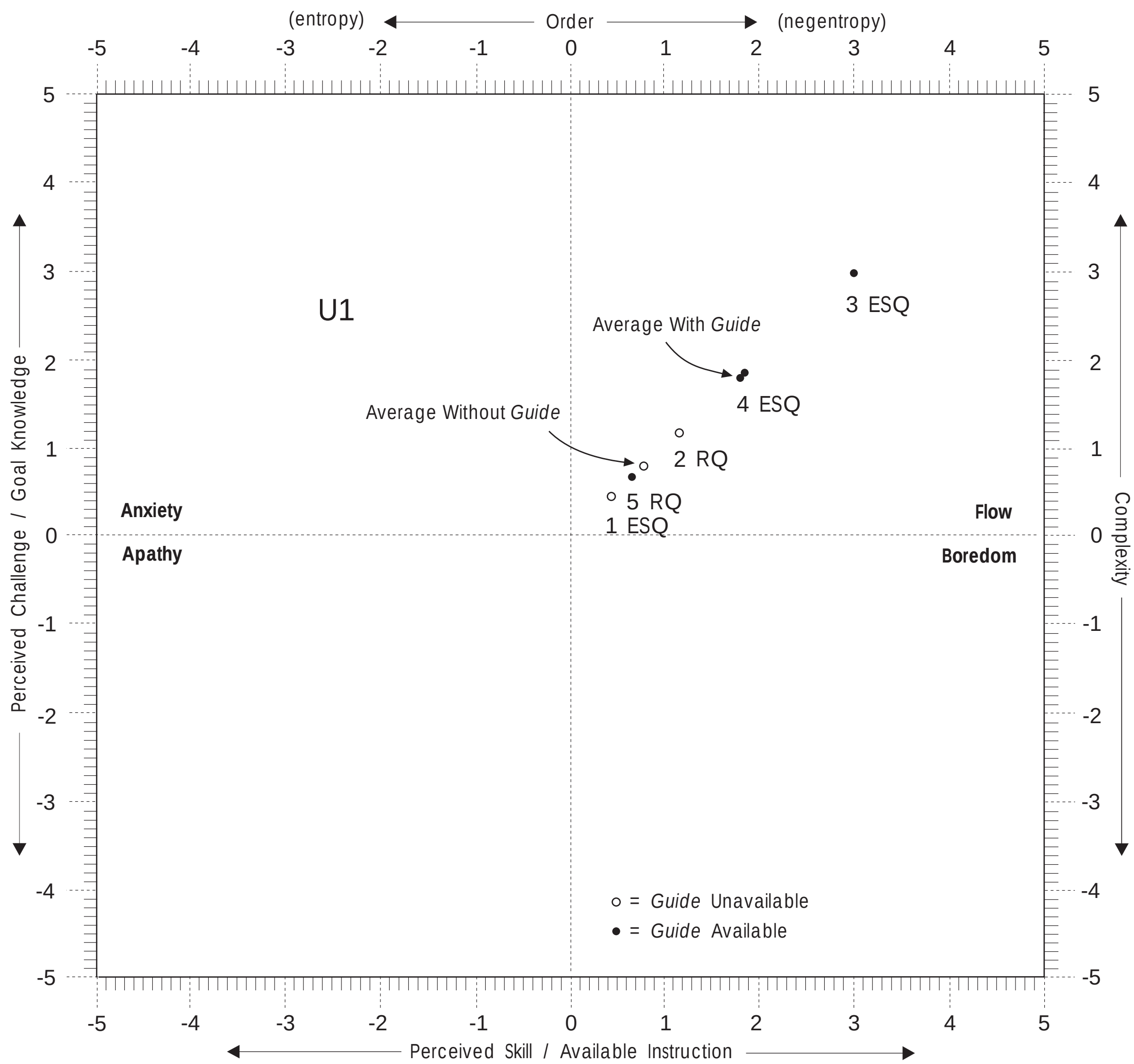


**Figure 29: Overall Experience for U1.**

U1's composite questionnaire data place her squarely in flow throughout the session. The video/audio and think-aloud recordings, however, offer little support for those self-reports, suggesting high confusion and the conditions for, if not obvious expressions of, apathy and boredom. It is difficult to believe that someone who succeeds only in locating one resource and trading it for another in a period of nearly four hours could be experiencing the high level of motivation that she indicates on the ESQs and RQs. The video-plus-TA and questionnaire data do not converge or triangulate here. In the absence of any outside reason to explain her abandonment of the activity, and in light of the subject's claim of high desire to continue, the fact that she abandoned the task leads one to question the accuracy of her responses on the questionnaires. Possible reasons for the discrepancy include her stated desire to please the researcher. Other possibilities are discussed below in the section on credibility of the questionnaire responses.

U1 responded to 80 items on five questionnaires (three ESQs and two RQs), during the single session of three hours and 45 minutes that she worked on the game. In the first 90 minutes before the introduction of the *Guide,* she responded to a single ESQ, which recorded somewhat contradictory data. These contradictions may indicate uncertainty or a lack of ability to accurately assess her emotions. On the 10-point scale for the Part 1 ESQ, after one hour and 15 minutes of play, especially salient were her low ratings for involvement (4), skill/information access (2), enjoyment (2), and control (1). These low numbers are more consistent with the video and TA data than the higher ratings on later instruments. However, another group of low responses from the same questionnaire seem to contradict the first set: difficulty concentrating (1), anxiety (2), and boredom (3), and self-consciousness (2). Of particular note was her rating for clarity of goal of "8," which is higher than might be expected for a goal-unaware subject.

As a holder of a baccalaureate degree in social work, she would have a good understanding of the meaning of the terms, so a likely hypothesis is that certain concepts like "boredom" may have seemed in conflict with an activity with which one expects not to be bored, and that the subject’s rating therefore reflected what she thought was expected, rather than what she was actually experiencing. Her TA data, however, do not provide much evidence either to support or contradict her self reports, except for the absence of anything that would support the state of high motivation or flow indicated by the questionnaires.

On Part 2 of ESQ1 (scale of 6) U1 reported "somewhat tense, involved, bored, confused, anxious, drowsy," and "quite irritable." The Part 2 responses are more consistent and also more congruent with the TA data. Parts two of the ESQs consistently contradict Parts one. For example, U1 selected a low number for Part 1 of ESQ 1 "not at all bored" ("3" on a scale of 10), whereas on Part 2 of the same questionnaire she responded "somewhat bored." Results for the ESQ numbers 2 and 3 are very consistent with these early responses.

What is going on here? The ESQ data are somewhat contradictory, but little evidence can be found in the remaining data to support the claim that U1 was experiencing flow. U1’s RQ summaries also show ambivalence, and highlight the contradictory nature of the subject’s self-assessments.

Despite the lack of variation overall in U1's affect, the second ESQ, which appeared after two hours and 32 minutes, showed a sharp increase in her Part 1 ESQ scores (from $M = 0.43$ to $M = 3.0$), a change that was accompanied by Part 2 responses of "somewhat irritable" and "somewhat confident," but "neither detached nor involved," "neither sad nor happy," "neither bored nor excited," and "neither confused nor clear."

## Guided Discovery

U1's approach to the game environment was tentative and restricted to trying to identify and solve one subtask at a time. She did not grasp the complexity of the overall project or understand the need to identify and sequence multiple potential tasks simultaneously. Consequently, her total accomplishment consisted of the acquisition and exchange of a single resource. Her use of the *Guide* was similarly limited — almost nonexistent. She failed to consult even the map of the desert, despite several attempts to explore that region.

U1 did not grasp, until it was explained by the researcher, the principle that in "restoring" the game, one does not keep what gains one has made since the point in the accumulated sequence of actions to which one is returning, and that one cannot jump back in time while retaining the resources accumulated up to the present. Her accumulated knowledge of both the game and the *Guide* were very limited as a result of the repetitive and restricted nature of her exploratory behavior.

The following protocols show the confusion, lack of exploratory effort, and fixation on a single at a time that characterizes U1's interaction with the learning task. In this example one sees little task identification or hypothesis testing.

TA Sample 1 Lapsed Time to Start of Sample: 00:16:23

Okay. So we want to just walk. No, this way. How about if we went this way? I betcha that's west, though. Okay, Cedric, do you want to talk? "If you walk to the south you'll run into the town bakehouse." Stop! I don't want to go south. We're not going south. Okay . . . okay. If that's south . . . if that is south, that's north. Wait. North, west, and east. So this way, it must be east. Okay, I hope this is east (chuckle). Do you want to say something? "Cedric isn't in the mood to talk right now." So, does that mean . . . we just wanted to keep walking east. Okay, lets keep walking east. Do, da-do, da-do. I really hope this is east! Hey, is this the castle? Oh, it's a sand castle. "There's nothing to the west but" . . . so this is . . . not the east. This is west. So I want to . . . I have to get back to the snake. (sigh) Okay, come-on, let's go this way. Do, da-do. So, there's a way past the snake that I don't know. I wonder . . . no that's south, I think. Unless that's . . . it could go east that way. Wait. Come back, Graham! Let's go here. Let's see if this is east. Okay, do you want to say something, Cedric? "If you walk south you'll run into the bakehouse." But that's not south, because south was that way. But I understand what you're saying. So, let's come back this way, Graham. Do, da-do. We just have to get back past the snake. Go to the next screen. There could be a way. Another trail. Is there another trail? There doesn’t seem to be another trail. There’s no other trail. So . . . okay, Graham, come-on, let’s go back to the snake. Okay, come-on, we’ll find a way. Now, stop. Okay. Now, there’s the snake, who’s ready to bite. Now, (chuckle) how do you think we can get across? Can you come around this way? Oh! This isn’t very fun if I can’t even get by the first obstacle. Come-on! "Watch out, a poisonous snake." Thank you very much, I’m quite aware of the poisonous snake. Okay, talk. "See how the path goes east to the mountains? That’s the route . . . " Okay, I got that. Thank you very much. So, if I see an eye . . . what’s the eye icon? That’s to watch. "Cedric keeps his eye on . . . nearby tree." Okay. "King Graham, heavy of heart, searches far and wide for his beloved family who’s been stolen by an evil wizard." Hmm. What’s the snake say? "A large venom . . . blocks Graham’s passage to the east." Really! You’re kidding.

**RQ Summaries**

Question seven on the Retrospective Questionnaire asks subjects to answer out loud, "What do you think of this game?" The answers are of special interest because they are extemporaneous summaries of the subject’s experience in her or his own words. The first and last subject summary statements are quoted here in full:

First Lapsed Time From Start of Game: 1:24:24

I don’t know yet. As soon as I win or get close to winning, or make some progress, I’ll let you know. But I have made some progress, so it’s okay. I don’t have negative or positive feelings about it.

<u>Last</u> Lapsed Time From Start of Game: 3:44:12

Too many choices. Its okay. Actually, it would be fun if I had more time and I could just turn it off and come back to it whenever I felt like it. I do want to get to the end.

These assessments indicate the subject's ambivalence toward the activity, and suggest the experience falls within apathy, not flow as indicate on the SEM.

**Offline Notes**

U1 made no offline notations.

**Learning Rate**

U1's LR was not be calculated, as she accomplished less than 5% of the learning.

**Posttest**

No posttest was given as U1 accomplished less than 5% of the learning.

**A2**

A2 was a 32 year-old single male holding a General Equivalency Diploma who packages software for a large software manufacturer. He had no computer or video game experience and limited computer experience. A2 arrived for the first session complaining of pain in his lower back. In general he appeared not to understand or to accept the activity or embrace the learning model, was somewhat confused by the interfaces of both the game and the Guide, and showed little interest in the game.

**Questionnaires**

A2's questionnaire output is shown on the SEM in Figure 30. Table 6, Questionnaire Data Summary, and the SEM provide the most succinct picture of U1's overall self reports. The mean ESQ and RQ points shown on the SEM are plotted from the data in Table 6. The points show the subject's overall experience (OE) as recorded for each questionnaire, calculated by averaging the converted values on the questionnaire worksheets (Appendix E). The points are numbered to show the sequence of questionnaires and to show how the subject's responses varied over time. The numbers refer to the order in which the questionnaires were completed, irrespective of questionnaire type. Also identified are the means for the subject's reported experience before and after the introduction of the *Guide.* Of the three non-finishers, A2's questionnaire output is the most credible, falling, as one would expect from his video and think-aloud data, slightly below the subject mean in the direction of apathy. As with the other non-finishers, this data set falls somewhat higher in the direction of the subject mean and toward flow than one might expect from observing the video/audio data. A2 was the only subject to show a *decline* in motivation (defined as flow) following introduction of the *Guide.*

A2 responded to 58 items on four questionnaires (two ESQs and two RQs) during a single session lasting two hours and 58 minutes. Except for a final RQ mean score slightly above the model's subject mean (zero), A2's questionnaire

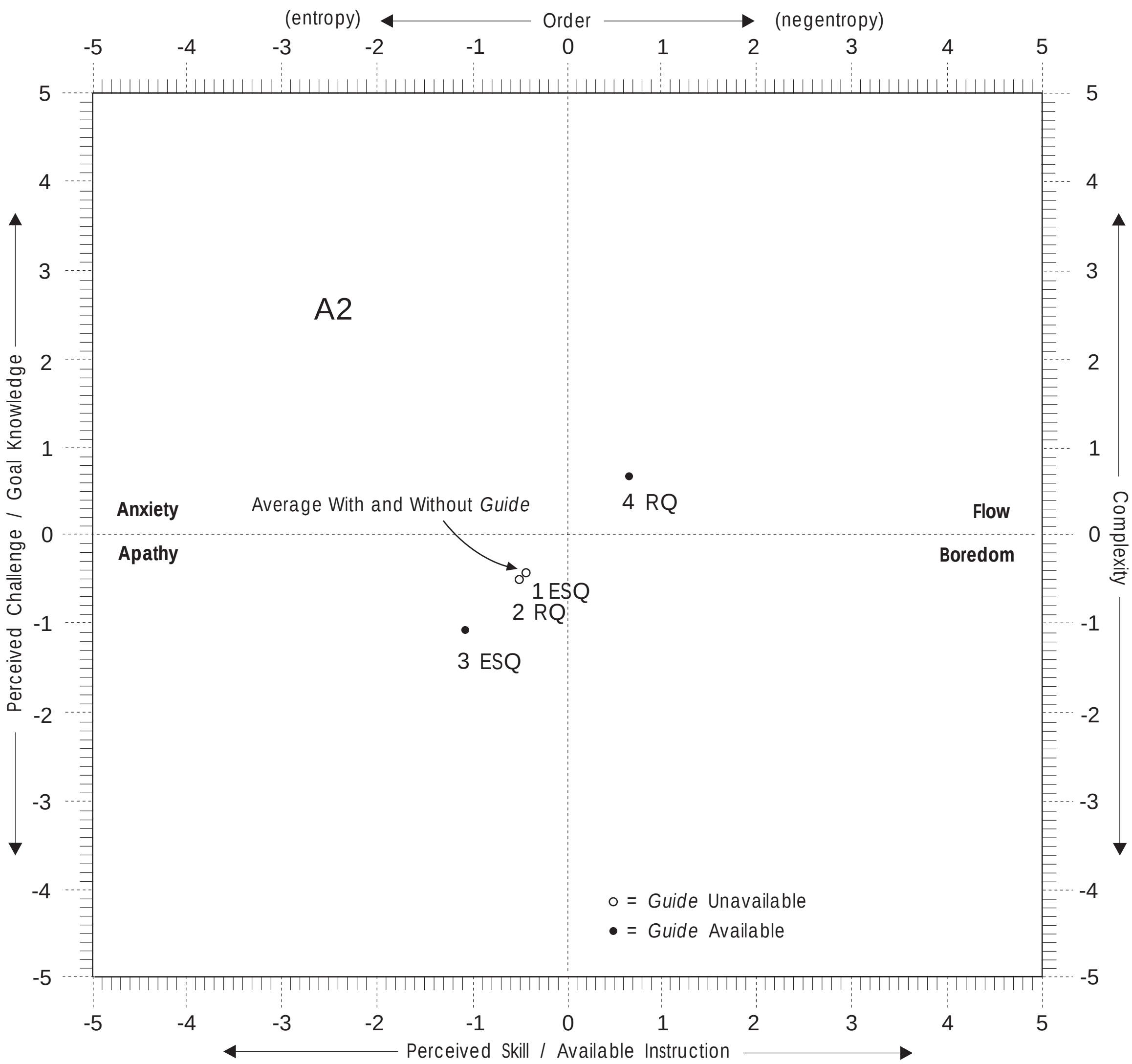


**Figure 30: Overall Experience for A2.**

means fall slightly below zero in the range of apathy. An interesting result is that the introduction of the *Guide* after one hour and 36 minutes made almost no overall difference ($M = 0.07$) in the subject's affect or behavior, even taking into consideration the slightly higher result of the final RQ. The sharp *increase* in the direction of apathy shown on the second ESQ, which followed the introduction of the *Guide*, is remarkable. A2 was the only subject for whom the availability of the *Guide* had a negative effect on motivation.

It is notable that after approximately 35 minutes of systematic exploration of several of the areas in the first region, the subject began to describe the activity as requiring too much effort ("This seems like it could take a long time to get around in this"). After approximately 51 minutes, subject notes: "I'm not really . . . not getting very far here." After one hour, seven minutes, he comments: "Well, it's nice that we're in these places, but, can't do anything, so what's the point, except to watch the movies?" At one hour and 19 minutes, subject remarks: "Now I think I'm getting a little bit frustrated" (chuckle). I don't know where I'm going or. . . I guess I'll walk through some water. Well, I'll keep gong this way. I think that's going to go back to the house. And I think there's not a lot of places to go from here."

The subject rated himself low on anxiety (2) and self-consciousness (2,1) on both ESQs. As with U1, this subject failed to look at any of the maps in the *Guide* despite several attempts to explore the desert where a map is essential to avoid losing one's way and to locate water. As the guided exploration learning model requires learners to use the game and the knowledge base together, this subject's progress was minimal.

A2's first ESQ appeared 53 minutes into the task and the second two hours and 38 minutes, approximately one hour after the introduction of the *Guide.* It is interesting to compare the subject's responses on these two instruments. On the 10-point scale for the first Part 1 ESQ, A2 reported low anxiety (2), low involvement (5), low enjoyment (4), low skill/information access (3), low self-awareness (2), little control (2), and little desire to win (4), along with high boredom (8) and effort to concentrate (8). Somewhat surprising as a goal-aware subject was his lack of knowledge of the goal (4), which did not improve on the second ESQ after more than 2.5 hours on task. The second ESQ showed marked increase in desire to do something else (7), boredom (9), and effort (9), and declines in involvement (4), enjoyment (3), desire to win (2) and, surprisingly, no change in skill/information access (3). Anxiety remained low, as before (2).

On Part 2 of the second ESQ, the subject reported less involvement (from "somewhat involved" to "somewhat detached"), less tension ("somewhat tense" to "somewhat relaxed"), and a slight increase in alertness, but otherwise the subject remained "somewhat bored" and "somewhat confused," and "neither sad nor happy," "neither irritable nor cheerful," and "neither anxious nor confident."

The first RQ, which all subjects complete just before learning about the *Guide*, was consistent with the ESQ, showing low enjoyment (4), high difficulty (9), and low control (1). The last RQ, however showed a decline in negative qualities and a slight increase in positives. Control increased by two points from 1 to 3, boredom declined by one point (from 8 to 7), enjoyment increased by two points, and difficulty dropped by two points. Given the greater number of indicators of apathy following introduction of the *Guide*, it seems likely that the more positive results on the final RQ were due to the subject's awareness that the session was ending, rather than that his feelings and interest had become more positive.

**Guided Discovery**

A2 appeared to understand the learning model, but lacked the interest to make much use of it. He explored the game environment but made almost no use of the *Guide*, and never looked at any of the maps. When asked about this he said he did not read ahead (browse) because there was no point in learning something he had no current use for.

**RQ Summaries**

Question seven on the Retrospective Questionnaire asks subjects to answer out loud, "What do you think of this game?" The answers are of special interest because they are extemporaneous summaries of the subject's experience in her or his own words. The first and last subject summary statements are quoted here in full:

> <u>First</u> Lapsed Time From Start of Game: 1:34:34
>
> It seems very complicated, and I'm not quite sure how long it would take to go through and figure it out, but probably a long time, so . . . I think it's got beautiful graphics, and, well, I guess that's about all.

> Last      Lapsed Time From Start of Game: 2:55:51
>
> I think it's interesting and I love the graphics and I think it takes a lot of going around and around to find what you need to know to solve it, which is probably . . . it was probably designed that way to make it last a long time and keep people's interest and variety going. I tend to maybe want to just get to the point on a lot of things. I like to know ahead of time what all of the possible things it is that I'm looking for and how to use them so that once I get going, I can just go and do it. That's probably why I tend to maybe get a little bored.

In his final statement A2 says he prefers activities that require little investment of effort or time.

**Offline Notes**

A2 made no use of offline notations.

**Learning Rate**

A2's LR was calculated as he accomplished less than 5% of the learning task.

**Posttest**

No posttest was given as A2 accomplished less than 5% of the learning (acquiring and exchanging one resource and acquiring a second).

## U2

U2 was a 12 year-old male seventh grader who volunteered for the study because of a keen interest in computer games. His enthusiasm showed little change throughout the activity. He appeared to experience little frustration, even in the *Guide*-unavailable condition, and his completion time was the second fastest of the eight subjects. U2 had difficulty pronouncing two or three of the words on the reading test, but appeared to understand their meanings.

### Questionnaires

U2’s questionnaire output is shown on the SEM in Figure 31. Table 6, Questionnaire Data Summary, and the SEM provide the most succinct picture of U2’s overall self reports. The mean ESQ and RQ points shown on the SEM are plotted from the data in Table 6. The points show the subject’s overall experience (OE) as recorded for each questionnaire, calculated by averaging the converted values on the questionnaire worksheets (Appendix E). The points are numbered to show the sequence of questionnaires and to show how the subject’s responses varied over time. The numbers refer to the order in which the questionnaires were completed, irrespective of questionnaire type. Also identified are the means for the subject’s reported experience before and after the introduction of the *Guide*. U2’s questionnaires changed little over the 7.5 hours he worked on the game varying between a low of $M$ = 3.84 and a high of $M$ = 4.50.

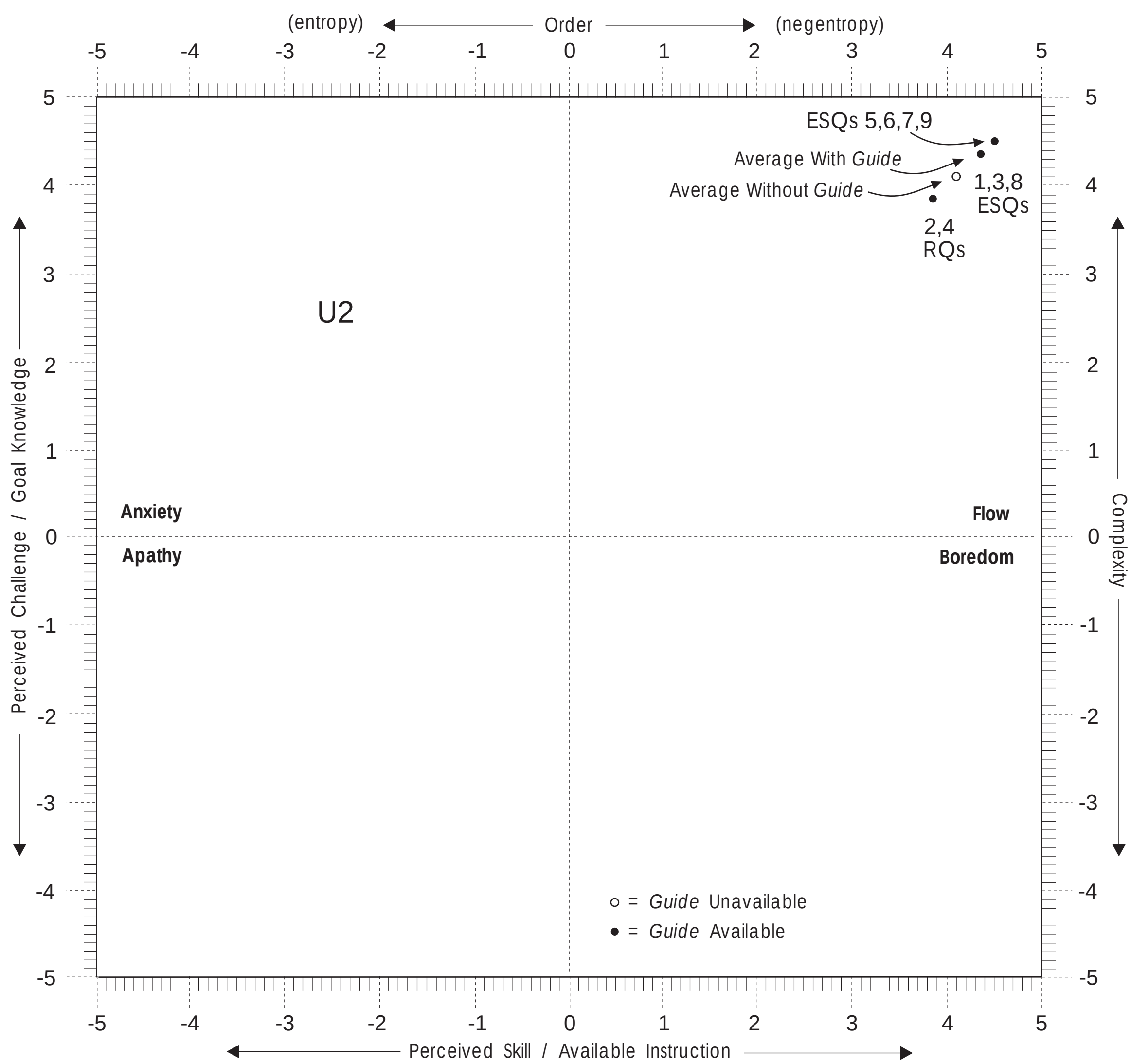


**Figure 31: Overall Experience for U2.**

U2 responded to 153 items on 9 questionnaires (six ESQs and three RQs) during two sessions that lasted seven and a half hours. The challenges and roadblocks encountered in solving the game's puzzles were seldom sources of frustration or puzzlement to this subject, but were handled through task-switching, alternative hypothesis formation, and use of the inquiry system. This overall characterization is reflected in his ESQ and RQ results, think-aloud protocols, and completion time. On the 10-point scale for the first Part 1 ESQ after approximately one hour of play, he rated his involvement, preference for the activity, enjoyment, and desire to win at the highest level possible (10). An important element in identifying the presence of flow is control — the sense that a person has that his or her skills and knowledge are matched with the demands of the task. The three measures of control on this subject's questionnaires remained high, never dropping below 9. Contrary to expectation, U2 also gave the highest value (10) to the goal knowledge measure, which is of special interest given that the subject was assigned to the goal-unaware group, so he had no background information or orientation at the start. U2's responses on Part 2 of the ESQs were consistent, both with Part 1 and with each other. The two elements on both parts of the ESQ that were rated closer to the center of the scale were the measures for anxiety and self-consciousness (between 4 and 8). These responses may indicate uncertainty about the meanings of anxiety and/or self-consciousness. The three RQs were entirely consistent with the ESQ and video/audio data. All measures converge in such a way that a stronger case for the presence of flow throughout the activity could hardly be made.

In many respects, U2's performance was exemplary. Task identification and hypothesis formation were taking place from the first moment. When U2 began working on the game, he had already made plans for what steps he would pursue, based on what he had learned during the think-aloud practice period in the orientation session. More than just to practice verbalizing, U2 had made use of that opportunity to begin working on the.

U2 played the game for one hour and 26 minutes before acquiring access to the *Guide.* During that time, despite making little progress, he expressed little frustration beyond brief, isolated observations like, "I'm really stuck. I can't think of anything to do. I've got to think of something" (one hour, 17 minutes).

However, after restarting the system, following the introduction of the *Guide,* U2 went directly to the Map button on he Desert Region page:

> <u>TA Sample 1</u> Lapsed Time to Start of Sample: 1:32:10
>
> Okay, what I'm going to try to figure out is the map. Map. I've got . . . I've gotten lost so many times. Oh! Wow! There's where the oasis is. Oh, look at all the oases! I wonder which one I'm at. I wonder which one of the oases I'm at. Look, there's one here. I think I'm at that one, because the skeleton's there. Yeah, and I wrote it down, see . . . oasis leads to the skeleton. And then, where did I . . . oasis, skeleton . . . go to skeleton, and you go over to reach an oasis.

**Guided Discovery**

U2 understood and made optimal use of both the game and the knowledge base to advance his learning, consistent with the requirements of the guided exploration model. The following example shows a fully formed hypothesis that is described as the procedure is enacted. The subject then turns to the *Guide* to find a match between a previously identified task and a rule, from which a new hypothesis will be formed for solving it.

TA Sample 2 Lapsed Time to Start of Sample: 1:58:13

> I'm going to go into the area and get the brass bottle and gold coin. And then I'm going to run out and — hopefully in time (chuckle) [he performs these steps as he speaks] — Now I've got that stuff. Now I'm planning to . . . I'm planning to pick up the remainders. Oh, I wanted to pick up the remainders of the staff. So I'm going to save the game again. Now I'm going to walk out away from the temple and hide behind the oasis in front of it for a little bit of time. Come on, stand right there. Now I'm going to go into the area where it gives you ideas on what to do [in the *Guide*]. I'm planning to see what else I can do. Ahm, I've already gotten all the stuff from here. I've gotten the gold coin. I've gotten the brass bottle. Wonder what the brass bottle will do. Hmm. Oh, wait . . . brass bottle will let me go and I can see more. Ahm . . . "anyone who tries to open the brass bottle will become trapped inside it for the next 500 years." Whoa! That's pretty harsh (chuckle). So, now I'm going to see what else . . . oh, it seems like I'm done with ah . . . bandits, brass bottle . . . seems like I'm . . . when

> bandits are heard . . . let’s see. So, I’m reading this. Now I’m planning to leave, I guess. I am done with the *Guide*. Now I’m gong to get a drink of water, and then leave, and then . . . walking elsewhere. Hit the walk button . . . I’m walking. I’m trying to think if whether I need to go one or more screens. I need to look at the map to deduce that. Let’s see. Right now I’m at these cliffs, so if I can go one, two, three, four, five, brushland. Oh, there’s the gypsy camp, ant colony, bee tree, brushland, brushland. Where’s that oasis . . . I’ve just got to go one more after this, then down. And so . . . there we go. I’m walking one more time. I’m going to . . . then see what I can do about the bear. I’m going to . . . about to go to the oasis. . . . Now I’m going to try to see what I can do about this bear. Ahm . . . Guide. I’m going to . . . let’s see . . . great mountains, beach, dark forest. Woods and town of Serenia. I just got to learn about . . . bear. "The bear prefers a smelly old fish to the sweet taste of honey." I’m going to get my smelly old fish, and give it to the bear! And off he goes.

Although the preceding excerpts are from U2’s early use of the *Guide* in the application of the learning model, it is typical of correct use throughout the course of the activity. What is needed is a balance between inquiry and exploration.

The following excerpt is included here as an example of the optimal application of the learning model. It illustrates all the essential elements: task identification, hypothesis formation, hypothesis testing, solution discovery and enactment, and resource acquisition. The subject is faced with the problem of how to proceed at the Frozen Waterfall. He determines that he needs a resource that he has not brought with him — a rope — to climb the ice wall (task identification / hypothesis formation). He has an idea where a rope might be found, but has not encountered the rope resource yet, so he must search both the game environment and the knowledge base to find it.

> <u>TA Sample 3</u> Lapsed Time to Start of Sample: 3:20:14
>
> Let's see. I'm going to go to the help, and go to the Great Mountains, I think this is. "Custard Pie," "Eagle," "Frozen Waterfall," "Ice Queen," "Leg of Lamb," "Locket." I think I'll try the Frozen Waterfall. Let's see what it says. "A rope thrown over a solid anchor can be used to climb the cliff beside the frozen waterfall." "A strong hand and a good balance are needed to cross on the little rock knobs from the upper ledge . . . fallen log on the other side of the frozen waterfall." Mmm. Okay, now I'm going to go back to the game. Let's see. Where . . . is this the frozen waterfall? Hah. Do I have a rope yet? No, I don't have a rope. I guess I have to get the rope from the robber's house, but. Don't go too close (chuckle). Okay, restore. Ice. I guess I'm going to go see if I can find the rope first. I'm going to go look for the rope. It's probably at the robber's house or something . . . somewhere there. So I'm going to go back into the robber's house, and hopefully the mouse will help me. Because the mouse hasn't done anything for me yet. Might be the one to help me. Now I'm going to scare the bird off. I think. I don't know. Yup. It just was fortune to happen (chuckle). Let's see. Nope, this is not the place I was thinking of. It's

below it. So, let's see. Hmm. I want to go into the robbers. Wait. I'll learn about the robbers first. Then I'll know what to do about them. Let's see. I'm going to go into the . . . see what I can do about the . . . what I can do about the . . . ahm . . . bad guys. "Toymaker." Okay, "Weeping Willow," "Tailor," "Stick." What's stick? "A stick lies at the base of the honey tree." Oh. Huh. Let's see. "Silver Coin," "Rattlesnake," "Bear," "Cobbler's Hammer." "Cobbler's hammer is an effective tool to break a padlock" . . . oh! Wooh! "This retiring shoemaker would gladly trade his cobbler's hammer" . . . yeah. Okay, let's see. I think I'm going to open the door first. Let's see. "Dog," "Fish," "Gnomes," "Leg of Lamb," "Rat." Yeah, leg of lamb, and then I'll check "rat." "A tasty leg of lamb is stored in the cupboard inside the Swarthy Hog Inn." Ah! Now to the rat. See what the rat can do. He is . . . "can stop the cat from catching the rat in the bakehouse. A stick might do it or an old shoe." Hmm. Let's see. "Guide." Now I'll go back to the game. And I'll take my little hammer and open a padlock door. Hmm, let's see. " . . . can see an unbreakable padlock on the door." Well then . . . "it's useless against the padlock." Well then, why won't it let me use it? Huh. Let's see. I'm going to try and try. Now I'm going to try using this. "Nothing would be accomplished by using the hammer here." You sure? I'm going to keep on trying. Seems like it's not going to let me. It even said in the *Guide.* Let's see. I'm going to check the *Guide* again to see if it will tell me. Hmm. "Hammer." "Cobbler's hammer is an effective tool to break the padlock on a cellar door." Ah, sigh. Didn't give me very much information. Hammer against door. Wait, what'd it say? What'd he say? What'd he say? "Back down the road to the east you run into the bakehouse." Huh. Maybe that's a hint. Walk, walk, walk, walk. Let's see. What about it? Does he have anything else to say? "You'll find a rundown inn if you follow the road to the west." Huh, that was help . . . ahm, let's see. We could just try walking in again. Mouse might help me. Let's find out. Hopefully . . . "I'll wait for you here. I don't like that place." Come on mouse. You'll help me, right? The mouse might be able to help me. I'm talking. Or I was (chuckle). Let's see. I'm trying to think of what I could do. Or if the mouse would help me. Oh, gosh! I'm going to get . . . oh! Let's see. Yup, I'm going to get hit. Then the mouse might save me. That's what the mouse might be able to do. I'll find out soon. Whack. Darn it! Oh, well. Let's see. Yes! I knew it! The mouse could have helped me somewhere. "I told you I'd repay your kindness when you saved me from that horrible cat. Good luck, friend." Yeah! That's good! Let's see. Now I'm going to save the game as "mouse." I probably spelled it wrong (chuckle). Yup. At least I'll know what it means. Let's see. What would happen if I got that? " . . . stoops and picks up the sturdy rope from the stone floor." Rope! That's exactly what I needed. What's in this barrel. Well. "A rusty . . . secures door preventing Graham from leaving the cellar. Well, let's see. A hammer should maybe be able to help. Yup! "Using the hammer . . . " Let's see. Hmm. I think I'll . . . "Inside the cupboard Graham sees a juicy leg of lamb." Now I'm going to try walking into this room and see where it leads. Oh! Okay (chuckle). Let's see. Restore . . . where is it . . . "mouse." I guess I went the

> wrong way. And I'll use the hammer against the padlock. Now I'll open the door and walk through. Get that lamb and then walk the other way this time. Out. That leg of lamb . . . Now that I have the rope, let's go to the *Guide.* I'm going to go to the *Guide* and see what that leg of lamb will do. " . . . is stored in the . . . " Oh, that's all it tells me. Oh, huh! Whoa, whoa, whoa, feedback! Better keep my mouth sort of far . . . whoa. Not exactly sure what that was, but it was noisy. Let's see. Now I'm going to walk out of here and go back to the area and use the rope to climb. Walk, walk, walk, walk. There I go!

While also representative of the approaches of other successful players, this example contrasts vividly with the approaches of the unsuccessful subjects in this study, who either failed to make use of the *Guide* (A2, U1) or tried to use it in lieu of exploring and acting within the game (A3).

**RQ Summaries**

Question seven on the Retrospective Questionnaire asks subjects to answer out loud, "What do you think of this game?" The answers are of special interest because they are extemporaneous summaries of the subject's experience in her or his own words. The first and last subject summary statements are quoted here in full:

> <u>First</u> Lapsed Time From Start of Game: 1:22:01
>
> I think it's a strategy game. You have to, like, find stuff and know what to do with it. It's mainly based on learning. And it's a cool game.

Last                                  Lapsed Time From Start of Game:  7:27:23

I think its a hard game.  You couldn't do it without the book.  A very good game, though.  Very fun, very intriguing.  And I beat it!  Solved, solved, solved. . . with help from the *Guide*."

**Offline Notes**

U2 used offline notes at three points in the game.  In his early journeys in the desert, he used pencil and paper to draw a map as he explored (a standard technique of adventure game players).  He also made notes to supplement the online map of the castle labyrinth and as a memory jogger to correctly sequence the transmutations during the end game combat with the wizard Mordack.  See Figure 32 for his offline notations.

**Learning Rate**

U2 finished the game in 7 hours, 29 minutes, in two sessions one week apart (see Table 6).  His learning rate was 13.36%, exceeded only by A4, an adult computer professional with extensive experience playing adventure games who took no meal breaks..

**Posttest**

U2 scored 47.5 out of 50 on the 24-hour test and 50 out of 50 on the second test a week later, a gain of 5%.  The details of his omissions on test one are shown in Table 5.  As the tests required the recall of specific concepts and procedures,

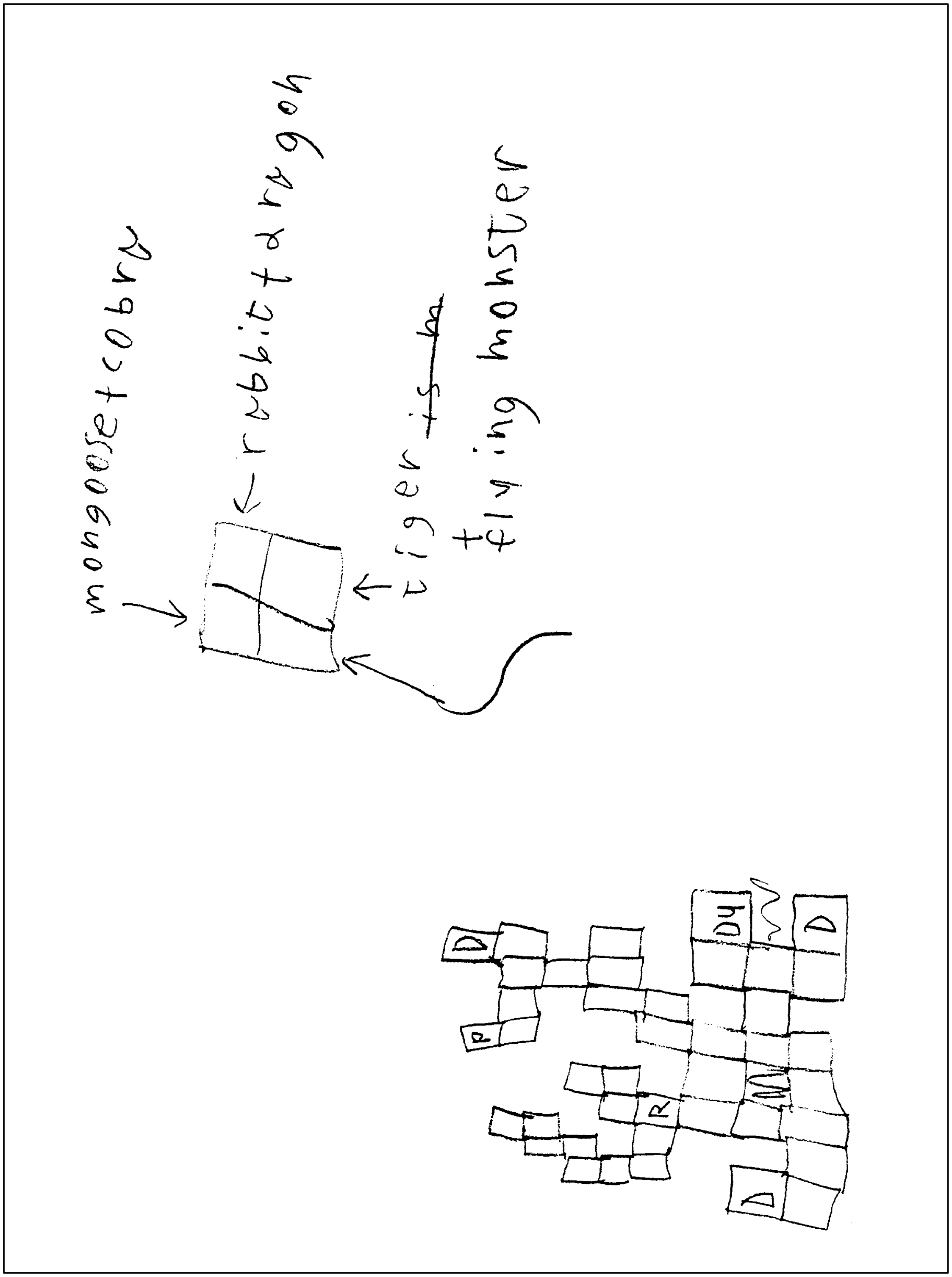


**Figure 32: U2's Offline Notes.**

answers had to be complete to receive full credit. In all cases in which full credit was not earned, some portion of the procedure was provided in U2's answer. His improved performance on the second test may, therefore, be accounted for simply in the care and completeness with which the answers were expressed.

U2 possesses an unusual spelling limitation, which had no bearing on his performance on the learning task, but was of interest because the test required short written answers. Although U2's spelling is unusual, his writing is decipherable. For example, his answer to question 1, "What did Graham do to rescue the bees?" was:

> "I gav the Bare a fise to mak hem go awa."

U2 also made substitutions for a few of the concept names asked for on the test. For example, he recalled the "amulet" as "naklis" and the "brass bottle" as "geni pot." As the test was an unstructured and open-ended measure of procedural knowledge, substitute concept names, providing the identity of the referent was clear, were scored correct on the test.

### A3

A3 was a 43 year-old Ph.D. student, married mother of two, who holds an MBA degree. Her previous computer game experience was limited to one game, a current best seller with a somewhat unchallenging "hunt-the-pixel" interface and state-of-the-art ray-traced graphics and animation. Her reason for volunteering for this study was "empathy for a fellow Doc student trying to drum up research subjects."  A3 was on a schedule that allowed her to participate between other commitments, so her available time was constrained externally. Despite her educational background, her learning rate was only one-fifth that of the 6th grader with the longest completion time (she completed 10% of the learning task in 5 hours versus his 100% in slightly over 10 hours).  Her response to the game, the learning model, the learning task, and the research interventions was overtly critical.

**Questionnaires**

A3's questionnaire output is shown on the SEM in Figure 33.  Table 6, Questionnaire Data Summary, and the SEM provide the most succinct picture of A1's overall self reports.  The mean ESQ and RQ points shown on the SEM are plotted from the data in Table 6.  The points show the subject's overall experience (OE) as recorded for each questionnaire, calculated by averaging the converted values on the questionnaire worksheets (Appendix E).  The points are numbered to show the sequence of questionnaires and to show how the subject's responses varied over time.  The numbers refer to the order in which the questionnaires were completed, irrespective of questionnaire type.  Also identified are the means for the subject's reported experience before and after the introduction of the *Guide.*

A3's SEM composites place her squarely in flow throughout most of her two data-collecting sessions.  It is apparent from the video/audio data, however, that this is not an accurate representation of her experience with the game and the research activity.  As with U1 and A2, she thought the game too difficult,

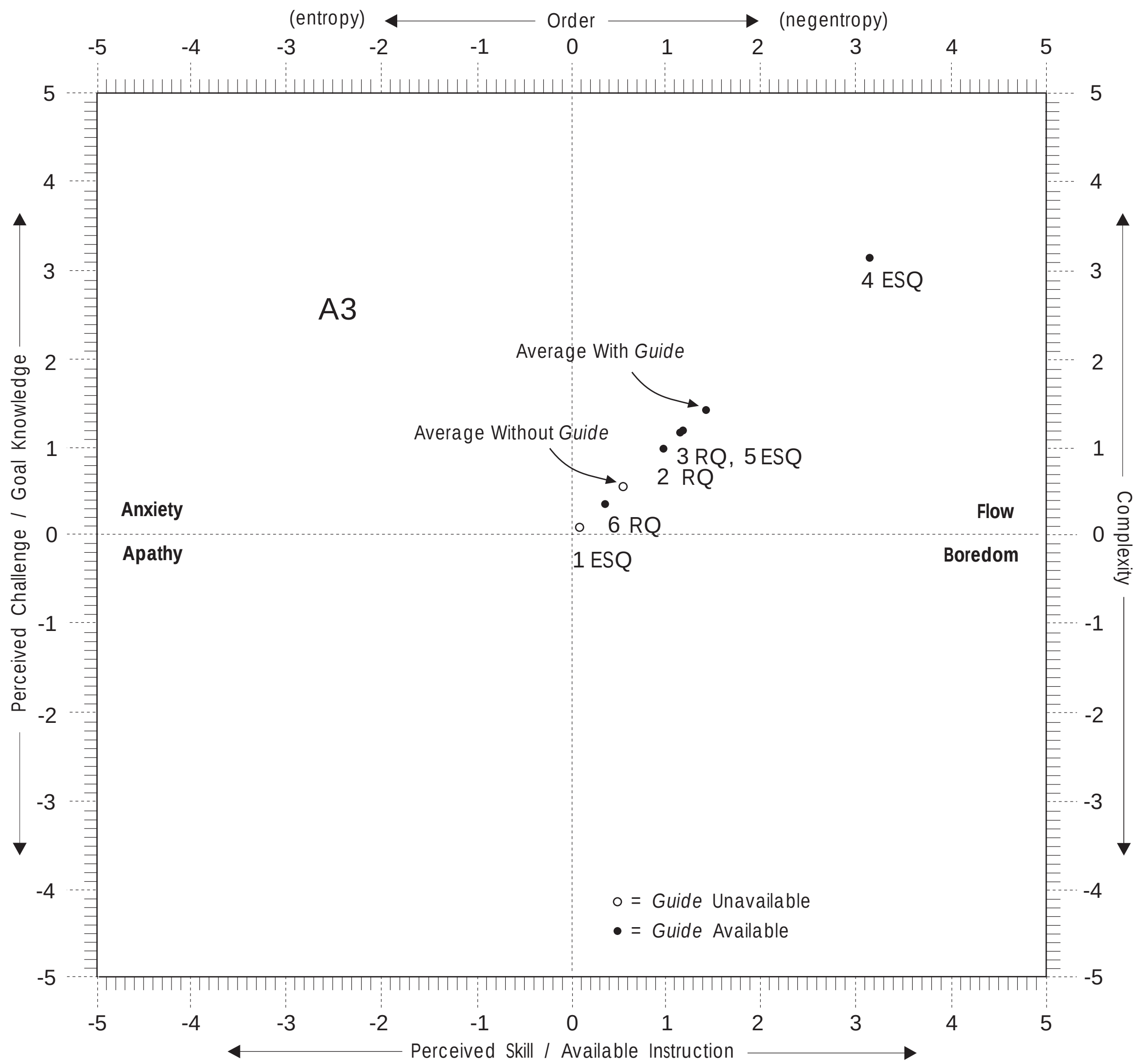


**Figure 33: Overall Experience for A3.**

although in her verbal protocol she rejected the term "difficult" in favor of "tedious," and was critical of the ESQ item that asks subjects to rate the game’s difficulty. In her RQ summaries, she said she thought there were not enough clues in the game and no obvious logic for discovering them, but this was not seen as a criterion of difficulty. She complained that the graphics did not suit her, that the game uses technology that is out-of-date, and "plays dirty tricks."

A3 was also critical of the apparatus’ robotic voice: "You sound like a very bored person," and "You sound like you have a cold in your nose." She "hated" the pop the speakers make when the microphone is switched on and was critical of the questionnaires. On a number of occasions, she complained that the ESQ scales were reversed (they aren’t), that the wrong word or question or the "wrong measure" was asked for. She was also critical, at first, of the organization and presentation of material in the *Guide,* believing that it was not useful, and criticized the labyrinth map as being "on a different scale entirely."

Given this wealth of negativity, it is difficult to believe that A3’s questionnaire responses are accurate and that she was in fact experiencing flow. The evidence for considering the questionnaire results of both A3 and U1 to be false is discussed more fully in the section on response credibility below.

**Guided Discovery**

During periods when A3 applied the learning model, she made good progress, but when she tried to figure everything out from within the *Guide,* progress stalled. A3 succeeded overall in completing the first two of the 20 enterprises, which involved finding and acquiring five resources, exchanging three of them, identifying two multiple-part enterprises, and forming and testing several hypotheses. She was unable to understand some of the requirements for hand-eye precision demanded of the interface in carrying out certain actions. For example, it is not sufficient simply to "grab" the staff from the bandits; one must also very accurately move Graham past the sleeping bandit or be killed while trying to escape with the staff. She could not understand the need for care in that situation, and after several attempts, quit trying.

At the beginning of her second and final session, A3 went directly to the *Guide* and spent the next 62 minutes taking notes and drawing concept maps to attempt to discover the solution to the game in a single, all encompassing step. The following protocols are from that extended episode of note taking on the concepts, rules, and facts in the *Guide.* An ESQ with a high flow value appeared after 57 minutes (see Figure 33, the point labeled "4 ESQ").

<u>TA Sample 1</u> Lapsed Time to Start of Sample: 1:55:30

I'm starting the game after one week lapse in time. I've thought about the game some over the period of time in which I've been . . . ahm . . . away from the game. I was pretty disappointed when the guide and map were revealed to me . . . ahm . . . during the last session, because I . . . ahm . . . could see the nature of the entire puzzle at that point, and . . . ahm . . . kind of found it less interesting, and certainly less mysterious than it had the potential to be. Oh, how do I get this to get bigger? "Expand window." Ahm . . . basically I don't expect to use much of the game, except for the *Guide* . . . need to use much of it, except for the

*Guide* to figure out the algorithm involved, and then just to follow it through, so I . . . that's my intended strategy at this point in time. So I need to start up the *Guide,* which is "AM," and I'm going to write down a few things that I already know . . . ahm . . . that I'm looking for. I know that . . . ahm . . . I want a hammer from the shoe shop. I know that I want the golden lyre. And to get that I need to find the heart of the girl. And . . . the heart of the . . . once I have the heart of the girl, I can return the girl to the man. And I know a silver coin can be had from the man pulling the wagon in town. Okay, so now I'm going to try to follow as many of the . . . ah . . . regional . . . ah . . . sets of concepts and link them together. So I'm going to start with the wood and town of Serenia, and I will look . . . I guess I'll just go down the list and look at the bear. I'm marking on my paper . . . ahm . . . "WTS" for wood and town of Serenia. "The bear prefers smelly old fish to sweet tasting honey." Okay. To get the bear's cooperation I need fish. Old fish. "Next." No. "Region." "Cobbler's Hammer." Ahm . . . is "effective padlock on the cellar door or to remove a crystal from the mountain cavern." So, I'm . . . crystal as a precursor of hammer. Now, let's see. Of hammer and the . . . ahm . . . padlock on wizard's cellar as precursor of hammer. "WTS," "WTS." Okay. Chet, I'm getting an awful lot of feedback from the mike! Does that make any difference? It just keeps ringing. When I get up here, it . . . I mean, I can live with it, if it's . . . but I wonder, is it going to make the recording unintelligible? It definitely seems to get worse as I get closer to the machine. [conversation on speaker feedback deleted] Okay. I think it'll be okay this way. Okey-doke. On I go. "Old fish." Okay, "cobbler hammer." I’ve got two purposes for that. Okay, back to the *Guide.* "The dog." "Dog loves to chase sticks and old shoes." "Dog" precursor to "stick" and "old shoe." "Old shoe" is probably the only one that matters. "WTS." Okay, I have to write down "heart," "girl," "man." And "golden lyre." Back to the region. "Fish." Okay. Now this is the fish to go to the bear. "A barrel in town contains smelly old fish." Okay, so I’ve got "old fish," "barrel in town." "WTS." Okay, back to the region. "Gnomes." "The witch stole the grandfather gnome’s spinning wheel and hid it in her house in the Dark Forest." Okay, if we want to get Grandfather Gnome to cooperate, we need to get a spinning wheel, which is in the house. "House." "The Dark Forest." In the gnome it’s the "WTS." "DF" for "Dark Forest." Okay. "Region." "Leg of Lamb." Okay, there’s a leg of lamb. "Leg of lamb in Hog Inn." And Hog Inn is in what land, I don’t know. "Region." "Rat." Okay, the stick or the old shoe can stop the cat, protect the rat. Says "bakehouse." Okay. So, either a stick or a shoe. "Rattlesnake." "You can scare a rattlesnake or please a dink with a tambourine." "Tambourine." "Rattlesnake." "Dink." And if I have to give it away, I probably want to do the rattlesnake first and the dink second. Back to the region. . . .

<u>TA Continued</u> Lapsed Time to Start of Sample: 2:35:48

. . . I think the hand in the satchel was in the witch’s house. Let’s go back to that one and double check that. Goes to the "Dark Forest" one. "Leather Pouch." That’s not the same. "The emeralds can be removed from the pouch by using the hand in the satchel." I don't know where the satchel is. Okay, so the witch's house has "emeralds," "leather pouch," and the "spinning wheel." Trying to find a way to organize this that makes sense. Okay. Boy, it's getting worse. Ahm . . . "stick." Okay, from the "emeralds" we want the "elf." And "elf" is the "honey tree." From the "honey tree" we have the "stick." Aah . . . this is just impossible. Let me . . . okay, go back and get the beach and ocean and island. "Beach Hut." "Doorbell is near the left front corner of the beach hut." "Beach." "Hut." "Doorbell." Left. Front. Corner. "Corner." That's an island. Okay. And the boat. "Beeswax from a honeycomb is an effective sealant for a leaking boat." So, we have a "boat with honey." Where's the honey tree? [sigh] So, I need the honey. I need the stick. And I need "wax" for "boat." Conch Shell. "Conch shell." Hearing aid. For hermit. "Region." "Fishhook." "Fishhook on Harpy Island." Okay. "Harpies." Okay. "Lyre music." "Iron Bar." What's the iron bar for? "Iron bar." "Beach north of waterfall." Okay, now on to the last page of the *Guide.* "Mordack's Island and Castle." Mordack's the bad guy. Let's see, I can look at this map for a second. Oh, this is the inside of the castle one. Okay. Anything look familiar? A "crystal." "Crystal against lethal rays." That was next to the "hammer." "Protect against lethal" . . . if I could spell it would help . . . "rays." And a "dink" I had mentioned somewhere here. What did they like? "Hairpin Graham needs to open the door to the castle is on top of the . . . of dink, the beast in the labyrinth." Okay. "A dink likes the tambourine," which has a "hairpin." And that's in the "labyrinth." In . . . ahh, boy. Okay. I have a fishhook. It might have

> something to do with this fish. "Old fish from beach on Mordack's Island make excellent bait for bagging a cat." "Fishhook." "Cat" . . . er . . . "fish." "Mordack's Island." "Bag." "Cat." No wait, a cat that was going to get a rat . . . where is that? It was at the stick and the dog and the old shoe and the cat and the rat. Hmm. [sigh] It sounds like I have a choice there, and I might . . . I don't want to use the dog on the cat. Okay.

This was an attempt by the subject to avoid the "tedium" of the exploration part of the learning task. A3's conclusion after approximately one hour engaged in taking notes on the *Guide* was that the first things to look for in the game are a fish and a silver coin in town, tasks usually identified during a player's earliest attempts at task identification through the initial stages of game exploration.

Fifty-seven minutes into this session, A3's second ESQ appeared. A3 had done nothing but browse the *Guide* and take notes up to this point. Nevertheless, her responses on the questionnaire, along with her verbal comments at the time she responded to the questions clearly indicate she thought she was performing well, in control of the task, and enjoying the activity — in a word, she was in flow. The result was an ESQ mean of 3.14 (Figure 33). This is a perplexing result. What it appears to mean is that for this subject the *Guide* is motivating but the game is not. Obviously, by virtue of the subject's continuous browsing within the *Guide*, learning was taking place. But that learning was insufficient to enable her to understand or solve the game. Moreover, much of it was simply wrong. As explained in Chapter 3, the *Guide* does not make concept associations or procedures explicit. At best, A3’s efforts might be of use during a genuine effort at exploration problem solving within the game — an activity the subject soon abandoned.

**RQ Summaries**

Question seven on the Retrospective Questionnaire asks subjects to answer out loud, "What do you think of this game?" The answers are of special interest because they are extemporaneous summaries of the subject’s experience in her or his own words. These are quite elaborate characterizations that offer considerable detailed information about A3’s particular difficulties with the game.

> <u>First</u> Lapsed Time From Start of Game: 1:23:53
>
> It’s relatively unsatisfying, because you don’t get much insight into potential avenues of finding the things you need. There are no sort of secondary levels of clues. It’s almost like you have to trip on something in order to find something that’s useful to you . . . . I don’t know; the satisfactions aren’t sufficient to keep me going, I guess. I don’t feel like the end is worth pursuing.

(For this subject I’ve included an intermediate RQ summary that A3 provided after receiving the *Guide*.)

<u>Second</u> Lapsed Time From Start of Game: 1:46:09

There's a lot more clues available now, but it looks just like a collecting kind of process. I don't think there's much intrinsic satisfaction in finding the things or going to the places. Its just kind of like a shopping trip. You know, you have to go to this isle and get this thing and then take it to another isle and get a different thing and it just doesn't intrigue me very much at the outset. I think that the way the *Guide* presents information also makes it kind of frustrating. You just have an enormous list of stuff. I'd rather have the clues be more sequential or something, so you'd get a reward, a next clue, for solving another problem. And the problems are not interesting to solve, or they don't appear that they're going to be interesting to solve in any other way than just going and collecting the thing. There is no puzzle involved.

<u>Last</u> Lapsed Time From Start of Game: 4:59:31

Well, it wasn't as dreary as I thought it was going to be at the start of this session. I wish that there were a little bit more productive ways that you could find clues. It seems pretty happenstance that you uncover them. Like, why can't I find the tambourine? And I don't have a clue about why I can't get that staff now. That's a little frustrating. If you fail, you ought to have some clues as to why, or a hint, anyway. Otherwise, its okay.

**Offline Notes**

As described above, A3 spent approximately one hour making extensive notes on the contents of the *Guide.* A sample page from her five pages of notes is shown in Figure 34.

**Learning Rate**

A3 worked on the game for 5 hours, accomplishing 10% of the total learning before quitting. Although she accomplished much more than the other non-finishers, her LR was just 2% per hour, the slowest of the measurable times. All of the learning occurred during the second session, after she had spent more than an hour browsing the knowledge base.

**Posttest**

No posttest was proctored as A3 accomplished just 10% of the total learning task, an amount deemed too small to make testing worthwhile.

**Debriefing**

Five days following A3's last session, the researcher learned A3 had recently spent 40 hours completely solving the newly released *Riven,* sequel to *Myst,* a best-selling adventure game, both of which differ in many ways from the expository style of classic adventure games like the one used for this study. Because this case was so unusual, the researcher asked A3 for more information about her abandonment of the study, in particular why she would invest so much time on *Riven,* but was unwilling to invest even the much smaller

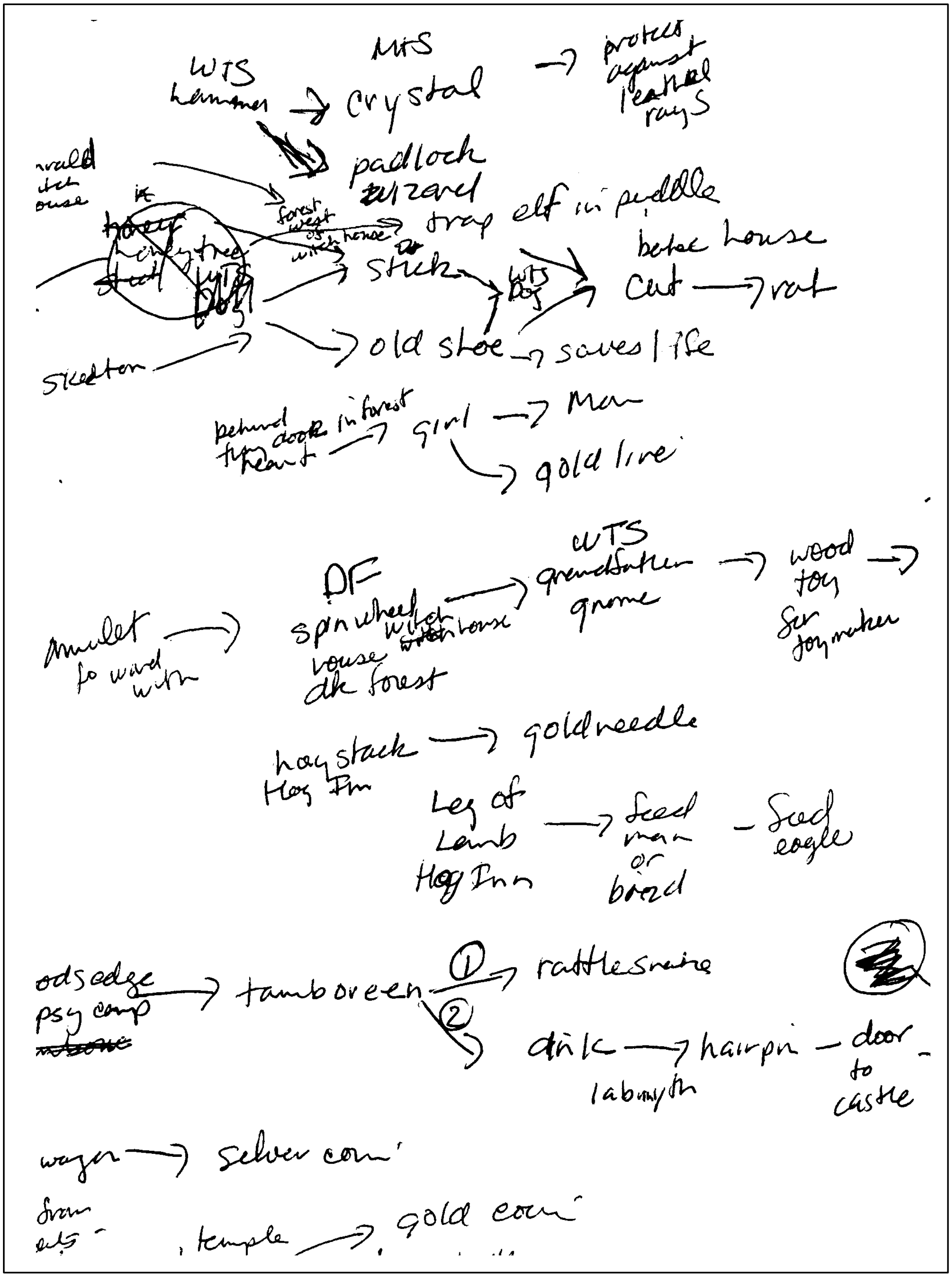


Figure 34: A3's Offline Notes

projected effort required to solve *King's Quest V*. She replied that she felt the game played "dirty tricks," by which she meant aspects of the graphical interface that require accurate pointer placement. Her architectural background meant that she required a higher standard for graphics and ease of locating clues than the state of the art available at the time *King's Quest V* was released. When the researcher described the guided exploration learning model and how the game and *Guide* were intended to work together, and that the *Guide* does not provide solutions to the puzzles, but that the procedures for solving the puzzles have to be discovered, she replied "Well, I didn't want to do that."

**U3**

U3 was a 13 year-old female 7th grader who had played "killing" games and text games with her step father. Like the other successful participants in this study, she volunteered because of an interest in playing computer games. Contact with U3 was initiated by her parent in response to a brochure and at the suggestion of a mutual friend. The parent was appreciative of the opportunity to have her daughter engaged in a supervised activity on a school holiday. U3 appeared to be in flow almost continuously from start to finish, except for a short time in the Great Mountains when she became quite frustrated. Of particular note was her responsiveness to the game's nearly continuous background mood music. Her enthusiasm for the game equaled U2's and she was one of the best performers overall, and, except for the single exception described below, an exemplar of a subject in flow.

**Questionnaires**

U3's questionnaire output is shown on the SEM in Figure 35. Table 6, Questionnaire Data Summary, and the SEM provide the most succinct picture of U3's overall self reports. The mean ESQ and RQ points shown on the SEM are plotted from the data in Table 6. The points show the subject's overall experience (OE) as recorded for each questionnaire, calculated by averaging the converted values on the questionnaire worksheets (Appendix E). The points are numbered to show the sequence of questionnaires and to show how the subject's responses varied over time. The numbers refer to the order in which the questionnaires were completed, irrespective of questionnaire type. With one exception, ESQ 4, which appeared four hours and 23 minutes into the game (about two hours into the second session), U3's self ratings range between 3.5 and 4.9 on the SEM.

U3 responded to 153 items on nine questionnaires (six ESQs and three RQs) during the eight hours and 52 minutes she spent on the game over two consecutive days. U3 was not subjected to the *Guide*-unavailable treatment, so, along with A4 and U4, she belongs to the second treatment group for which the knowledge base was available throughout the data collection process. With some interesting exceptions, the questionnaires show consistently high numbers on the SEM scales. Although assigned to the goal-unaware group U3 reported high scores ("9" and "10") for goal knowledge on all but ESQ 4 (questionnaire number 5 on the SEM). Excluding the responses on ESQ number 4, on the ten-point scale for the Part 1 ESQ, U3 consistently rated anxiety, difficulty concentrating, boredom, and preference for another activity at "1," the lowest

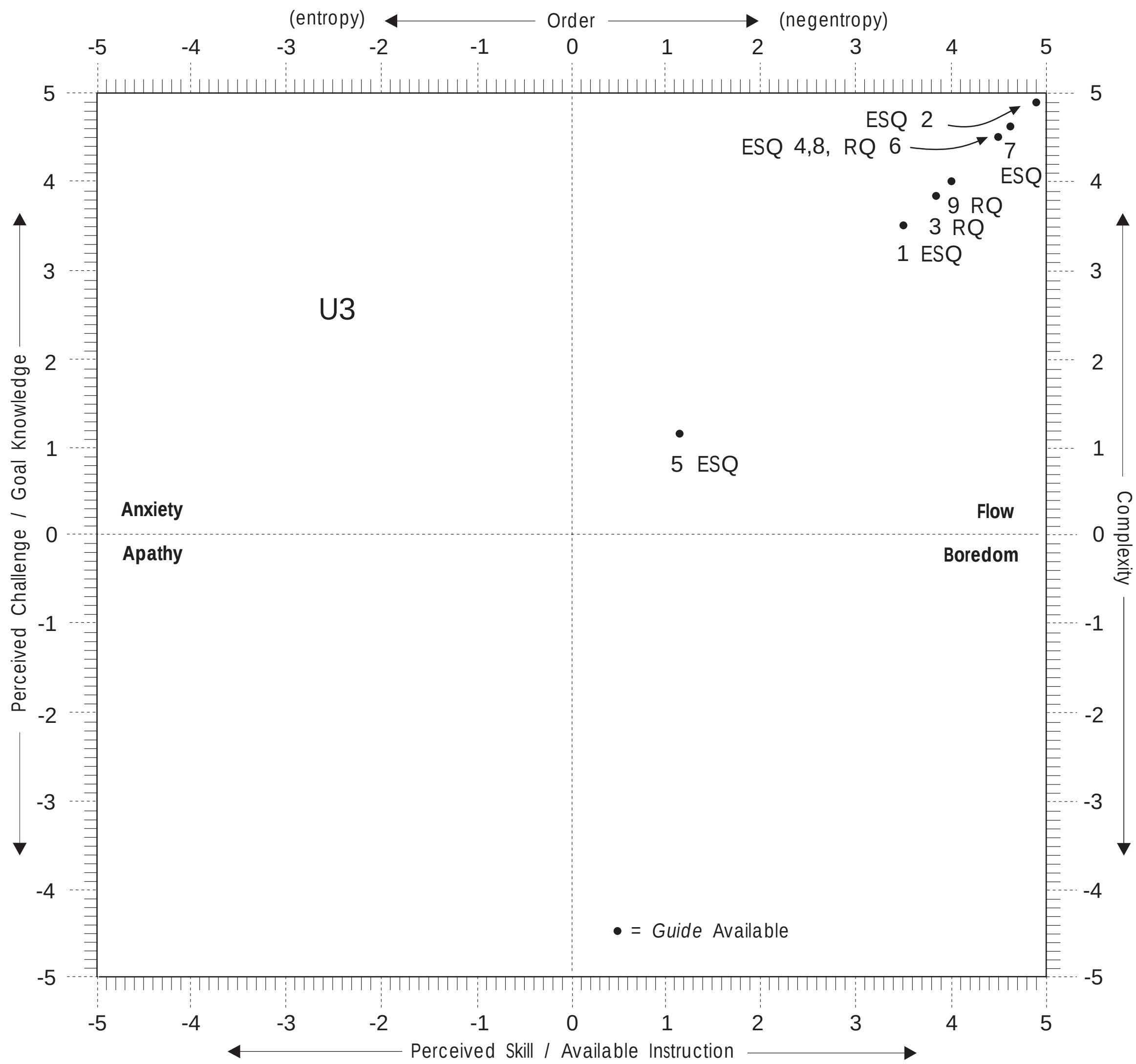


**Figure 35: Overall Experience for U3.**

possible. She rated involvement, skill / knowledge, preference for the current activity, enjoyment, and desire to win consistently at the maximum possible (10) across all ESQs. With two exceptions, she rated the control item either "9" or "10" on all Part 1 ESQs. U3's ESQ Part 2 responses were, with minor exceptions, all at the highest level: "very involved," "very happy," "very cheerful," "very excited," "very clear," "very relaxed," "very confident," and "very alert."

An exception to U3's consistently high ratings of the elements of her experience was the rating for the item for self consciousness, which was, with one exception, consistently in the mid to high range ("4" to "9," average "5"). U2 returned similar results, so it is possible that the rating on self-consciousness could be an artifact of the research situation (the unfamiliar setting, procedural restrictions, and requirement to think out loud).

Of particular interest were U3's three RQs. They are of particular interest because they are the only instruments that ask an explicit question about the "difficulty" (level of challenge) of the game. Because challenge is generally confounded with goal knowledge, skill level, and knowledge level, it is indirectly assessed with questions on the ESQ that ask about skill, information access, and goal knowledge. However, on the RQ, the operative term is "difficulty," the very term that A3 found so objectionable. U3, however, appears to have it right. For flow, the requirement is an "optimal" level of challenge, which means mid-range difficulty. When one considers U3's "polar" RQ responses for enjoyment (10 of 10), boredom (1 of 10), anxiety (1 of 10), and control (10 of 10) it is striking that her just-as-consistent "equatorial" rating of "difficulty" (3, 4, or 5 of 10) perfectly represents the flow criterion for challenge. This result, coming as it does from a flow-oriented subject, may contain a clue in the development of a better instrument for future studies.

**Guided Discovery**

U3's understanding and application of the guided exploration learning model was one of the two most skillful in the study (U2 being the other). Because the *Guide* was available for use from the very beginning, there was no period during which it was necessary to unlearn total reliance on the game as a source of information. At the same time there was no extended period of frustration to motivate the *Guide's* use. The subject's first use of the inquiry system was therefore motivated by the need to acquire additional information in response to a specific problem. For this subject, the problem that motivated first use was a deadly encounter with the witch in the Dark Forest. Her initial exploration of the *Guide* was a model of correct exploratory use.

> <u>TA Sample 1</u> Lapsed Time to Start of Sample: 0:37:50
>
> Okay. Now, let me see the *Guide* for a second. All right. The Dark Forest. All right. The witch. Oh, man! How are we ever going to get to Madam Mushka? All right. "Hidden inside the witch's house are three items that Graham needs." Wow, he's got a . . . oh, wow! "A leather pouch, a spinning wheel, and a small key." All right! All right, it's hid. All right, I'll do that one. All right. Region. Okay. Oh, I can't go anywhere. Okay, how can I find a gold coin? All right, let's see. Go to the *Guide.* Okay. The Dark

> Forest, I'll go to again and I'll see . . . no I've already seen that. Woods and Town . . . I'll go to that place. Oh, the rattlesnake. See how I get past that. Hee, hee. Hee, hee. A dink. All right. How do I find the tambourine? Oh, they did! How do I get the silver coin? Ahah! Okay. I get it now. All right.

Although all but one of U3's questionnaires reported high flow, there was one exception when things began to unravel and she nearly quit. The results are shown on the SEM and her Part 1 ESQ responses. To understand why the subject's experience deteriorated it is necessary to examine the video and think-aloud recordings. This example illustrates the delicate balance among learner autonomy, the "minimal" instruction that supports guided discovery, and the occasional "teacher" (i.e., researcher) intervention, that is necessary to optimize and sustain motivation, and shows how critical the element of control of one's environment is to the maintenance of flow.

The subject's difficulties began when she lost patience because she could not figure out how to climb the cliff next to the Frozen Waterfall in the Great Mountains. The rope must be thrown to a solid point of rock and not to the dead tree branch next to it. The rope must be attached to the exact point where it will work. U3's problem was that she had not found the exact spot and she had overlooked the clue hidden in the rule in the *Guide* that says, "A rope thrown over a solid anchor can be used to climb the cliff beside the frozen waterfall." The clue is "solid anchor." Because U3 missed the clue, she continued to throw the rope either to the rotten tree branch, which breaks, sending Graham to his death, or to other parts of the cliff. When the researcher noticed her frustration, he coached her by suggesting she take the rule literally and search for something more solid than the tree branch. At the top of the cliff, however, the player faces an even more difficult interface problem. The "hand" must be used to jump across an irregular series of rock knobs. The interface is unforgiving here, as the "hand" must be placed very accurately.

> TA Sample 2 Lapsed Time to Start of Sample: 4:17:53
>
> Great! [Graham steps off the edge and falls to his death] He's never going to get across. Bla, bla, bla, bla, bla, bla, bla. Ah, whatever. Have to feed him again, and again, and again. File, save "eat . . . fall, eatfall." Save. Now let me try and get across. Don't! God! [Graham steps off the edge again] What is wrong with you! He's not making it. He won't even try. Uhh! What! Oh. Shit! Go across. [as Graham falls to his death again] Thanks a lot. I am . . . oh, God. Oops! Darn it. Oh, God! I really am not in a good mood. [reminder to keep talking pops up] Okay, I'm going to keep talking, then! Why won't it let me climb up there so I can get down? Hold on! Well, thanks a lot! Thanks. [Graham falls over the edge again] I'm so happy! Just happens to . . . [Graham falls again]. God! I'm never going to get past this part. Don't fall off the edge again! [Graham tumbles over the edge] Great! I ought to *make* you die. Stupid guy. No! [Graham heads over the cliff again] Whatever. This is not working! What the fuck did you . . . God damn it! This stuff [in her inventory] is really going to help me. I don't think so. Whatever. God! Thanks. Then, why is it in there?

> Okay. Ah! I don’t believe he ate the pie! You butthead . . . you ate the pie! Aaaaaaeeeeeeaaaaiiieeeahhhh! Go over there! No! I didn’t say go over there! [Graham tumbles over the cliff]. I didn’t . . . I’m not going to play this for a long time, now. Might as well die. Look at that! [Graham tumbles over the cliff again] Restore!. Stupid! God! Use the sled. At least you can get over with that. [ESQ4 pops up.] God!

Despite her intense frustration, U3 gave high ratings on the ESQ that appeared at this point, to involvement and desire to win (10) and anxiety remained at "1." Some of the other elements changed dramatically. For example, enjoyment dropped from "10" to "4," control dropped from "10" to "3," and goal knowledge dropped from "10" to "6." This example illustrates how an interface that is difficult may defeat a player even when all other conditions are optimal. The subject is in flow, and is making good progress through appropriate use of the knowledge base. The *Guide* tells the subject, "A strong hand and good balance are needed to cross on the little rock knobs from the upper ledge to the fallen log on the other side of the frozen waterfall." This is explicit instruction in the form of a rule. Yet, as subject struggles, the interface does not appear to cooperate. Despite her previous success and appropriate use of the *Guide,* the subject was ready to give up until the researcher intervened and helped her focus on making the instruction in the *Guide* work.

**RQ Summaries**

Question seven on the Retrospective Questionnaire asks subjects to answer out loud, "What do you think of this game?" The answers are of special interest because they are extemporaneous summaries of the subject's experience in her or his own words. The first and last subject summary statements are quoted here in full:

> <u>First</u> Lapsed Time From Start of Game: 2:12:31
>
> I think this game is very fun.

> <u>Last</u> Lapsed Time From Start of Game: 8:51:51
>
> [Spoken in machine-like monotone in imitation of the robotic voice in the apparatus] I think this game is the best game that I've ever played, because I've never played a game like this and this game is not the first game that I've ever, ever played. So, I'd like to say that this game is really, really great and I loved playing it. Dink, dink, dink. It's very challenging, so it did not make me bored.

For purposes of speculating about the motivational qualities of this technology, it is worth comparing this subject's extemporaneous assessment of the learning task with that of A3's RQ responses above.

**Offline Notes**

As A1 and U2 had done, U3 used offline notes to assist with navigating the labyrinth under Mordack's castle and to track King Graham's transmutations in the battle with Mordack. Her notes appear in Figure 36.

**Learning Rate**

U3 solved the game in 8 hours, 52 minutes, midway between the longest and shortest times returned by the subjects in this study. Her LR was 11.28% per hour.

**Posttest**

U3 scored 49.5 out of 50 on the first test at 24 hours, and 50 out of 50 on the second, one week and one day after solving the game, an increase of one percent on the second test. Her only error on the first test was the omission of a key procedural step that is subsumed by the answer she gave.

## A4

A4 was a 27 year-old single female college senior in engineering. She is an experienced computer professional with extensive knowledge of both text- and graphics-intensive adventure games. Despite her inability to keep to the specified system operating procedures, and four system crashes, her performance overall reflected her gaming expertise. She achieved the fastest solution time and the highest scores on the posttests of the eight subjects. She volunteered for the study because of her interest in computer games and helping

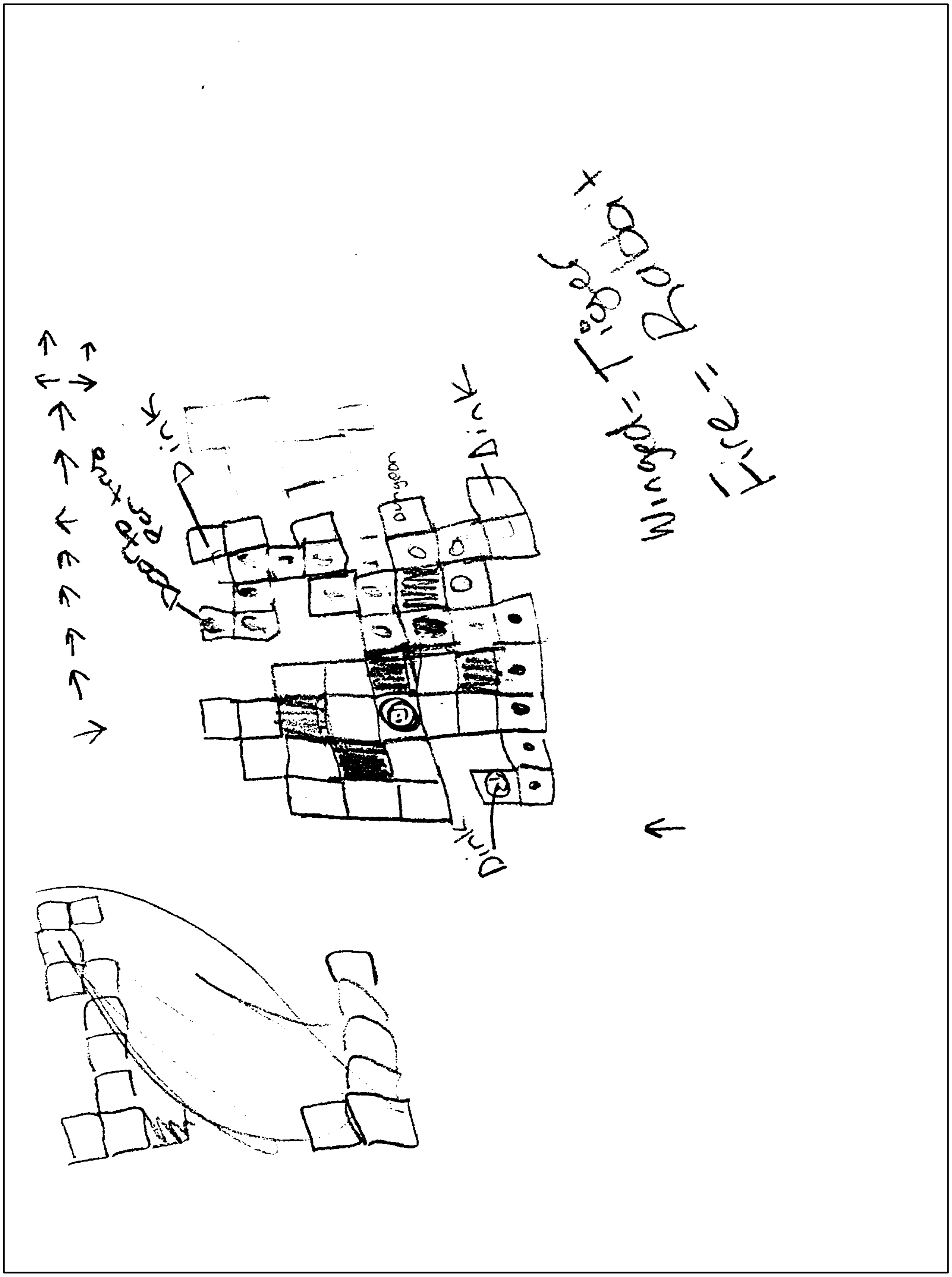


**Figure 36: U3's Offline Notes**

with the research. More than five weeks passed between her first and second session, during which she apparently forgot much of the training. The four system crashes unfortunately resulted in loss of several ESQs from A4’s data set.

**Questionnaires**

A4’s questionnaire output is shown on the SEM in Figure 37. Table 6, Questionnaire Data Summary, and the SEM provide the most succinct picture of A4’s overall self reports. The mean ESQ and RQ points shown on the SEM are plotted from the data in Table 6. The points show the subject’s overall experience (OE) as recorded for each questionnaire, calculated by averaging the converted values on the questionnaire worksheets (Appendix E). The points are numbered to show the sequence of questionnaires and to show how the subject’s responses varied over time. The numbers refer to the order in which the questionnaires were completed, irrespective of questionnaire type. Because this subject experienced three system crashes at intervals of 30-55 minutes during her second, 5.5 hour-long session, very little questionnaire data was obtained for this subject. The frequency of these unexpected system crashes prevented the appearance of the expected number of timed ESQs because the ESQ timers automatically reset to zero each time the system starts up. Both the final ESQ and the final RQ appeared just after the subject had won the game. Although recorded virtually at the same time, the data from the two final instruments are based on different questions and characterize different time periods (current versus recalled). This may be assumed to explain the fairly large difference in the individual instrument means, because the averages for both instruments overall are similar ($M$ = 2.33 versus $M$ = 2.50).

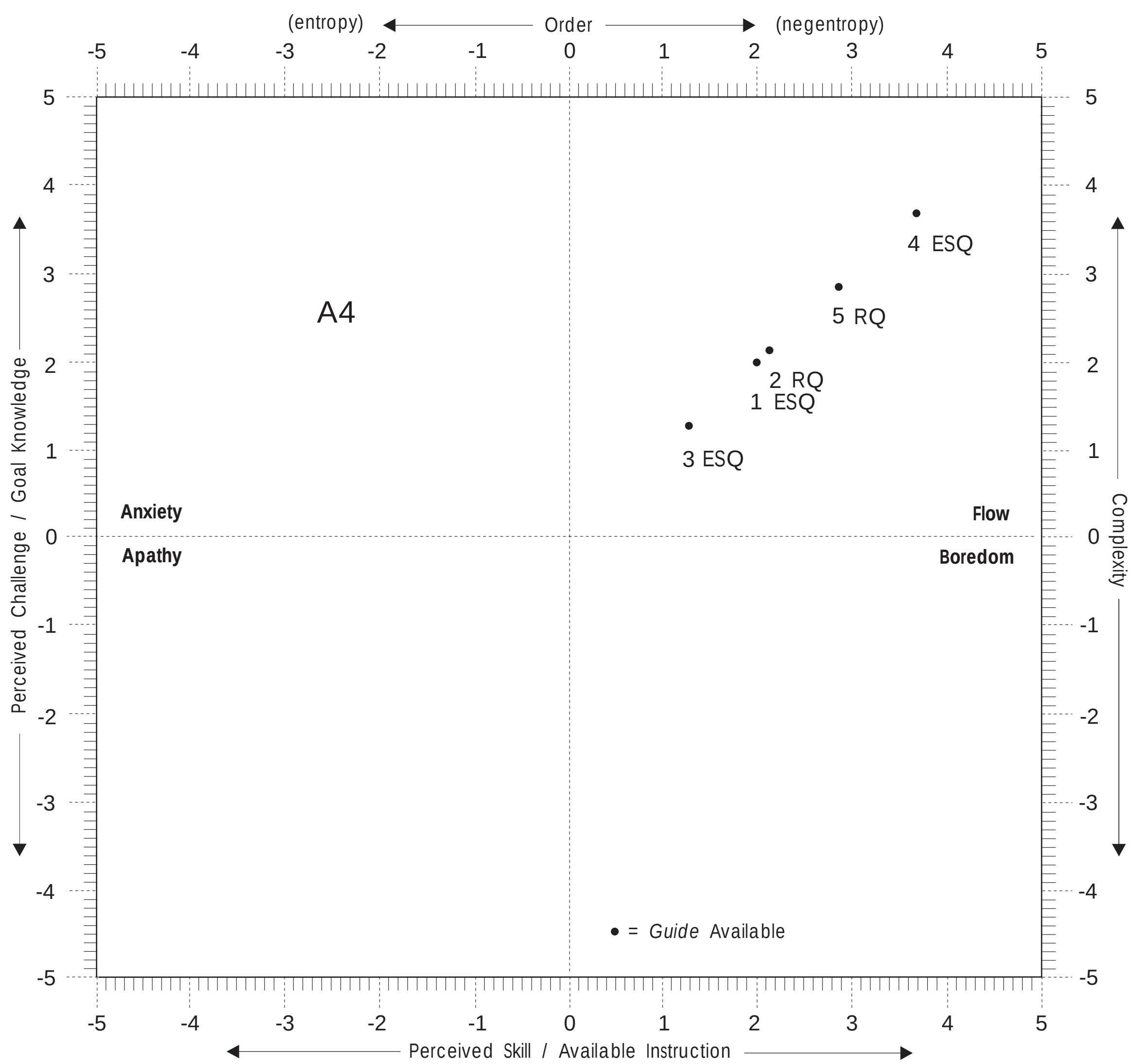


**Figure 37: Overall Experience for A4.**

A4 responded to 80 items on five questionnaires (three ESQs and two RQs) during the seven hours and six minutes that she worked on the game. A4 was not subjected to the *Guide* unavailable condition, so, along with U3 and U4, she belongs to the second treatment group for which the knowledge base was available throughout the data collection process. Although none of this subject's questionnaire scores were consistently high, and, especially at the beginning of the second session, were more similar to the non-finishers than the other finishers, they increased dramatically between the second and third ESQs ($M$ = 1.29 versus $M$ = 3.71).

Interestingly, on the ESQ Parts 1 and the RQs, this subject consistently rated anxiety in the mid- to high range (6-7), yet on the ESQ Part 2 (semantic differential scale), when anxiety is opposed by confidence, she consistently rated herself as "quite confident." The presence of anxiety would account for her low overall ratings on the ESQ and RQ elements (except for the last ESQ).

Other measures on the first two ESQs were somewhat lower than might be expected for an experienced adventure game player (skill / information access = 4, 5; control = 4, 5; goal knowledge = 3, 7; skill = 8, 5), but considering A4's reluctance to adopt the regular use of the knowledge base as a deliberate strategy, it is understandable that she might have been as dissatisfied with her progress and lack feelings of control over the environment (both of which influence enjoyment) as subjects for whom the knowledge base was unavailable.

**Guided Discovery**

Considering her experience with similar games, A4's use of both the game and the *Guide* was interesting. Because A4 had learned to reject outside help, or at least to regard it with suspicion, and because she did not experience a *Guide*-unavailable condition to raise the level of frustration to the threshold that motivates its use, the necessity of the inquiry system in the successful execution of the learning task was not apparent to her at first, and full acceptance of the regular use of the knowledge base took several hours. Gradually A4 began to realize that the *Guide* (a) did not offer solutions as do standard hint-guide or clue-book "cheats," but only minimal rule and fact statements that contain clues; and (b) that use of the *Guide* was critical to her success. Then and only then did she correctly apply the guided exploration learning model and begin to move smoothly through the puzzles.

The protocols from A4's first use of the *Guide* after a *self-imposed Guide*-unavailable period of one hour and seventeen minutes, illustrate two key points: (1) they reflect A4's game culture-based bias against the "guided" portion of the learning model (hence her initial reluctance to follow it), and (2) they show how the minimalist knowledge base does not provide solutions, but only supports discovery.

TA Sample 1 Lapsed Time to Start of Sample: 1:17:21

At this point in time, I'm going to go ahead and consult the *Guide,* because I have exhausted all my . . . big "Bear." Okay. "Guide." "Woods and town" . . . "Dog," "Fish," "Gnomes," "Leg of Lamb," "Rat," "Rattlesnake,"

> "Silver Coin," "Stick," "Tailor," "Tambourine," "Toymaker," "Weeping Willow"! You know, I haven't done any of this! [sigh] Well, I could check . . . I want to click on something that I've already seen. All right. Because I don't want to see any more . . . ah . . . clues than I have to. So I'm trying to click on things that . . . ah . . . I already . . . that I know about []. What's this "Dog"? "Dogs love to chase sticks and old shoes." Okay, so there's going to be, like, a dog at the beginning of the . . . that's great. How the hell am I going to come up with a shoe? I need a clue. I need a clue somewhere. Okay, I'm going to click on the "Gnomes." Its a total cheat. Well, this is a . . . great! Well that tells me nothing! "Leg of Lamb." Why not. "A tasty leg of lamb is stored in a cupboard inside the Swarthy Hog Inn." Hmm! "Rat." Let's hit the rat. "Cat from catching the rat in front of the bakehouse. A stick might do the trick or an old shoe might do." Okay. I have learned nothing! There is a rattlesnake. "Stick." Fine! I'll click on the stick. At the base of the honey tree is a stick. Okay. We're going to start with that.

**RQ Summaries**

Question seven on the Retrospective Questionnaire asks subjects to answer out loud, "What do you think of this game?" The answers are of special interest because they are extemporaneous summaries of the subject's experience in her or his own words. The first and last subject summary statements are quoted here in full:

First Lapsed Time From Start of Game: 1:42:32

The interface is somewhat difficult. It's one of the first graphics interfaces games, so it doesn't give you, like, clues on where to click and that kind of thing. Other than that, though, its very very similar to the old *Zork* games. I like it overall. Its going to prove an interesting challenge. I hope to finish it.

Last Lapsed Time From Start of Game: 7:03:24

This game was actually a lot of fun. And it represents a good hybrid between the visual games and the text-based games.

These remarks reflect the subject's sophistication and professional orientation vis-a-vis adventure games. It should be noted that her superior computer experience, adventure game experience, and adventure game knowledge did not give A4 an advantage in solving the puzzles in this game. Her mistakes were just as devastating as any experienced by the other participants, and they were usually of an interface independent, cognitive nature. Therefore, despite her game culture bias against it (as a "cheat") the *Guide* was just as critical for her as for anyone else.

**Offline Notes**

A4 did not make use of offline notations.

### Learning Rate

A4 solved the game in 7 hours, 6 minutes, the shortest completion time. Her LR was 14.08% per hour. A4’s case, however, points to a limitation in the use of the learning rate as a comparison of performance between subjects. Because of the technical complexity of keeping accurate records on breaks, as well as the variability of other equally important intervening variables, meal breaks were treated as part of the total effort required and not subtracted from the calculations of task completion times. Because A4 took no time out for meals, it is likely that her time actually working on the task was greater than U2’s. It is also a virtual certainty that had U2 had access to the *Guide* from the beginning of the activity, his completion time would have been less than A4’s.

### Posttest

A4 scored 100% on both posttests. Her answers frequently were elaborated well beyond the minimum required to answer the item correctly. These elaborations included vivid or descriptive language and additional detail.

## U4

U4 was a 12 year-old male in 6th grade who had only a little computer experience, but had played video games and purchased his own home video game unit. Though he had no experience with computer-based adventure games, he volunteered on the recommendation of his older brother who had participated in a related pilot study in 1994. U4’s affect appeared less positive than his answers on the questionnaires indicate, although the latter are consistent. He had difficulty complying with the operating instructions, which caused loss of data from one RQ. The researcher mentioned in his notes on the second session that U4 said he wanted to work on the game, but "appeared very tired and impatient."

**Questionnaires**

U4’s questionnaire output is shown on the SEM in Figure 38. Table 6, Questionnaire Data Summary, and the SEM provide the most succinct picture of U4’s overall self reports. The mean ESQ and RQ points shown on the SEM are plotted from the data in Table 6. The points show the subject’s overall experience (OE) as recorded for each questionnaire, calculated by averaging the converted values on the questionnaire worksheets (Appendix E). The points are numbered to show the sequence of questionnaires and to show how the subject’s responses varied over time. The numbers refer to the order in which the questionnaires were completed, irrespective of questionnaire type.

U4 responded to 168 items on nine questionnaires (seven ESQs and two RQs), although only the responses to eight instruments (161 items) were recorded because the subject turned off the recording equipment before entering his responses on the first RQ. U4 was not subjected to the *Guide*-unavailable treatment, so, along with U3 and A4, he belongs to the second treatment group for which the knowledge base was available throughout the data collection process.

Highest ratings on the first ESQ Part I were involvement (8), goal knowledge (8), enjoyment (8), and desire to win (10). Control, skill, and skill/information access were mid-range (5). ESQs 2 through 7, however,

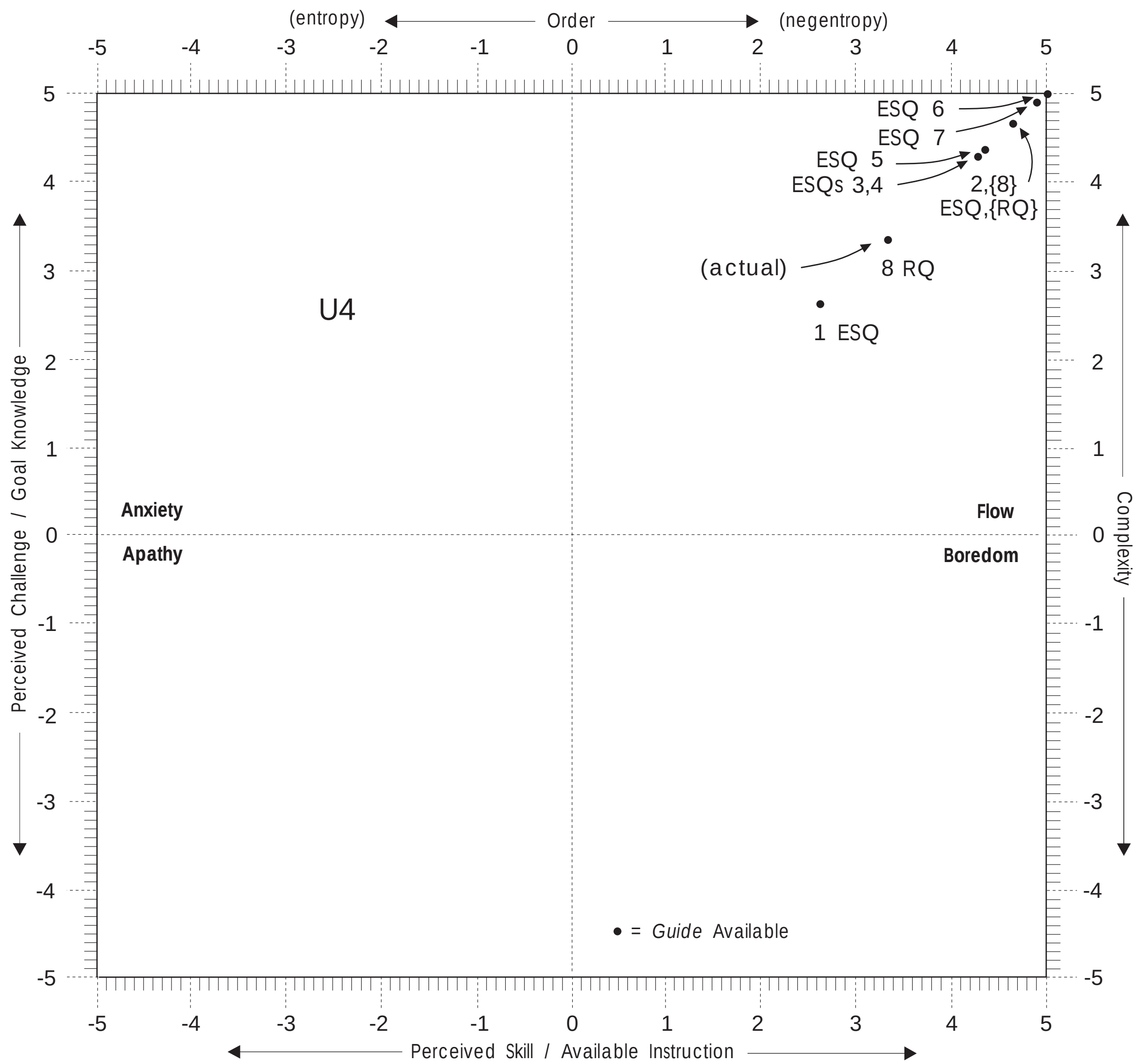


**Figure 38: Overall Experience for U4.**

showed increasing polarization on the expected measures of flow. Involvement, goal knowledge, control, and enjoyment were high (at or near the top), while anxiety, effort, self-awareness, boredom, and preference for alternative activity were low (at or near the bottom). U4 was the only subject to hit the flow ceiling, the maximum mean value that can be calculated with this method (5).

The final questionnaire in the data set for this subject contains one response that may be invalid, because it is inconsistent with the subject's other responses. Question 3 on the RQ asks, "How difficult is this game?" U4's answer was "2" (on a scale of 1-10). It is unlikely that this was what U4 intended. Therefore, Figure 38 shows two points for questionnaire number 8: the one that assumes the subject's rating was accurate and the one that assumes the subjects rating was reversed. The latter is higher (4.67) and enclosed in braces.

**Guided Discovery**

Perhaps because of his lack of prior experience with adventure games, U4 made no attempt to postpone consulting the *Guide.* His first use was just 8 minutes, 45 seconds into the activity. He continued to alternate between exploration and inquiry, consulting the *Guide* every three to four minutes for the first two hours. This is in distinct contrast to those who either were denied access to the *Guide*, denied themselves access to the *Guide,* or failed for some other reason to make use of it. U4's early mastery of the knowledge base was incremental, methodical, and systematic, but not comprehensive, as he did not notice the large red "Map" button on "The Desert" region page, or, like A1, the "Next" button at the bottom of certain fact and rule cards. As might be expected, U4’s progress reflected his use of the *Guide.* During periods of frequent use, he made steady progress, identifying tasks, and forming, testing, and enacting the necessary steps in the correct sequence.

In the first two hours, U4 consulted the *Guide* 20 times. Then he wandered off into the desert and forgot about it. Twenty minutes passed. After numerous "deaths" in the desert from lack of water, U4 reached an impasse. He looked in the *Guide,* but instead of clicking the Map button on the desert region page, the subject continued to re-read the concept cards that offered no new information.

At two hours and 32 minutes, the researcher intervened and "reminded" U4 of the existence of the map within the *Guide.* This intervention did not amount to giving extra help, because the Map button had already been shown through the *Guide* tutorial at the beginning of the session. After gaining new appreciation for the possibilities of the *Guide,* U4 then resumed the previous pattern of consulting the *Guide* every three or four minutes, at which time he began once again to make slow, steady learning gains, and was soon out of the desert with the brass bottle and gold coin "in hand." These *natural* variations in "treatment," with their concomitant variations in observable achievement, are powerful evidence for the need for balanced use of both the knowledge base, through search and browsing, and the game, through exploring and acting, to maintain flow and successfully and expeditiously master the learning task.

**RQ Summaries**

Question seven on the Retrospective Questionnaire asks subjects to answer out loud, "What do you think of this game?" The answers are of special interest because they are extemporaneous summaries of the subject’s experience in her or his own words. This subject's first RQ was not recorded because he turned the microphone and VCR off prematurely at the conclusion of his first session. His second RQ summary said little:

> Last Lapsed Time From Start of Game: 9:51:19
>
> I think this game is a really good game.

### Offline Notes

U4 made no offline notes.

### Learning Rate

U4 completed the learning task in 9 hours, 52 minutes. His LR was 10.14% per hour.

### Posttest

U4 scored 48 out of 50 correct on the first test and 48.5 out of 50 on the second. Like A1, he located the "small key" incorrectly in the wooden chest (question 17), but he was the only subject to miss question 12, which asks for a critical procedure and the names for two concepts (the resources located within the temple).

# Chapter 6:  Discussion and Conclusions

The purpose of this project was to take a first step toward a new way of studying learning with technology.  To do that it was necessary to use the technology itself to create and test a prototype apparatus and a sound research methodology to go with it.  Areas investigated were:  (a) motivation, operationalized using measures of flow; (b) use of the knowledge base and its and the game's reciprocal roles in the discovery process; and (c) content learning and retention.  The study's conclusions are based on the answers the data provided to the following questions:

- What are the factors that determine success or failure in complex problem-solving learning environments like adventure games?
- How effective is a guidance-enhanced computer-based adventure game as a learning environment?

The short answer to the first question is that, based on a study using an adventure game as the learning task, success with the learning task depends on the application of the correct heuristic to optimize performance — the guided exploration problem-solving discovery learning model — and that individual differences of unspecified source appear to affect the learner's ability and / or motivation to do so.

The short answer to the second question is the guidance-enhanced game is a very effective learning environment for some subjects, but not for others.  The lowest score on any posttest for subjects who completed the learning task was 97%. The learning was cumulative and durable, usually acquired over a period of several weeks.

The centerpiece of this research, however, is the formulation of a new general theoretical model of problem-solving discovery learning. This model is a conceptual framework for relating the learning process with the elements of design. The guided exploration model structures content and learning activities in ways that force learners to discover knowledge for themselves. The model is described in Chapter 3.

The main conclusions of this study are:

- Success or failure in solving the game (accomplishing the learning) depends on how effectively a learner makes use of the learning model.
- Individual differences probably account for much of the variation in subjects' success in applying the learning model to the learning task, but the sources of those differences are not known and were not studied.
- For some subjects, the adventure game learning environment may induce flow or flow-like motivational states.
- Sufficient motivation is a necessary condition for learning in challenging problem-solving discovery learning environments.
- Sufficient learning is a necessary condition for continued motivation in challenging problem-solving discovery learning environments.
- Availability of an inquiry system is a necessary but not sufficient condition for learning in challenging problem-solving discovery learning environments.
- Knowledge of the ultimate goal of the protagonist, or of the overall scenario, is not a significant factor in success.

Conclusions concerning the research methods are:

- The multimedia data obtained with these methods offer very powerful, persuasive evidence for the conclusions.
- Thinking out loud does not appear to interfere with learning, and may enhance it.
- For reasons not yet well understood, some subjects may not respond accurately or truthfully on questionnaires.

An observation on design of educational adventure games is:

- Although not studied, it is apparent that to support verbal learning and written testing, educational games should use graphics, text, sound effects, and music, and *not* substitute audio speech and narration for text.

Many of these points are elaborated in the sections that follow on learning outcomes, motivation and learning, individual differences, knowledge base availability, goal knowledge, thinking out loud, credibility of the questionnaire responses, and the methods and apparatus.

**Learning Outcomes**

A characteristic result of the discovery process is a superior kind of learning, as demonstrated by the posttest results. For the five successful subjects, the learning was cumulative. Several days or weeks separated sessions, but the learning, for the most part, held up during those intervals. Reasons for this should be investigated. Possibilities include (a) that the content itself, or the way it is presented, is compelling, therefore memorable; (b) the effort required is large, and one remembers what is most difficult to acquire, and (c) the process of discovery leads to inherently robust learning. Recall Gagné's remark that ". . . the individually constructed higher-order rule is . . . highly resistant to forgetting" (1985, p. 193).

The non-finishers in this study did not use the learning model effectively. As the results show, U1, A2, and A3 each handled the task differently, yet each failed to exploit some aspect of the learning model (either did not understand it or rejected it). There were differences and similarities in the three non-finishers. Two were very passive and the third very critical. The characteristics of passivity and rejection of a learning model and task that does not conform to prior expectations present motivational roadblocks to learning in any context, and they are easily seen using a neutral learning task like an adventure game.

The non-finishers attributed their lack of success, not to lack of effort, but to the difficulty of the task, their inadequacy to meet the challenge, or its unsuitability. Only A2 attributed his performance to his own limitations and preferences. A2 said he lacked computer experience and an interest in problem-solving, and preferred to have things spelled out in advance in a learning situation. His questionnaire responses corroborate the verbal self-assessment. U1 attributed her lack of progress to the difficulty of the game, while disclaiming the affect that showed her boredom, confusion, and indifference toward it. A3, on the other hand, expressed dissatisfaction with the game, the learning task, and the research interfaces and interventions.

However, in all cases the video and think-aloud data clearly show that the factor that determined success or failure with the learning task was the subject's understanding and consistent and effortful employment of the guided exploration learning model. Of course there was variation. All subjects, whether finishers or non-finishers, experienced periods during which their progress seemed stalled, and which could be attributed to some failure of skill in moving to an appropriate new stage of the guided exploration process. Strategies that did not work included: not exploring when one should, not inquiring when one should, excessive exploring when inquiring was needed, and excessive inquiring when exploring was needed. To succeed, it was necessary to use the knowledge base in concert with the game, and to engage in exploration, resource acquisition, inquiry, hypothesis formation, and hypothesis testing. Inquiry was usually precipitated by (a) an inability to identify a task through exploring the game alone, (b) repeated fatal errors, and (c) entry into a new area or situation. While the first and last of these require mindfulness, the second, tantamount to repeatedly running into an immovable object, is an effective reminder to all but the most unresponsive that they should open the *Guide.* Whatever the stimulus, the knowledge base was either searched or browsed, or both searched and browsed at the same time.

It is difficult to find a single explanation for the performances of the three non-finishers in this study, particularly because their approaches were so different; but one possibility, suggested by the data, is "cognitive" or "negentropic inflexibility": a lack of openness to the task and an inability to adapt to the requirements of the learning model or task through play or the acquisition of information. As Fagen writes (1981, pp 25-26):

> In play research, perhaps the single most pervasive and widely held belief about effects is that play makes the player behaviorally flexible: versatile, resourceful, creative, and able to cope productively with the novel and the unexpected. Play is said to develop generic learning skills that enable the player to adapt to new environments and to new situations . . . . Versatility is said to result from self-control, inhibition of arousal, and the ability to alternate responses rather than persevering with an unsuccessful tactic.

Given that subjects who did not perform well also did not enjoy the experience enough to continue with it, it is difficult to believe much real play was taking place. Sayre offers another interesting possibility (1976, p 122-124):

> The natural course of evolution . . . gives preference to organisms capable of acquiring energy (for metabolism), structure (for growth) and information (for guidance) under a wide variety of environmental conditions. Since energy, structure, and information are forms of negentropy, this capacity has been entitled 'negentropic flexibility' . . . .
>
> This ability to adapt behavior to contingencies of the organisms' local surroundings is known in psychological literature by various titles, 'learning' and 'conditioning' being perhaps the most common.

The cybernetic explanation is helpful because it stresses the need for energy, structure, and information seeking, qualities generally lacking in the affect and behavior of the non-finishers, who seemed tired or bored, and either unsystematic in their approach to exploring, or did not seek information when it was needed.

Evidence that the five successful subjects were more flexible and adaptable than the non-finishers comes from their questionnaires and think-aloud protocols, which acknowledged the game's difficulties and the frustration it induces, while at the same time expressing moderate to high satisfaction and enjoyment overall. This juxtaposition of high challenge and high satisfaction is an important indicator of optimal experience, or flow.

**Motivation and Learning**

The eight case studies described here were undertaken in part to investigate theoretical issues in motivation and learning and their possible relevance to elements of software design that may affect motivation and learning, and to lay the groundwork for a program of research to investigate these and other issues not accessible to study through conventional methods.

Data collected continuously during the learning activity showed that motivation and learning are interdependent and that both are necessary. In addition, the data support the conclusion that, to one degree or another, the successful subjects' overall experience can be characterized as autotelic and that the unsuccessful subjects' overall experience should not be so characterized. This conclusion is based on self-reports and observations of video and think-aloud protocols on subjects' sense of control, awareness of self, ease of concentrating, amount of enjoyment, task preference, and feelings of boredom, anxiety, and apathy. However, it is important to understand that this result does not justify the claim that computer games induce flow. What it means is that in this small study results show that for those who performed well the experience was autotelic.

As Table 4 shows, however, results of the measure of subjects' sense of time are inconclusive as evidence of flow. This is probably an unavoidable consequence of the requirements and circumstances of the research. All subject contacts were scheduled in advance and occurred within prearranged blocks of time that subjects set for themselves. As a rule, subjects committed a block of time between two other committed blocks of time, with the intention of filling the entire block of time to which they had committed. This makes it unlikely that the answer to the question, "How much time do you plan to spend on this session?" when compared against actual time on task, would produce evidence of loss of sense of time. This variable is most likely to be operable when subjects embark on an unscheduled session with the software, much as they might turn on the television and become engrossed in watching a program they had not been aware of in advance.

An important condition for the maintenance of high motivation during the learning activity is some degree of regular, if incremental, success. A reasonable maximum time a frustrated learner should be expected to persist without detrimental effects on motivation and learning is probably about 20 minutes. An even more optimal balance between frustration and satisfaction (i.e., less frustration) is desirable. At least a modicum of positive feedback is needed to sustain interest. Continuous negative feedback, on the other hand, attenuates motivation very quickly, as can be seen in the sample from U3's transcript in Chapter 4. Most subjects could tolerate only a few repetitions of "death" in any given situation. The consequences of and contrasts between repeated negative feedback and incremental success, variables mostly controlled by the subjects' use of the learning model, were dramatic, and evident in the video and think-aloud data of all subjects. Those who experienced little success, quit; those who experienced alternating periods of entropy and negentropy, persisted; and those who experienced continuous success, performed optimally.

A question not investigated is what differences might be found with both successful and unsuccessful subjects if an extrinsic reward had been attached to the learning task, such as payment, or if the learning task had been assigned as part of a requirement for course credit. In such cases, the intrinsically motivating elements of the experience would interact with the extrinsically motivating elements. A number of studies have found that extrinsic rewards negatively affect intrinsic motivation (e.g., Lepper & Greene, 1978), but these interactions are not well understood.

**Individual Differences**

It is clear that the software "toy" used in the study is not an effective instructional medium for everyone. Yet, for five of the eight, it was very effective. In this study the two most important predictors of success were the availability of a knowledge base and individual differences of unknown nature and source. Of the two, individual differences made the most difference. Some individuals may require additional help or specialized guidance on how to apply the model. Research is needed to determine what differences predispositions or other variables make, and whether, and how, the design of software learning environments might be changed to assist individuals for whom the present designs are not effective. Whatever the sources or causes of these differences, the approaches of the non-finishers when compared with the finishers were similar in their inability to apply the guided exploration learning model successfully to the task.

Although the study did show that games can sometimes motivate some people to explore and solicit instruction by interacting with software, it also showed that, just as students in conventional classrooms may reject aspects of the learning tasks or environment or fail to respond with enthusiasm, no instructional method, tool, or activity may be universally effective, even if the environment, method, tool, or activity is supposed to be intrinsically motivating. However these differences may be mediated somewhat by instructional interventions that target such differences using teachers or other means. Use of alternative strategies, interventions, and / or knowledge base designs, including more complex and "intelligent" interactions between learner and knowledge base, might increase the effectiveness of the technology in motivating the less successful performers.

**Knowledge Base Availability and Use**

Both unsuccessful and successful players reported extreme frustration in the absence of access to a source of information like a knowledge base to help them maintain progress, but only successful subjects showed a significant or lasting increase in their flow scores when the initially unavailable knowledge base became available.

With the exception of A2, whose overall experience moved away from flow toward greater apathy after it became available, the introduction of the *Guide* had a pronounced positive effect on subjects' ESQ and RQ scores, as well as their affect as evident from the video and audio data. In most cases the SEM plots clearly show differences in the questionnaire data before and after the introduction of the *Guide.*

A reason for A2's ambivalence is suggested by the verbal remarks of two other subjects. A3 commented that she felt "disappointed" by the introduction of the *Guide,* which she supposed to have revealed the "nature of the entire puzzle" and she felt that made the game "less interesting and certainly less mysterious." However, while engaged in a detailed analysis of the *Guide,* she reported an experience of flow. A4, because of her prior experience with adventure games, similarly at first believed the introduction of the *Guide* to have significantly reduced the challenge, and therefore her interest in pursuing the game. In the case of A2, it is likely that the *Guide* showed the level of effort and commitment required to succeed, and that was sufficient to extinguish what little initial interest he had in the project.

There is some basis for questioning the motivational benefits of providing instruction in an environment in which uncertainty is the principal motivator. Does instruction actually enhance motivation by reducing challenge, or does it decrease motivation despite the reduction in challenge? Steinberg's (1989) results show that the mere presence of the problem-solving help or "tool":

> . . . is not beneficial if a learner does not understand how it can help. On the other hand . . . the motivation to develop strategies may be severely impaired if the [help] provides enough information to solve the problems (Steinberg, 1989, p. 119).

Two studies by Sansone, Sachau, and Weir (1989) suggest that in providing instruction (which they define as structure and direction), ". . . we may be harming the motivation to continue to learn and perform the activity." In performing a task whose outcome is uncertain, a student's motivation might decrease if the presence of the instruction is perceived as limiting his or her exercise of fantasy — or the exercise of imagination in arriving at solutions. Their results also indicate that motivation may vary with the student's perceived latitude in the instructions: the more prescriptive the guidance, the less intrinsically motivating the task or activity. The latter finding supports the minimalist principle of on-demand, random access, context independent (less prescriptive) access to the knowledge base (Carroll, 1982, 1990, 1998), as well as Gagné's (1964, 1966, 1985) version of discovery learning. Although two subjects worried that they would not be challenged after learning about the guide, this is not what the model predicts, and it is not what the results show. For the highest motivation, challenge must be matched by knowledge or skill. Adventure games are based on puzzles that are solved through both knowledge and skill. Challenge that is not matched by knowledge, however, discourages rather than motivates, so some means of access to knowledge must be provided for.

Most of the expected differences in a subject's affect and performance between the *Guide*-unavailable and *Guide*-available treatments were present in the results. However, after studying the first five subjects (2 females, 3 males) using this method, the within subject, two-treatment design was discontinued. It was felt that the *Guide*-unavailable condition was so frustrating for subjects that, despite the eventual availability of the *Guide*, only the most highly motivated would be likely to pursue the activity to completion. Of the eight subjects studied, five succeeded in completing the activity. The three non-finishers were among the first five tested, so it is possible that discontinuing the *Guide*-unavailable treatment prevented additional failures. In any case, the point had been established that a successful experience requires access to a knowledge base, so there appeared to be no advantage to continuing to withhold it. In effect, this created a second treatment group — the "*Guide*-always-available" group. All subjects in the *Guide*-always-available group (U3, A4, and U4) finished.

The guided exploration learning model requires learners to discover the solution procedure for each puzzle of an adventure game or other problem-solving task by finding and selecting information from a knowledge base, comparing it with the facts, concepts, and rules learned previously and through the exploration process, and then searching for, selecting, and assembling the components of hypothetical sets of procedures, trying procedures and interpreting feedback until the right steps are discovered, then assembling and sequencing the steps and applying the steps to the task. This process requires greater mental effort than simply looking up and following a fully compiled procedure like users of adventure game hint books may do. The carefully constructed minimal information data base or instructional support document used in the study differs from standard hint books that are known as "cheats" in the game culture. As A4's data show, when the puzzles are impossible to solve without instruction, the notion of cheating is not a deterrent to the unqualified use of an inquiry system.

**Goal Knowledge**

Data from the questionnaires clearly show the ineffectiveness of manipulating terminal goal knowledge as a variable in the study. Goal-aware subjects indicated on the questionnaires that they did not understand what King Graham was trying to accomplish just as often as goal-unaware subjects indicated they did. In fact, no evidence was found that knowledge of the terminal goal made any difference in how well subjects performed.

Three explanations come to mind. The first is that it was impossible to completely obscure the goal. Subjects in the goal-unaware group quickly learned about the goal through other clues in the game. The second explanation is that the question on the Part 1 ESQ is too general to ascertain *the extent to which* goal knowledge is or is not present. The third explanation is that while a goal orientation is a requirement of flow, specific, long-term goal awareness is not. It is sufficient to identify an intermediate goal or subtask upon which to focus one's efforts.

This finding does not invalidate goal knowledge as an element of flow, however, because most of the time all subjects knew in a general sense what the goal was, even though the specific steps to arrive there were not clear.

**Thinking Out Loud**

Most of the time, subjects had very little difficulty maintaining constant and consistent verbalization while on task, although the more verbal subjects provided clearer and more coherent protocols. Subjects sometimes forgot or became preoccupied at particularly tense moments — moments that require great concentration, or where speed, timing, or hand-eye accuracy are required. Presumably the reason for this is limited short-term processing overhead. Examples of such points where subjects tend to forget to think aloud are the battle with the wizard at the end, which involves four transmutations or shape "morphs" that must be performed from visual clues in just the right sequence, and when enacting a long procedure for the first time, like capturing an elf. At such times the researcher can "wake them up" with stern reminders to continue talking.

Thinking out loud did not appear to interfere with the learning task. Most research supports that observation. Some studies have shown no difference or even slight improvement in both problem-solving performance and retention of problem solution procedures when the performance is accompanied by thinking out loud (Gagné & Smith, 1962; Ericsson & Simon, 1983). Furthermore, with one exception (U4), subjects with the highest flow scores also did the best job with thinking out loud. In addition to providing valuable data in a study using multiple data sources, the practice appears to help subjects think things through and maintain focus on the task.

**Credibility of Questionnaire Responses**

As mentioned in Chapter 4 (Convergence and Redundancy), an important reason for collecting and analyzing multiple data types is to increase confidence in one's conclusions. In two of the cases, U1 and A3, the results from the questionnaires and the audio/video recordings, are inconsistent — meaning that convergence did not take place, and, consequently, that precise conclusions about motivation are not possible for those subjects. These findings raise the broader question of the believability of self-reports of mental processes in general. While Kubey and Csikszentmihalyi are confident of the methodological soundness of the Experience Sampling Method (1990, pp. 54-55), their research asks about the experiences of populations rather than individuals. For that reason they can afford to be less concerned with the accuracy of individual self-reports. Because they do not collect collateral data, however, they are not likely to notice such variance, should it occur. Experience sampling (flow) research does not normally involve think-aloud and video data for triangulation. Adding the latter shows that there are limits to the ESM, as some subjects' responses on the questionnaires are corroborated by the video/think-aloud data and some are not.

On at least three occasions A3 mentioned either that she had accidentally moved the ESQ pointer in the wrong direction, or that the scales were "backwards" or "reversed," indicating that she may have had difficulty responding accurately to a number of the onscreen Likert-type items. Such errors could account for the discrepancy between her questionnaire and other data. There is no way to determine how many of her responses may have been different from what was intended, because, contrary to A3's perceptions, no scale was reversed. In addition to the possibility that she simply may not have understood her true feelings or state of mind, there is the surprising matter of her greater enjoyment in browsing the *Guide* than in playing the game. On the ESQ that appeared in the midst of her extended investigation of the *Guide,* there was *not* a divergence in the data; her remarks as she positioned the pointer on the scale indicated that her responses to the questionnaire were congruent with the conclusion that she was in an autotelic state.

A different factor may have been at work in the case of U1, whose data are also suspect. U1 did not appear to be in flow, nor did her accomplishments or her early withdrawal from the task indicate that she was. Yet, both in her answers on the questionnaires and in her statements she consistently claimed high interest in completing the task and rated other measures in a way that when averaged, indicate flow.

For self-reports to be taken seriously, at least three assumptions must be true: (1) that the subject understands the question to which he or she is responding, (2) that the subject knows the answer (i.e., has access to the mental process or feeling), and (3) that the subject will respond truthfully to the question. When one observes a subject struggling against boredom to remain on task while claiming to be highly involved and having fun, either one's observations or the subject's claims must be wrong. Motivations are complex, but the answer may be as simple as that the subject is unable or unwilling to take the position that he or she does not enjoy an activity which he or she believes the researcher expects him or her to enjoy. Such an explanation is plausible for U1, but does not work for a subject whose comments about the task are strongly negative, yet chooses answers on the questionnaires that show the opposite, as was the case with A3. In the latter case, one might suspect a fault with the instruments. On the other hand, if convergence is seen in six out of eight data sets, it may still be reasonable to trust the instruments in cases where convergence does exist.

At issue in the larger debate over self-reporting is whether "mentalistic predicates," "private facts," and the like are part of or separate from the state of mind they represent. Arguments can be found in the literature that support the use of "direct methods" (asking people about their motivations through instruments and interviews) in motivation research (Allport, 1953); of an "open souls doctrine" (taking what people say about themselves seriously) in social psychology theory (Harré & Secord, 1972) when the self-reports match the "context and manner of what is said;" and of "direct self-reports" (albeit with multiple additional data sources) in cognitive assessment (Mischel, 1981). Debate on the reliability of self-reporting usually begins with reference to Nisbett and Wilson (1977), taking a position vis-a-vis what has become the seminal argument against relying on such reports. The Nisbett and Wilson article argues that people simply do not know what they think and feel, but instead make judgments based on "implicit causal theories" or give answers that seem plausible in a given situation. So, for example, U1 may simply have responded in a way that conformed to her expectations under the circumstances, or that she thought the researcher wanted, regardless of her true feelings or state of mind. Ericsson and Simon (1983) dispute many of the conclusions of the Nisbett and Wilson article, but their counterarguments focus on cases where there is observer agreement with subjects' self-reports. Although evidence from the video/audio data appears more convincing than the subjects' self-reports, the results from A3 and U1 point to an "empirical puzzle" (Cook, 1985).

**Methods and Apparatus**

Despite the intrinsically motivating nature of the activity, recruitment of subjects proved difficult. Only volunteers who had had some prior experience with computer or video games in other contexts were able to solve the game, possibly because their reason for volunteering was a genuine interest in the task. Many who did not volunteer expressed concern about the time that participating in the study would take away from their busy lives. Yet, the successful volunteers were motivated enough to remain on task for sessions lasting up to six hours without complaint. For the latter, time was rarely an issue. This in itself suggests a predispositional effect.

The setting, though a compromise, as explained in Chapter 4, appeared to support subject autonomy while affording the necessary degree of structure in the data collecting sessions. Overall, the subjects responded positively to the opportunity to "take possession" of the situation and the task. This writer would prefer to find a way to collect the data remotely and under more spontaneous conditions such as those that might arise in the privacy of a subject's home.

Although it was not known in advance how the online knowledge base would affect motivation or learning, the fact that the knowledge base was online instead of offline did not appear to affect either. A better system for switching between the two interfaces would be one that uses the mouse instead of a two-key combination, the only option available with the present system. The results show that the straightforward, hierarchical design of the *Guide* was very effective in performing its essential functions for the finishers and was not a factor in the performances of the non-finishers. The brevity of the verbal information doubtless contributed to its effectiveness in the online format. Subjects accepted the online format so easily that only A4 (the computer professional) realized that the *Guide* was a research manipulation and not part of the game.

The system began to experience software failures (crashes) of unknown origin with increasing frequency near the end of the data collection phase of the study. During a "save game" action, the screen goes black and the computer restarts. This interrupts and resets the data collecting timers. Only two ESQs could be obtained from A4 during her seven hours of game play because ESQ timers were so frequently reset by system crashes. Nevertheless line number, time, and sequence data were maintained by the system, and redundant think-aloud and visual data compensated for most of the losses of questionnaire output.

Finally, a note on game design. The trend in recent years has been away from reading from computer screens and toward listening from computer speakers. It is now common for actors to perform the roles of the characters in adventure games just as they do in motion pictures. The onscreen actors are no longer cartoon-like, but human beings who appear in full-motion video sequences. The convergence of digital and analog technologies has made all this possible. However, for educational purposes, this trend has not been helpful. Just as audio-visual technologies have not replaced written communication in other information-rich environments, so spoken dialog and narration should not replace reading and writing in educational software environments. At least two arguments support this recommendation.

1. Audio-only learning does not support written testing. Subjects in this study were asked to write down the names of key concepts and characters from the story. If their only exposure to the verbal information they needed to know had been through the sense of hearing, it is unlikely they would have been able to write out answers to the questions. In this sense, text may provide a superior form of learning support. The same principle applies to the verbal information available through a knowledge base. An audio-only knowledge base would not have supported conceptual learning, or efficient searching.
2. People read faster than they speak. An audio-only design greatly slows the process and intensifies frustration. Many potential volunteers and some of the subjects in the study had trouble managing to set aside the 8-10 hours needed to complete the activity for this study. An audio-only interface

would have increased both the time required and the levels of frustration beyond acceptable limits. The necessity to repeat portions of the game following "fatal errors," with no way to skip over spoken dialog and narration already listened to, would discourage even the most eager learner / players.

The research tools and methods designed and built for this project worked well enough to satisfy the requirements of the project, but they should be simplified and refined for use by nontechnical researchers, for deployment on more widespread platforms, and to apply similar methods to the study of other software learning environments.

# List of Initials

ESF - Experience Sampling Form

ESM - Experience Sampling Method

ESQ - Experience Sampling Questionnaire

LR - Learning Rate (percent learned per hour)

OE - Overall Experience (arithmetical mean)

PQ - Prospective Questionnaire

RQ - Retrospective Questionnaire

SEM - Subjective Experience Model

TA - Think-Aloud

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# Appendix A

Knowledge Base Script

## Knowledge Base Script

The Woods and Town of Serenia

| Concept | Filename | | Instruction |
|---|---|---|---|
| Bear | bear | Rule: | The bear prefers a smelly old fish to the sweet taste of honey. |
| Cobbler's Hammer | hammer1 | Rule: | A cobbler's hammer is an effective tool to break the padlock on a cellar door or remove a crystal from within a mountain cavern. |
| | hammer2 | Fact: | A retiring shoemaker would gladly trade his cobbler's hammer for a pair of fine shoes made by elves! |
| Dog | dog | Rule: | Dogs love to chase sticks and old shoes. |
| Fish | fish | Fact: | A barrel in town contains a smelly old fish. |
| Gnomes | gnomes1 | Fact: | The witch stole the grandfather gnome's spinning wheel and hid it in her house in the dark forest. |
| | gnomes2 | Fact: | The toymaker in town would love to trade something for a toy made by the gnomes of the forest. |
| Leg of Lamb | lamb | Fact: | A tasty leg of lamb is stored in a cupboard inside the Swarthy Hog Inn. |
| Rat | rat | Rule: | If he is quick Graham can stop the cat from catching the rat in front of the bakehouse. A stick might do the trick or an old shoe might do! |
| Silver Coin | silver | Fact: | After abandoning his broken wagon the man carelessly dropped a shiny silver coin in the street. |
| Snake | snake | Rule: | You can scare a snake or please a dink with a tambourine. |
| Stick | stick | Fact: | A stick lies at the base of the honey tree. |
| Tailor | tailor | Fact: | The tailor lost a golden needle in a haystack near the Swarthy Hog Inn. |

| | | | |
|---|---|---|---|
| Tambourine | tambo | Fact: | When the Gypsies abandoned their camp near the edge of the woods they left their tamborine behind. |
| Toymaker | gnomes1 | GoTo Gnomes-1 | |
| Weeping Willow | witch3 | GoTo Witch-3 | |

The Desert

| | | | |
|---|---|---|---|
| Bandits | bandits1 | Rule: | When bandits are heard approaching on horseback near the temple it is best to hide behind the rocks next to the oasis and watch what they do. |
| | bandits2 | Fact: | When the bandits are in camp the staff that Graham needs to open the temple door is kept in the smaller tent. It is guarded by a sleeping bandit. |
| Brass Bottle | bottle1 | Fact: | A gold coin and a brass bottle can be taken from the temple if one is quick enough to escape before the door slams shut. |
| | bottle2 | Rule: | Anyone who tries to open the brass bottle will become trapped inside it for the next 500 years! |
| Fresh Water | water | Rule: | To survive in the desert a traveler should drink from every source of fresh water that can be found. |
| Gold Coin | bottle1 | GoTo Brass Bottle-1 | |
| Skeleton | skeleton | Fact: | An old shoe--no longer needed by this poor fellow--could help Graham save someone's life. |
| Staff | bandits2 | GoTo Bandits-2 | |

The Dark Forest

| | | | |
|---|---|---|---|
| Brass Bottle | bottle2 | GoTo Desert-Brass Bottle-2 | |
| Elves | elves1 | Fact: | Elves peer from the thick foliage in the forest to the west of the witch's house. |
| | elves2 | Rule: | Only a captive elf can be persuaded to reveal the way out of the dark forest. |

| | | | |
|---|---|---|---|
| | elves3 | Rule: | When you squeeze a honeycomb the honey runs out and forms a sticky mass that is like glue. A tiny elf could be trapped if he could be tricked into into stepping in a puddle of honey on the ground. |
| | elves4 | Fact: | The leather pouch from the witch's house contains three brilliant emeralds that the elves would love to have. The emeralds can be removed from the pouch by using the hand inside the satchel. |
| Emeralds | elves4 | GoTo Elves-4 | |
| Honeycomb | elves3 | GoTo Elves-3 | |
| Leather Pouch | elves4 | GoTo Elves-4 | |
| Spinning Wheel | gnomes2 | GoTo Woods & Town-Gnomes-2 | |
| Witch | witch1 | Rule: | To stop the witch's evil magic Graham must wear the amulet he obtained from Madam Mushka. |
| | witch2 | Fact: | Hidden inside the witch's house are three items that Graham needs: (1) a leather pouch (2) a spinning wheel and (3) a small key. |
| | witch3 | Fact: | The witch stole the heart of the weeping willow and locked it away behind a tiny door in the forest. |

<u>The Great Mountains</u>

| | | | |
|---|---|---|---|
| Crystal | hammer1 | GoTo Woods & Town-Cobbler's Hammer-1 | |
| Custard Pie | pie1 | Rule: | A leg of lamb makes a better meal for man or bird than a custard pie. |
| | | pie2 | Rule: A pie in the face is the only defense against the mysterious yeti. |
| Eagle | eagle | Rule: | Sharing food with a hungry eagle could save your life. |
| Frozen Waterfall | frozen1 | Rule: | A rope thrown over a solid anchor can be used to climb the cliff beside the frozen waterfall. |

| | | | |
|---|---|---|---|
| | frozen2 | Rule: | A strong hand and good balance are needed to cross on the little rock knobs from the upper ledge to the fallen log on the other side of the frozen waterfall. |
| Ice Queen | icequeen | Rule: | The sweet sound of harp music can distract a group of hungry harpies or melt the frozen heart of a murderous ice queen. |
| Leg of Lamb | pie1 | GoTo Custard Pie-1 | |
| Locket | locket | Fact: | A gold locket is kept by a giant two-headed bird near the edge of its nest high in the great mountains. |
| Rope | frozen1 | GoTo Frozen Waterfall-1 | |
| Sled | sled | Rule: | From the top of an icy slope a wooden sled can be used to leap a wide crevasse. |
| Yeti | | pie2 | GoTo Custard Pie-2 |

<u>Beach, Ocean, and Harpy Island</u>

| | | | |
|---|---|---|---|
| Beach hut | hut | Fact: | The doorbell is near the left front corner of the beach hut. |
| Boat | boat | Rule: | Beeswax from a honeycomb is an effective sealant for a leaky boat. |
| Conch Shell | conch1 | Rule: | A conch shell makes an excellent hearing aid for a hermit. |
| | conch2 | Fact: | A gleaming conch shimmers in the sun on Harpy Island. |
| Fishhook | fishhook | Fact: | A solitary fishhook glimmers on Harpy Island. |
| Harpies | icequeen | GoTo Mountains-Ice Queen | |
| Iron Bar | ironbar | Fact: | An iron bar lies on the beach north of the waterfall. |

<u>Mordack's Island and Castle</u>

| | | | |
|---|---|---|---|
| Blue Beast | peas2 | GoTo Peas-2 | |
| Book | library2 | GoTo Library-2 | |

| | | |
|---|---|---|
| | library3 | GoTo Library-3 |
| Cat | cat1 | Rule: To move through the castle without being discovered Graham must "bag" Mordack's cat. |
| | cat2 | Rule: Mordack's cat must be bagged at the earliest opportunity...preferably while feeding. |
| | cat3 | Rule: An old fish from the beach on Mordack's island makes excellent bait for bagging a cat. |
| Cheese | cheese | Fact: The mouse's hole in the dungeon wall hides some cheese that Graham must retrieve with a hook he is carrying. |
| | machine2 | GoTo Mordack's Machine-2 |
| Cobra | cobra | Rule: A mongoose is quick enough to dodge the strikes of the cobra. |
| Crystal | crystal | Rule: A sparkling crystal can protect against lethal rays. |
| Dink | dink1 | Fact: The hairpin Graham needs to open the door to the castle is on top of Dink--the beast in the labyrinth. |
| | dink2 | Fact: Dink loves a tambourine. |
| Fiery Dragon | fiery | Rule: A rabbit is quick enough to avoid injury when facing the attacks of a fire-breathing dragon. |
| Fish | cat3 | GoTo Cat-3 |
| Hairpin | dink1 | GoTo Dink-1 |
| Lethal Rays | crystal | GoTo Crystal. |
| Library | library1 | Rule: After bagging the cat Graham must wait in the library until Mordack returns and goes to sleep in his bedroom. |
| | library2 | Rule: While waiting in the library Graham should study the magic spells in the book on the desk. |

| | | | |
|---|---|---|---|
| | library3 | Fact: | The magic spells in the book in the library can save Graham from Mordack's deadly tricks if Graham is careful to apply the spells correctly. |
| Locket | locket | GoTo Mountains-Locket | |
| | locket1 | Fact: | Princes Cassima wishes for the return of the gold locket she lost in the mountains. |
| Mordack's Machine | machine1 | Fact: | Mordack's power transfer machine can transfer energy from one object to another. |
| | machine2 | Rule: | Cheese is the key that starts Mordack's power transfer machine. |
| | machine3 | Rule: | Graham must use Mordack's machine to transfer the power from Mordack's wand to Crispin's wand. |
| | machine4 | Rule: | When the transfer of power is complete Graham must act quickly to remove Crispin's wand from the machine! |
| Peas | peas1 | Fact: | A bag of dried peas is stored in a cupboard in Mordack's pantry near the door to the labyrinth. |
| | peas2 | Rule: | The blue beast in the castle must catch Graham one time--after Graham has made friends with Princes Cassima. But on his second encounter with the blue beast Graham must be ready to defend himself with the bag of dried peas. |
| Rusted Grate | grate | Rule: | The rusty grate can be pried open with an iron bar. |
| Wand | wand1 | Rule: | Graham should take Mordack's magic wand only after the wizard has gone to sleep. |
| | wand2 | Fact: | Mordack leaves his wand on the table beside the bed while he sleeps. |
| | wand3 | Rule: | Graham must use Crispin's magic wand to defend himself against each of Mordack's deadly transformations. |
| Winged Dragon | winged | Rule: | A tiger is mightier than the flying monster. |

# Appendix B

*Guide* Tutor Script

# *Guide* Tutor Script

"Spoken" by the AmigaDOS robotic "voice" (SAY program).

Thank you for restarting me.  Please listen carefully, now.

From now on, whenever you work on the game you can access information from a knowledge base that I call "the Guide."

The Guide contains some, but not all, of the information that you need to know to solve the game.

The first thing to remember about the Guide is how to access it.

From inside the game you can switch back and forth between the game and the Guide by pressing and holding the "left Amiga-A" command key, and while holding that key striking the "M" key.

The left Amiga command key is marked with a red tag, and the "M" key is marked with a blue tag.

Use those keys to switch from the game to the Guide; and use those same keys to switch back from the Guide to the game.

But you will need to press the "M" key twice when switching back to the game from the Guide.

The Guide contains information on all the concepts that you need to know to solve the game.

The concepts are shown as buttons on each of the six region pages.

This is a region page.

Use the left mouse button to click each concept button to learn the facts and the rules that explain the concept.

Some region pages, like this one, also have a button that connects with a map to help you find your way around in the game.

The Guide also has an index page that shows the concepts in the game all in one place.

The concepts are listed in the index in alphabetical order.

You can access the index page at any time from within the Guide by pressing the right mouse button and dragging down to highlight the index of concepts menu item in the upper left corner of any page in the Guide and then releasing the mouse button.

Please go to the index page yourself now.

Press the right mouse button.

Drag down to highlight the index of concepts menu item in the upper left corner of the page.

Release the right mouse button.

Good job.

You can get to this index page from anywhere in the Guide except the help page and the Guide cover page.

Highlighting the top bar menu icon with the right mouse button from either the index page or the help page returns you to the page from which you accessed the index or help page.

Please return to the Desert Region page now, to see how that works.

Good job.

You can review this information at any time that you are looking at the Guide by pressing the key labeled help on the keyboard.

The help key is marked with a green tag.

Try pressing the help key now to see how it works, then return to this page using the right mouse button, just as you did when you returned to this page from the index.

Good job.

Now, there is one very important thing to remember.

Let’s look at the cover page.

This is the Guide cover page.

From now on you will see this page each time you start the system.

It will remind you to look at the Guide often and to use it as a strategy for solving the game.

You can access any region page from here by clicking on its name with the left mouse button.

But the right mouse button has a completely different function here.

From this page, the right mouse button is used to quit the Guide.

And you must always quit the Guide from this page each time that you end a session and are shutting the system down.

To quit the Guide when shutting the system down first go to this page.

Press the right mouse button.

Drag down to highlight the "Quit Guide" menu item in the upper left corner of the page.

Release the right mouse button.

Click "yes."

Please try to quit the Guide by pressing the right mouse button now.

Very good.

Remember to do that when ever you are shutting the system down but not at any other time.

Don’t forget that you can review this information whenever you are looking at the Guide by pressing the help key.

# Appendix C

Experience Sampling Questionnaire

# ESQ (Part 1)

(system records mm/dd/yy and 00:00:00)

[apathy]

**I am involved with this game . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[anxiety]

**I get anxious when playing the game . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[challenge / goal knowledge]

**I clearly know what King Graham is trying to accomplish . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[skill/information access]

**I feel that I can handle the demands of this game . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[concentration]

**I have to make an effort to keep my mind on what is happening . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[self awareness]

**I feel self-conscious . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[boredom]

**I get bored while playing the game . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

## ESQ (Part 1) (continued)

[choice]

**I would like to play this game even if it were not part of a study . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[concentration]

**I get distracted while playing the game . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[enjoyment]

**I am enjoying this experience . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[skill / information access]

**I have the skill and/or knowledge that I need to beat this game . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[control]

**I am making good progress toward solving the game . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[apathy]

**I want to win this game . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

[choice]

**I would rather do something else . . .**

*not at all* 1 2 3 4 5 6 7 8 9 10 *very much*

## ESQ (Part 2)
## (mood scale)

(system records mm/dd/yy and 00:00:00)

**While playing the game, I am . . .**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **detached** | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | **involved** |
| **sad** | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | **happy** |
| **irritable** | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | **cheerful** |
| **bored** | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | **excited** |
| **confused** | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | **clear** |
| **relaxed** | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | **tense** |
| **anxious** | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | **confident** |
| **drowsy** | *very* | *quite* | *some* | *neither* | *some* | *quite* | *very* | **alert** |

# Appendix D

Prospective & Retrospective Questionnaires

## PROSPECTIVE QUESTIONNAIRE

(system records mm / dd / yy and 00:00:00)

[time sense]

**How much time do you plan to spend on this session?**

*Please answer out loud*

# RETROSPECTIVE QUESTIONNAIRE (RQ)

(system records mm/dd/yy and 00:00:00)

[self awareness]

**How comfortable were you while playing this game?**

| | | |
|---|---|---|
| *not at all comfortable* | 1 2 3 4 5 6 7 8 9 10 | *extremely comfortable* |

[enjoyment]

**How enjoyable is this game?**

| | | |
|---|---|---|
| *not at all enjoyable* | 1 2 3 4 5 6 7 8 9 10 | *extremely enjoyable* |

[challenge/goal knowledge]

**How difficult is this game?**

| | | |
|---|---|---|
| *not at all difficult* | 1 2 3 4 5 6 7 8 9 10 | *extremely difficult* |

[boredom]

**Were you bored while playing this game?**

| | | |
|---|---|---|
| *not at all bored* | 1 2 3 4 5 6 7 8 9 10 | *extremely bored* |

[anxiety]

**Were you anxious?**

| | | |
|---|---|---|
| *not at all anxious* | 1 2 3 4 5 6 7 8 9 10 | *extremely anxious* |

[control]

**Do you think you will solve the game?**

| | | |
|---|---|---|
| *not at all likely* | 1 2 3 4 5 6 7 8 9 10 | *extremely likely* |

[uncoded]

**What do you think of this game?**

*Please answer out loud*

# Appendix E

Questionnaire Worksheets

Code_________ Session#_________ ESQ#_________ Lapsed Time_____________________

**PART 1 ESQ SCORESHEET**

| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *not at all* | | | | | | | | *very much* | |
| 1 | I am involved with this game. **[apathy]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 2 | I get anxious when playing the game. **[anxiety]** | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 3 | I clearly know what King Graham is trying to accomplish. **[goal knowledge/challenge]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 4 | I feel that I can handle the demands of this game. **[skill]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 5 | I have to make an effort to keep my mind on what is happening. **[concentration]** | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 6 | I feel self-conscious. **[self awareness]** | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 7 | I get bored while playing the game. **[boredom]** | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 8 | I would like to play this game even if it were not part of a study. **[choice]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 9 | I get distracted while playing the game. **[concentration]** | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 10 | I am enjoying this experience. **[enjoyment]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | I have the skill and/or knowledge that I need to beat this game. **[skill/information access]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 12 | I am making good progress toward solving the game. **[control]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 13 | I want to win this game. **[apathy]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 14 | I would rather do something else. **[choice]** | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

**Description:**

Code:__________Session:__________ESQ#__________

## Part 1 ESQ Matrix

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **I am involved with this game. (apathy)** | | | | | | | | | | | 1 |
| **I get anxious when playing the game. (anxiety)** | | | | | | | | | | | 2 |
| **I clearly know what King Graham is trying to accomplish. (challenge/goal knowledge)** | | | | | | | | | | | 3 |
| **I feel that I can handle the demands of this game. (skill/info access)** | | | | | | | | | | | 4 |
| **I have to make an effort to keep my mind on what is happening. (concentration)** | | | | | | | | | | | 5 |
| **I feel self-conscious. (self awareness)** | | | | | | | | | | | 6 |
| **I get bored while playing the game. (boredom)** | | | | | | | | | | | 7 |
| **I would like to play this game even if it were not part of a study. (choice)** | | | | | | | | | | | 8 |
| **I get distracted while playing the game. (concentration)** | | | | | | | | | | | 9 |
| **I am enjoying this experience. (enjoyment)** | | | | | | | | | | | 10 |
| **I have the skill and/or knowledge that I need to beat this game. (skill/info access)** | | | | | | | | | | | 11 |
| **I am making good progress toward solving the game. (control)** | | | | | | | | | | | 12 |
| **I want to win this game. (apathy)** | | | | | | | | | | | 13 |
| **I would rather do something else. (choice)** | | | | | | | | | | | 14 |
| | -5 | -4 | -3 | -2 | -1 | 1 | 2 | 3 | 4 | 5 | |

Code__________ Session#__________ ESQ#__________

**PART 2 ESQ SCORESHEET**
**(mood scale)**

*While playing the game, I am:*

| | | *very* | *quite* | *somewhat* | *neither* | *somewhat* | *quite* | *very* | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 15 | detached | | | | | | | | involved |
| 16 | sad | | | | | | | | happy |
| 17 | irritable | | | | | | | | cheerful |
| 18 | bored | | | | | | | | excited |
| 19 | confused | | | | | | | | clear |
| 20 | relaxed | | | | | | | | tense |
| 21 | anxious | | | | | | | | confident |
| 22 | drowsy | | | | | | | | alert |

**Description:**

Code__________ Session#__________ RQ#__________ Lapsed Time______________________

**RETROSPECTIVE QUESTIONNAIRE SCORESHEET**

**1 2 3 4 5 6 7 8 9 10**

1 How comfortable were you while playing this game? **[self awareness]**
(not at all comfortable) (extremely comfortable)

1 2 3 4 5 6 7 8 9 10

2 How enjoyable is this game? **[enjoyment]**
(not at all enjoyable) (extremely enjoyable)

1 2 3 4 5 6 7 8 9 10

3 How difficult is this game? **[challenge]**
(not at all difficult) (extremely difficult)

1 2 3 4 5 6 7 8 9 10

4 Were you bored while playing this game? **[boredom]**
(not at all bored) (extremely bored)

10 9 8 7 6 5 4 3 2 1

5 Were you anxious? **[anxiety]**
(not at all anxious) (extremely anxious)

10 9 8 7 6 5 4 3 2 1

6 Do you think you will solve the game? **[control]**
(not likely) (extremely likely)

1 2 3 4 5 6 7 8 9 10

7 What do you think of this game? **[uncoded]**

**Description:**

Code:__________Session:__________RQ#__________

## Retrospective Questionnaire Matrix

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| How comfortable were you while playing this game? (self awareness) | | | | | | | | | | | 1 |
| How enjoyable is this game? (enjoyment) | | | | | | | | | | | 2 |
| How difficult is this game? (challenge/goal knowledge) | | | | | | | | | | | 3 |
| Were you bored while playing this game? (boredom) | | | | | | | | | | | 4 |
| Were you anxious? (anxiety) | | | | | | | | | | | 5 |
| Do you think you will solve the game? (control) | | | | | | | | | | | 6 |
| | -5 | -4 | -3 | -2 | -1 | 1 | 2 | 3 | 4 | 5 | |

# Appendix F

Reading Test / Posttest

## Reading Test

(Text from *King's Quest V,* copyright 1990 by Sierra On-Line, Inc.)

A worn dirt path wanders through a thick wood, alive with the sound of many creatures. Between the trees, to the east, Graham can see the outline of a great mountain range. A large venomous snake blocks Graham's passage toward the mountains. This snake has a menacing look which Graham should heed.

The quaint little town of Serenia nestles at the base of the great snowcapped mountain range. A wild river tumbles down from the mountains and flows swiftly below the small town. A tributary of the larger river powers an old water wheel. The town is busy with people going about their daily chores. Blocking an alleyway, a frustrated man fixes a broken wheel on his wagon. Quaint houses and cute shops line the town's main cobblestone street.

Nearly hidden at the end of the street is a small shoe shop. The old shoemaker, eyes squinted and fingers calloused from years of making shoes, drives tiny nails into a shoe sole with a small cobbler's hammer. Business doesn't seem to be so good for the shoemaker and his wife. There isn't one pair of shoes for sale, and the old couple look worn out.

With a fine view of the rushing river, the bake house sits out of town along an old, rutted road. Delicious, mouthwatering custard pies line the counter top. The cold river courses swiftly past the bake house.

Out in the woods near the town, an old grandfather gnome sits contentedly on a stump and smokes a large pipe. He watches his grandson at play. Sitting on a stool in front of his house, the young gnome happily plays with an exquisite marionette.

The wide dirt path ends at a crude warning sign placed before an ominous-looking forest. Beyond the sign, the path narrows to nothing more than a root-ensnarled trail. The trees seem to close in, entangling and confusing all who enter here. The scraggly bushes of the brushland taper off to dry, sandy desert as far as the eye can see to the west.

# Posttest

WOODS & TOWN OF SERENIA

**Graham saw a bear attacking a beehive in a tree.**

What did Graham do to rescue the bees?

(1)____________________________________________________

What did the bees let Graham have?

(2)____________________________________________________

**Graham saw a dog attacking a giant anthill.**

What did Graham do to rescue the ants?

(3)____________________________________________________

How did the ants help Graham in return?

(4)____________________________________________________

**After exiting the dark forest, Graham returned the stolen objects that he had recovered from the witch's house to their owners.**

What did he do with the heart of gold?

(5)____________________________________________________

What did he do with the spinning wheel?

(6)____________________________________________________

**Graham saw a cat chasing a rat in front of the bakehouse.**

What did Graham do to save the rat from the murderous cat?

(7)____________________________________________________

DIRECTIONS: WRITE YOUR ANSWERS ON THE NUMBERED LINES

**After returning the stolen articles to their owners, Graham collected additional items from town to help him on his journey.**

Graham traded the (8)________________________________________ that he got from the gnomes for a (9)________________________________________________ in the toy shop.

**Graham was attacked, tied up, and imprisoned by thugs in the country inn.**

How did Graham "unlock" the cellar door?

(10)______________________________________________________________________

Before leaving the country inn by the side door, Graham found a

(11)__________________________________________________ in the kitchen cupboard.

**A rattlesnake blocked the only path to the great mountains.**

What did Graham do about the rattlesnake?

(12)______________________________________________________________________

## THE DESERT

**Some bandits were camped out in the endless desert.**

Why did Graham need to visit their camp?

(13)______________________________________________________________________

Why did Graham need to get inside the temple in the desert?

(14)______________________________________________________________________

## THE DARK FOREST

**In the dark forest Graham encountered a nasty witch.**

What did Graham do to protect himself from the witch’s deadly magic?

(15)______________________________________________________________________

What did Graham do to get the nasty witch out of his way for good?

(16)________________________________________

**Inside the witch's house Graham found some stolen articles.**

Where in the witch's house did Graham find the little key?

(17)________________________________________

What did Graham do with the little key?

(18)________________________________________

What did Graham find in a little bag in a drawer inside the witch's house?

(19)________________________________________

**Along one section of the path in the dark forest Graham noticed some glowing eyes.**

Why did Graham want to catch one of the creatures with the glowing eyes?

(20)________________________________________

The first thing Graham did to trap the little elf was:

(21)________________________________________

THE GREAT MOUNTAINS

**Crossing the great mountains, Graham faced many challenges.**

To stay warm in the mountains, Graham wore the cloak he obtained from the tailor in exchange for a lost (22)______________________________.

How did Graham climb to the ledge above the frozen waterfall in the mountains?

(23)________________________________________

The sled Graham brought along helped him to

(24)_______________________________________.

DIRECTIONS: WRITE YOUR ANSWERS ON THE NUMBERED LINES

**Cedric and Graham were captured by Icebella and were about to be eaten by wolves!**

What was the first thing Graham did to soften the cold heart of the ice queen?

(25)________________________________________________

What did Icebella ask Graham to do for her to earn his freedom?

(26)________________________________________________

What did Graham find just before his rescue from a giant bird’s nest in the mountains?

(27)________________________________________________

BEACH, OCEAN, & HARPY ISLAND

**Graham and Cedric were "dropped" on the ocean beach near a waterfall.**

How did Graham repair the leaky boat he found on the beach?

(28)________________________________________________

How did Graham escape from the clutches of the nasty winged creatures on Harpy Island?

(29)________________________________________________

**Back on the main beach, Graham found a little house made from part of a shipwreck.**

Who lived in the little house? (30)________________________________

What did Graham do to summon the resident of the beach house?

(31)________________________________________________

What was needed for Graham to talk to him?

(32)________________________________________________

MORDACK'S ISLAND & CASTLE

**To sneak into the wizard's castle, Graham had to pass through the wizard's deadly security system, then open a rusty grate and climb down into the castle labyrinth.**

How did Graham disable the cobra-like statues guarding the front entrance to the castle?

(33)________________________________________

How did Graham raise the grate covering the hole above the labyrinth?

(34)________________________________________

What did Graham do when he found Dink in the labyrinth?

(35)________________________________________

In its excitement, Dink dropped a hairpin which Graham needed to

(36)________________________________________.

**Graham found his way through the labyrinth and up into the main floor of the castle.**

Who was the first person Graham met there?

(37)________________________________________

What special favor did Graham do for that person?

(38)________________________________________

How did Graham end up in the castle dungeon?

(39)________________________________________

What important item did Graham find in the dungeon?

(40)________________________________________

How did Graham retrieve it?

(41)________________________________________

After escaping from the dungeon, how did Graham prevent a second attack and avoid a another trip to the dungeon?

(42)________________________________________

DIRECTIONS: WRITE YOUR ANSWERS ON THE NUMBERED LINES

**As Graham wandered through the castle, he noticed a black cat watching him.**

What did Graham do about the cat?

(43)________________________________________________________________

**While exploring the upstairs of the castle, Graham wandered into Mordack's library. Through the doorway he could see into the wizard's bedroom.**

What important information did Graham find in the library?

(44)________________________________________________________________

What was the first thing that Graham did after Mordack went to sleep?

(45)________________________________________________________________

**Graham found the power transfer machine on the balcony in Mordack's laboratory.**

What did Graham do to start the power transfer machine?

(46)________________________________________________________________

When Mordack appeared in the laboratory and angrily turned himself into a winged monster, what did Graham turn himself into?

(47)________________________________________________________________

When Mordack turned himself into a flame-throwing dragon, what did Graham become?

(48)________________________________________________________________

When Mordack turned himself into a cobra, what did Graham become?

(49)________________________________________________________________

When Mordack surrounded Graham with a ring of fire, what did Graham do?

(50)________________________________________________________________