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# What Makes Things Fun to Learn?

# A Study of Intrinsically Motivating Computer Games

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## Abstract

This report is an examination of two questions:

(1) Why are computer games so captivating? and

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

First, three studies are described that focus on what makes computer games fun, not on what makes them educational. Then a rudimentary theory of intrinsically motivating instruction is developed, and a set of heuristics for designing instructional computer games is presented.

The first study is a survey of the computer game preferences of 65 elementary students. There are large individual differences in game preference, and the presence of a goal is found to be the most important feature in determining what games the students like to play.

The second and third studies involve testing multiple versions of specific games. The versions are isomorphic to each other except for certain key features such as fantasy, feedback, or scorekeeping. Differences in the appeal of the versions are then attributed to the features varied. The first game analyzed in this way is "Breakout", a computer game involving sensorimotor skill. The game is analyzed in terms of characteristics of the visual display, the motion of the simulated ball, and the score. The most important feature of the game is found to be the graphic display that simultaneously presents a score and multiple level goals. Versions with no obvious goal are significantly less appealing than the other versions.

The last study analyzes "Darts", a computer game designed to teach fraction concepts to elementary students. A significant individual difference is found, in this case based on sex. Boys like the fantasy of arrows popping balloons and dislike verbal constructive feedback, while girls appear to dislike the fantasy of arrows popping balloons and to like the music played in the game. Both fantasy and music appear to be more important in the appeal of the game than simple feedback.

The theory of intrinsically motivating instruction is organized in three categories: *challenge, fantasy,* and *curiosity.* Challenge is hypothesized to depend on goals with uncertain outcomes. Several ways of making outcomes uncertain are discussed, including *variable difficulty level, multiple level goals, hidden information,* and *randomness.* Fantasy is claimed to have both cognitive and emotional advantages in designing instructional environments. A distinction is made between *extrinsic fantasies* that depend only weakly on the skill used in a game and *intrinsic fantasies* that are intimately related to the use of the skill. Curiosity is separated into sensory and cognitive components and it is suggested that cognitive curiosity can be aroused by making learners believe their knowledge structures are *incomplete, inconsistent,* or *unparsimonious.* Relationships between this rudimentary theory and other theoretical frameworks such as mathematical game theory and information processing models of cognition are described.

## Preface

This report is a slightly revised version of the author's Ph.D. dissertation submitted to the Department of Psychology, Stanford University. The research was supported by the Xerox Corporation Palo Alto Research Center and by a National Science Foundation Graduate Fellowship.

For those readers who are primarily interested in experimental results, each of chapters 2, 3, and 4 is relatively self-contained. Chapter 4 describes the major study of the dissertation. For readers who are primarily concerned with a theoretical analysis of intrinsically motivated learning, Chapters 1 and 5 can be read independently of each other and of the rest of the report. Finally, the practical implications of the theory for designing instructional computer games are described in Chapter 6. This chapter can be read with only occasional references to Chapter 5.

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# Chapter I

> "No compulsory learning can remain in the soul. . . In teaching children, train them by a kind of game, and you will be able to see more clearly the natural bent of each." (Plato, *The Republic*, Book VII)

In this report, I will discuss the problem of motivation in a practically useful science of instructional design. I will argue that a crucial and insufficiently studied aspect of this problem is the design of intrinsically motivating instructional environments--in short, what makes things fun to learn?

As illustrated by the above quotation from Plato, this is not a new idea. But there will be two new aspects in my treatment of it. First, I will be primarily concerned with a new kind of instructional environment--one involving interactive computers. Second, as a source of insight into the problem, I will analyze a new kind of intrinsically motivating activity--computer games. In other words, I will try to answer two questions:

(1) Why are computer games so captivating? and

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

My answer to the first question is based on a series of empirical studies of what people like about computer games. The primary technique used in these studies is the construction of multiple game versions that are isomorphic to each other except for certain features such as fantasy, feedback, or score-keeping. Differences in the appeal of the versions are then attributed to the features varied. Since these studies are a first step in addressing the complex question of what makes things fun to learn, they focus only on what makes the games fun, not on what makes them educational. Using these empirical studies as a base, the second part of this report consists of a set of theoretical speculations and practical suggestions about how to design environments that are both interesting and educational.

Throughout the report, I have emphasized questions and principles that could be practically useful in what Simon (1969) has aptly called a "science of design". Simon and many others (e.g. Dewey, 1900; Glaser, 1976; Atkinson, 1976) have argued for the development of prescriptive sciences of design in psychology as in, for example, medicine and engineering. Not only can a design science provide for intellectually sound applications of fundamental principles, it can also lead to the development of new theory in response to issues that are highlighted by practical applications. In fact it is not at all unusual in the history of science for practice to precede theory.

One part of psychology in which there is an important need for the development of a strong linking science is in the area of instructional design. Recent progress in cognitive psychology and the availability of more powerful tools like computers and optimization theory have revived interest in this topic (see, for example, Klahr, 1976). Much of this recent work has consisted of hypothesizing about the changes in cognitive structures and processes that occur in the course of learning conventional academic skills like arithmetic and geometry (e.g., Resnick, 1976; Greeno, 1976). These hypotheses are usually couched in terms of flow charts, semantic networks, and other information processing concepts. The assumption behind much of this work is that more detailed and formal descriptions of what is to be learned will help in deciding how it should be taught. In a few cases (e.g., Resnick, 1976) alternative teaching strategies suggested by these representations are actually tested.

Similarly, the most impressive recent work in intelligent computer-assisted instruction has involved programming elaborate cognitive models of the learner so the program can make real-time instructional decisions based on inferred knowledge states of the learners (Brown & Burton, 1978; Burton & Brown, 1976, 1979; Atkinson, 1976; Stevens, Collins, & Goldin, 1979; Goldstein, 1979).

One potentially overpowering factor that has been largely neglected in most of this recent work is the role of motivation in learning. The role of motivation in learning figured prominently in the historical development of psychology (e.g., Thorndike, 1911; Hull, 1943; Skinner, 1953), and there is some reason to believe that given sufficient motivation and even moderately informative environments, most people could learn most of the things they are taught in school. There is also a persistent subjective feeling among many classroom observers that motivation has been the foremost problem in education in the last half century (Cremin, 1961).

There already exists an extensive psychological literature about the motivational effects of various kinds of reinforcement--material reinforcement, social reinforcement, and self-reinforcement--and of various kinds of modelling (e.g., Skinner, 1953; Bandura, 1969).

But externally administered reinforcement is not a motivational panacea for instructional designers. Another growing body of research has begun to explore the conditions under which external reinforcement destroys the intrinsic motivation a person has to engage in an activity and degrades the quality of certain kinds of task performance (Condry, 1977; Lepper & Greene, 1979). For example, Lepper, Greene, & Nisbett (1973) found that when nursery school children who liked to play with marking pens received a promised reward for doing so, they later played with the marking pens less than a control group that received no reward. Another reason for hesitation in the indiscriminate use of external reinforcement as a motivation comes from the work of cognitively oriented learning theorists (Piaget, 1951; Bruner, 1962) who argue the importance of intrinsically motivated play-like activities for many kinds of deep learning.

What all these converging lines of argument lead to is the importance to a science of instructional design of studying how to use and increase students' intrinsic motivation in learning. If students are intrinsically motivated to learn something, they are likely to spend more time and effort learning, feel better about what they learn, and be more likely to use it in the future. Some theorists would also argue that they may learn "better" in the sense that more fundamental cognitive structures are modified, including the development of such skills as "learning how to learn" (Shulman & Keislar, 1966).

## The distinction between intrinsic and extrinsic motivation

As is often the case with well-known dichotomies, the distinction between intrinsic and extrinsic motivation is much fuzzier than is commonly supposed. In general, an activity is said to be intrinsically motivated if there is no obvious external reward associated with the activity. Conversely, an activity is said to be extrinsically motivated if engaging in the activity leads to some external rewards like food, money, or social reinforcement. Generally, an external reward is dispensed by a human or mechanical agent in a way that is not "naturally" a part of the rewarded activity (cf. Condry, 1977). Several problems with this distinction are immediately apparent. First there may be external rewards contingent on an activity in a non-obvious way. For example, studies of experimental demand characteristics (Rosenthal, 1966) have dramatically demonstrated the subtle power of often unconscious social reinforcement. There may also be potential future rewards for an activity that are not obvious to an observer. For example, learning any skill may lead to external rewards in future situations where that skill is valuable.

Instead of defining intrinsic motivation in a negative way as the absence of rewards, we can also define it in a positive way as need for competence and self-determination (White, 1959; deCharms, 1968; Deci, 1975), as a search for an optimal amount of psychological incongruity (Hunt, 1965), or as the "experience of flow" (Csikszentmihalyi, 1975). These definitions, though they have richer implications for psychological theorizing, are more difficult to apply in experimental or observational settings. Increases in competence, for example, might be extrinsically as well as intrinsically motivated.

Still another way of defining intrinsic versus extrinsic motivation is to let the person make the distinction. The literature on locus of control (Rotter, 1966; deCharms, 1968) deals with whether people perceive that their actions and consequences are largely under their own control or are primarily determined by external forces.

In spite of these ambiguities the distinction between intrinsic and extrinsic motivation is conceptually appealing and heuristically useful. I will continue to make this distinction, and I will use the words "fun", "interesting", "captivating", and "intrinsically motivating", all more or less interchangeably, to describe activities in which people engage without any obvious external rewards.

## Characteristics of intrinsically motivating instructional environments

As instructional designers, our task is to create settings where students are motivated to learn as efficiently and enjoyably as possible. To the degree that this can be done by creating intrinsically motivating environments, it may have the kind of cognitive and attitudinal advantages mentioned above. The obvious question that arises is: What are the characteristics of intrinsically motivating environments? One likely source for hints about the answer to this question is in the study of children's play. In this section, I will review partial answers to the question from a variety of sources in psychology, education, and sociology, including several specific studies of children's play. I will organize the answers under the three major categories to be developed in Chapter 5: *challenge, fantasy,* and *curiosity.*

*Challenge*

A number of theorists have emphasized the importance of challenge in intrinsic motivation. White (1959) argues that motivational theories based only on the reduction of primary drives are inadequate to account for much of human and animal exploration, manipulation, and general activity. He postulates a new "effectance" motivation that leads an organism to develop competence and feelings of efficacy in dealing with its environment. This new motivation can be used to explain both exploratory striving toward new skills and also what Piaget (1951) calls "practice games", the repetitive, pleasureful exercise of recently acquired skills.

Neither White nor Piaget, however, has much to say about exactly what features of an environment or activity make it challenging. Csikszentmihalyi (1975, 1979) extends their analysis by describing what he feels are the most important structural features of intrinsically motivating activities. Based on interviews with rock climbers, chess players, and other people who seemed to be highly intrinsically motivated, Csikszentmihalyi describes intrinsically motivating activities as follows:

> "1. The activity should be structured so that the actor can increase or decrease the level of challenges he is facing, in order to match exactly his skills with the requirements for action.
>
> 2. It should be easy to isolate the activity, at least at the perceptual level, from other stimuli, external or internal, which might interfere with involvement in it.
>
> 3. There should be clear criteria for performance; one should be able to evaluate how well or how poorly one is doing at any time.
>
> 4. The activity should provide concrete feedback to the actor, so that he can tell how well he is meeting the criteria of performance.
>
> 5. The activity ought to have a broad range of challenges, and possibly several qualitatively different ranges of challenge, so that the actor may obtain increasingly complex information about different aspects of himself." (p. 14)

All of these features except number 2, involve ways of making an activity challenging. While Csikszentmihalyi's analysis is useful, it gives us little idea of why these features are important or how they relate to each other. In chapter 5, I will show how these ways of structuring a challenging activity all follow from the need for a challenging environment to have a goal with uncertain outcome.

Eifferman (1974) illustrates the importance of the notion of "challenge" by using it to explain the different patterns of popularity in children's playground games. According to her insightful analysis, a game is a steady game (i.e., played steadily thoughout the year, like tag) if each participant can adjust the level of challenge to his or her abilities while still leaving the outcome of each round of the game undetermined. (In tag this adjustment of challenge occurs by the "It's" choice of whom to chase and the other players' choice of distance to stay from the "It".) A game is a recurrent game (i.e., played in intermittent but intense "waves", like jumprope and marbles) if, after the hierarchy of players is established, the outcome of each round becomes predictable. A game is sporadic if there is little variation in the degree of challenge and little challenge to begin with. And finally, a one-shot game (like hoolahoop) has considerable initial challenge, but little hope of improvement beyond an early mastery level even after several years.

*Fantasy*

Another motivational aspect of environments has to do with the themes or fantasies which they embody or encourage. Disneyland is perhaps an archetypical example of an intrinsically motivating environment that derives much of its appeal from the fantasies it evokes. Many children's games also include essential fantasy elements (e.g., "cowboys and Indians", "playing house").

Piaget emphasizes the predominance of "assimilation" to existing structures in this child-determined play with minimal needs to "accomodate" to an external reality. Freud (1950) explains such symbolic games as an attempt by the ego to repeat actively traumatic events that had been experienced passively, thus attaining a belated emotional mastery over the event. In addition to this symbolic conflict resolution, Freud explains much of fantasy, especially dreams, as wish fulfillment--often the fulfillment of unconscious wishes. Singer (1966) suggests that one of the primary functions of fantasy in daydreaming is to maintain optimal levels of mental arousal.

*Curiosity*

One of the most important features of intrinsically motivating environments is the degree to which they can continue to arouse and then satisfy our curiosity. Berlyne (1960, 1965, 1968) has studied these processes extensively with humans and other animals and proposed the rudiments of a theory emphasizing concepts like *novelty, complexity, surprisingness,* and *incongruity.* He reports, for example, that rats are more likely, other things being equal, to enter a maze arm that differs from the one they entered on the preceding trial (Berlyne, 1960), that monkeys confined in a box will work for as long as 19 hours at repeatedly opening a door so they can see what is going on in the room outside (Butler & Harlow, 1954), and that people spend more time looking at the more complex or incongruous stimuli in a pair of similar pictures or patterns (Berlyne & Lawrence, 1964).

Ellis and Scholtz (1978) used similar concepts to explain their studies of toy preferences in children. While attributes like color made little difference in choice of play object, novelty was very important in determining which toys a child began playing with, and complexity--either of construction or of possible uses--was crucial in determining how long a child played with a given toy.

The kind of complexity or incongruity that is motivating is not simply a matter of increased information in the technical sense used in information theory. Rather it involves surprisingness with respect to the knowledge and expectations a learner has. Berlyne, as well as others (e.g., Hunt, 1965; Piaget, 1952) point out, however, that there are limits to the amount of complexity people find interesting. They postulate that there is some *optimal level of informational complexity* for a given person at a given time.

So far this is all very hard to argue with. But in his most recent major work on the topic, Berlyne (1965) goes further and claims that the principal factor producing curiosity is what he calls *conceptual conflict*. By this he means conflict between incompatible attitudes or ideas evoked by a stimulus situation. For example, imagine someone who believes that fish cannot survive outside of water and then hears about a fish (the mudskipper) that walks on dry land. Conceptual conflict, and thus curiosity, will be induced.

It is clear that conceptual conflict is an important factor in curiosity, but a theory based primarily on this factor seems to be unduly limited. In Chapter 5, I will suggest an alternative theory based on a cognitive motivation to bring the three qualities of *completeness, consistency,* and *parsimony* to all knowledge structures. In essence, Berlyne's "conceptual conflict" would be called a "lack of consistency" in the new theory. But the new theory hypothesizes two other kinds of curiosity-evoking situations and some of Berlyne's own examples seem to fit more naturally into these other categories.

*Structural features.* Moore and Anderson (1969) discuss several other kinds of informational complexity that are particularly relevant to structuring educational environments. In particular, they enunciate four principles of instructional design: the perspectives principle, the autotelic principle, the production principle, and the personalization principle. Their principles are deduced from a theoretical framework based primarily on the work of Mead (1932, 1934, 1936, 1938) and Simmel (1959).

The perspectives principle suggests that learning is more rapid and deeper if the learner can approach the subject matter from as many as possible of the following perspectives: agent, patient, reciprocator, and referee. For example, learning to read may be facilitated by concurrently learning to write messages, both to yourself and to others, and to read similar messages. Moore and Anderson accomplished this by having their four- to seven-year-old students publish their own newspaper. Learning arithmetic might be improved by letting students not only solve problems that were given to them, but also give problems to other students (or a computer) and check the solutions for accuracy.

The autotelic principle requires that, in general, the initial learning of complex skills be protected from serious consequênces so that it can be enjoyed for its own sake. Most obviously physical dangers should usually be removed from educational environments, but this principle also requires that prizes, honors, and other potential gains or losses should also be cut off from certain parts of the educational day. This principle is essentially just a requirement that learning be intrinsically motivated. Moore and Anderson do feel, however, that once the learning of a skill is well underway, it may be appropriate to test it in serious competition. (This view is consistent with Zajonc's (1965) principle that the presence of other people hinders the performance and learning of new skills but enhances the performance of well-learned skills.)

The productive principle suggests that learning is more efficient in environments that are structured in such a way that students can make deductive inferences or probable inferences about parts of the environment that they have not yet observed. For example, in a mathematical system, once a student learns the axioms and transformation rules, he or she can in principle deduce all sorts of theorems independently. Similarly the periodic table is a more "productive" way of arranging information about chemical elements than alphabetic order would be, and phonetic alphabets are more "productive" than ideographic writing systems like Chinese. This notion of productivity is closely related to the Gestalt concept of good form and to the idea of coherence referred to by Condry (1977): "In the development of mathematical knowledge, it is not enough to allow children the freedom to explore. . . in addition, one must have a 'mathematically coherent' world in which to conduct our explorations." (p. 478, attributed to Herb Ginsburg).

The personalization principle includes the ideas that an environment should be both responsive to the learner's activities and helpful in letting him take a reflexive view of himself. The requirements for a responsive environment are:

> "(a) It permits the learner to explore freely. . .
>
> (b) It informs the learner immediately about the consequences of his actions. . .
>
> (c) It is self-pacing. . .
>
> (d) It permits the learner to make full use of his capacity for discovering relations of various kinds. . .
>
> (e) It is so structured that the learner is likely to make a series of inter-connected discoveries about the physical, cultural, or social world." (p. 590).

As an example of a responsive environment, Moore and Anderson describe the "talking typewriter" (Moore & Kobler, 1963; Kobler & Moore, 1966), a typewriter that says the names of the letters as their keys are pressed.

The reflexive condition requires an environment structured so a learner can learn not only about the subject matter, but also about himself or herself as a learner. For example, the use of motion pictures of athletic contests to help players spot their weaknesses and strengths encourages a reflexive view of learning.

I have presented Moore and Anderson's views here at length because they are a good example of insightful principles directly relevant to instructional design. One weakness of their approach is that, because they have very little empirical support for their principles, there is no way to know which principles are most important and which ones have a negligible effect. For instance, they have completely neglected the role of fantasy which I will claim is an important element in intrinsically motivated learning. Nevertheless, these principles have a great deal of intuitive plausibility and they receive further credibility from their apparent usefulness in designing instructional devices like the talking typewriter.

*Other structural features*

In a brief but very useful article specifically devoted to computer games, Banet (1979) lists thirteen structural features that, based on his informal observations, make for successful computer games. These features include:

(1) "Skilled performance is made instrumental to attaining an objective posed by the rules of the game."

(2) "The game increases in its ability to challenge the player; it does not become boringly simple."

(3) "Audio or visual effects are used to reward success and present the game situation."

(4) "Competition is possible with an opponent, the computer, or oneself."

(5) "Random, chance elements may be part of the game."

(6) "The game incorporates fantasy elements (piloting a space ship, finding treasure, etc.)."

(7) "The game incorporates opportunities for cooperation or combines cooperation and competition through team efforts."

(8) "The computer can time the players' responses and calculate scores based in part on quickness of response."

In Chapter 6, I will discuss how most of these features of computer games are related to the general characteristics I have been discussing so far. For the present, they suggest a number of specific features to be aware of in analyzing what makes computer games enjoyable.

*Choice.* Another important issue in designing instructional environments is how much choice to give the learners. As Zimbardo (1969) and others have shown, giving people a choice, or even just the illusion of choice, often increases their motivation to do a task. Steinberg (1977), in a review of studies of learner control in computer-assisted instruction, found inconclusive but suggestive evidence that learner control did increase motivation but might also decrease learning efficiency.

One particularly important kind of choice is the learner's control over the difficulty level. Fisher, Blackwell, Garcia, and Greene (1975) found that their elementary school subjects divided into two groups: those who chose arithmetic problems a year or two above their measured grade level, and those who chose problems a year or two below their grade level. That is, neither group chose problems very close to their presumed optimal learning level.

In other words, while freedom of choice seems to be important in making environments appealing, it is not clear how to structure educational environments in which free choice leads to productive learning. Groen (1978) nicely summarizes Piaget's (1971) view on this point as follows: "Free activity is important, and so is the structure of the environment. . . . Ignoring the second can lead to aimless play. Ignoring the first can lead to a sophisticated curriculum that most students fail to assimilate or understand" (p. 290, 293).

## Summary

I have just described a number of features of intrinsically motivating environments--things like informational complexity, responsiveness, challenge, and fantasy. In a sense, this list suggests a set of competing theories for what makes learning fun. One purpose of the three studies I will describe next is to distinguish between these competing theories--to see which factors really are the most important in making computer games fun.

However, the different features do not have to be viewed as competing theories, each of which says, "X is the most important factor in creating intrinsically motivating environments." A more sophisticated view is a general additive model that says, "$X_1$, $X_2$, $X_3$, . . . all contribute to making an environment intrinsically motivating. The features may have different weights in different environments and for different people." This model is, of course, so general that it is non-falsifiable. It does, however, focus attention on what I think are more productive questions: What features are most important for different kinds of environments? What features are most important for different kinds of people? These questions are largely empirical questions, and the studies I will describe begin to collect the evidence that will be necessary to answer them.

It is certainly not the case that all intrinsically motivating environments are games or that all educational problems can be solved using games. But games often provide particularly striking examples of highly motivating activities. Furthermore, computer games are especially clear illustrations of how the unique capabilities of computers can be used to create motivating environments. For these reasons, I have chosen to study game-like activities on computers as a source of insight for designing intrinsically motivating instructional environments.

# Chapter II
## Study 1: Survey of computer game preferences

While games are perhaps as old as civilization, games played on computers are a new phenomenon in our culture. It is only in the last two or three years that computer games have become widely available outside the restricted world of scientific and business computing centers. There have been numerous scholarly studies of games in general (e.g., Avedon & Sutton-Smith, 1971), but there is almost no systematic knowledge about the new phenomenon of computer games. Which games are most popular? What makes a game popular? Are there big differences between people in the kinds of games they like? As a preliminary attempt to answer these questions, I interviewed 65 elementary school students about their computer game preferences and analyzed the results in various ways.

### Method

*Subjects*

The subjects for this study were all students in the computer classes at a private elementary school near Palo Alto, California. Sixty-five children ranging in grade from kindergarten through eighth grade were included. There were 42 boys and 23 girls.

All the children had been playing with computer games in a weekly class for at least two months and some for over two years. (See Tables 1 and 2 for the number of children at each grade level and at each level of computer experience.) In addition to the approximately 45 minutes per week in the computer classes, many of the students had also played computer games during free time at school or at home. There were classes in beginning computer programming as well as games, so a few of the students had some experience programming the computers they played with. At the time of the study (May 1979), the computer room included 4 Commodore Pet computers and 1 Apple II computer.

The children to be interviewed were selected randomly from those present. The 65 children surveyed constituted about 75 percent of the children enrolled in computer classes and about 25 percent of the children enrolled in the school.

Many of the students in this school come from relatively affluent families and the educational philosophy of the school is substantially more liberal than is found in most American schools. For

**Table 1**
**Grade levels of students in survey**

| *Grade* | *Boys* | *Girls* | *Total* |
|---|---|---|---|
| K | 2 | 2 | 4 |
| 1 | 6 | 3 | 9 |
| 2 | 14 | 1 | 15 |
| 3 | 5 | 6 | 11 |
| 4 | 3 | 3 | 6 |
| 5 | 4 | 6 | 10 |
| 6 | 2 | 1 | 3 |
| 7 | 2 | 1 | 3 |
| 8 | 4 | 0 | 4 |
| Total | 42 | 23 | 65 |

**Table 2**
**Computer experience of students in survey**

| *Experience* | *Boys* | *Girls* | *Total* |
|---|---|---|---|
| 2 mos. | 12 | 10 | 22 |
| 2 mos. - 1 yr. | 20 | 7 | 27 |
| 1 yr. - 2 yrs. | 3 | 6 | 9 |
| more than 2 yrs. | 7 | 0 | 7 |
| Total | 42 | 23 | 65 |

these reasons, I do not think these children are a particularly representative sample of American elementary students. They do, however, have a great deal of collective experience with computer games. Since it was very easy for all the children in the school to participate in the computer classes if they wanted to, these students are probably more typical than children who had to make a special effort to go to a science museum or other public access computer center. For these reasons, the children interviewed provided a convenient source of information about what computer games children like and why.

*Procedure*

The teachers of the computer classses provided a list of the 25 games they thought were the most popular among the students. Then each child was interviewed individually for about 5 to 10 minutes about his or her computer game preferences. For each game on the list, the children were first asked if they had ever played the game. If they had, they were asked if they liked it. If they liked the game, they were asked if they "liked it a lot or just liked it." Each game was thus rated on a four point scale: 0 - never played, 1 - didn't like, 2 - liked, and 3 - liked a lot. This question seemed easy for even the youngest children to understand. To test for any possible effect of the order in which the games were mentioned, the order of the list was randomized and half the subjects saw one order, the other half saw the reverse order.

To get a rough measure of how reliable the children's ratings were, the questionnaire was administered two times, one week apart, to 4 children. There were no scheduled classes during this week, but some of the children may have played with the games outside of class. The children rated 71 percent of the games identically both times. Their ratings for 18 percent of the games changed by 1 point and on 11 percent of the games they changed their mind about whether they remembered playing the game.

After they had rated all the games, the children were asked, "Of all these games, which one do you like best?" Then they were asked, "Which one do you like next best?" repeatedly until either the child had ranked his or her top ten choices or until the child seemed to be having trouble answering the questions. Most children, especially the younger ones, began having trouble after about 5 or 6 games were ranked.

Finally, for each of the first few choices in the child's rankings they were asked, "What did you like best about [the game] ?" For the games the child disliked, they were asked, "What did you dislike about [the game] ?"

Using the childrens' *ratings* ("liked", "didn't like", etc.) and their *rankings* (1st choice, 2nd choice, etc.), there are at least four possible ways to measure game popularity: (1) proportion of children who had played the game, (2) average rating among children who had played the game, (3) proportion of children who ranked the game, and (4) average ranking among children who ranked the game. I chose to use the second measure, average rating among children who had played the game, for the following reasons. Since the children ranked so few games (average of 5.2 out of 25), there was much less information from this source than from the ratings. There were also a number of inconsistencies between the ratings and the rankings (e.g., games rated "liked a lot" were sometimes ranked lower than games rated "liked"). Judging from the cognitive difficulty some children seemed to have in ranking the games and the relative ease of rating them, the ratings seem to be more trustworthy. Finally, it seems more important to know how well children who have actually played a game liked it than to know how many children have been persuaded to play the game by a teacher or by other children or by an appealing name.

## Results

Two possible sources of error need to be discussed before considering the main results of this survey. First, to test for a possible effect of the order in which the games were presented, an analysis of variance was performed with order of presentation, sex of child, and game as factors. There was no significant influence on ratings of the order of presentation, either as a main effect ($F(1,779) = .50$, $p > .4$) or as an interaction effect with games ($F(24,779) = .99$, $p > .4$). The only significant effects in this analysis of variance were the sex of the child ($F(1,779) = 11.52$, $p < .001$) and the sex by game interaction ($F(24,779) = 1.63$, $p < .03$). A detailed examination of these sex differences is presented below.

### *Popularity of different games*

Table 3 lists all the games in order of their average rating by children who had played the game. As a rough indication of the precision of these overall ratings, the correlation between the average ratings of the children who saw the games in one order and those who saw the games in the opposite order was .64.

### *Personal differences in game preferences*

One might have expected to find that there was a strong consensus among children about which games were best, but as it turned out, this was definitely not the case. For example, no single game received more than 17 percent of the first place rankings.

We can understand these differences better by looking at the games for which there were significant relationships between the ratings of the game and the personal characteristics I recorded about the

**Table 3**
**Computer games in order of preference**

| *Game* | *Average Rating* | *Description* |
|---|---|---|
| Petball | 2.8 | Simulated pinball with sound |
| Snake2 | 2.6 | Two players control motion and shooting of snakes |
| Breakout | 2.6 | Player controls paddle to hit ball that breaks through a wall piece by piece |
| Dungeon | 2.6 | Player explores a cave like "Dungeons and Dragons" |
| Chase S. | 2.6 | Two players chase each other across an obstacle course with sound effects |
| Star Trek | 2.5 | Navigate through space and shoot Klingon ships |
| Don't Fall | 2.5 | Guess words like Hangman but instead of a person being hung, a person or robot advances to a cliff |
| Panther | 2.4 | Guess who committed a murder by questioning witnesses who may lie |
| Mission | 2.4 | Bomb submarines without getting your ship sunk |
| Chaser | 2.4 | Capture a moving square with perpendicular lines |
| Chase | 2.4 | Like Chase S. but without sound |
| Horses | 2.4 | Bet on horses that race along track |
| Sink Ship | 2.3 | Bomb a ship from an airplane |
| Snake | 2.3 | Like Snake2 but snakes can't shoot |
| Lemonade | 2.3 | Run a lemonade stand: buy supplies, advertise, etc. |
| Escape | 2.2 | Escape from moving robots |
| Star Wars | 2.2 | Shoot Darth Vader's ship on screen |
| Maze Craze | 2.2 | Escape from randomly generated maze |
| Hangman | 2.1 | Guess letters of a word before man is hung |
| Adventure | 2.0 | Explore cave with dragons, etc. |
| Draw | 2.0 | Make any design on the screen |
| Stars | 2.0 | Guess a number. Clues given by number of stars |
| Snoopy | 1.9 | Shoot Red Baron by subtracting Snoopy's position on number line from Red Baron's position |
| Eliza | 1.8 | Converse with simulated psychiatrist |
| Gold | 1.5 | Fill in blanks in story about Goldilocks |

Note: Average ratings are on the scale: 1 = don't like, 2 = like, 3 = like a lot.

children interviewed. Table 4 shows the games for which an analysis of covariance of game ratings showed a significant effect of the sex, grade in school, or amount of computer experience of the child. (Game rating was the dependent variable, sex was the independent variable, and grade and experience were covariates.) Since there was a significant tendency for older children and children with more computer experience to rate games less favorably, the ratings on which Table 4 is based were first adjusted to be deviations from each subject's average rating.

*Game features that affect popularity*

One of the most interesting questions we can ask about these results is what features the popular games share that the unpopular games don't have. To answer this question, I rated each game on a number of dimensions that seemed likely to affect their motivational value (see, e.g., Banet, 1979). Most of the dimensions (like whether there were audio or visual effects) were fairly easy to rate as either present or absent. One dimension--randomness--was rated on a scale from 0 (not present) to 5 (present and very important in the game).

Table 5 shows the correlations between these game features and the average ratings the games received from the children. The most important feature determining game popularity in this sample was whether or not the game had a goal. For example, the top 3 games all had obvious goals (getting a high score in Petball, trapping the other person's snake in Snake2, and destroying all the bricks in Breakout) while the bottom 2 games had no clear goals (conversing with a simulated psychiatrist in Eliza or filling in blanks in a story in Gold). Other features that had high correlations with game popularity included scoring, audio effects, and randomness. Graphic games were liked and word games were significantly disliked.

In addition to these correlations with "objective" features of the games, Table 6 shows samples of comments the children made about things they liked or did not like about the games. All of the comments, including those not shown in the table, were coded into content categories. Of the reasons given for liking a game, 38 percent had to do with the fantasy in the game ("I like it because it's just like Star Wars," "I like it because it has bombs"), 13 percent had to do with the difficulty level of the game ("It's challenging"), and the remaining 59 percent had to do with various other things like visual effects, liking to win, and so forth. Of the reasons given for not liking a game, 43 percent had to do with the difficulty level ("It's hard", "It's too simple").

**Table 4**

**Individual differences in computer game preferences**

*Games with significant effect of grade:*

| | |
|---|---|
| Petball | (+) * |

*Games with significant effect of computer experience:*

| | |
|---|---|
| Star Wars | (+) * |
| Star Trek | (+) * |
| Escape Robots | ( - ) * |

*Games with significant effect of sex, controlling for grade and computer experience*

| | |
|---|---|
| Gold | (F) ** |
| Star Trek | (M) ** |
| Petball | (M) * |

KEY:

(+) Grade or experience had a positive effect on preference
( - ) Grade or experience had a negative effect on preference
(M) Boys liked the game better than girls
(F) Girls liked the game better than boys

* $p < .05$
** $p < .01$

**Table 5**
**Importance of game features in determining game preferences**

| *Feature* | *Correlation with average preference* |
|---|---|
| Goal | .65 ** |
| Computer keeps a score | .56 ** |
| Audio effects | .51 ** |
| Randomness involved in game | .48 ** |
| Speed of answers counts | .36 * |
| Visual effects | .34 |
| Competition | .31 |
| Variable difficulty level | .17 |
| Cooperation | .02 |
| Fantasy | .06 |
| Kind of game: | |
| Graphic game | .38 * |
| Math game | -.20 |
| Word game | -.38 * |

* $p < .05$
** $p < .01$

**Table 6**

**Comments about computer games**

STAR WARS

I like the aiming and shooting and I played with my dad.
I like it because it's just like Star Wars.
I like winning and making Darth Vader lose.
---
I didn't know how to play it. It's too hard to get the guy in range. They don't give you very much time.
I don't like shooting.
I don't like it because it's too easy.

DON'T FALL

I like it when he falls.
I like it when the guy falls.
I like guessing games. It's like an adventure on how you can guess a word.
It's fun watching him fall and fun guessing.
I like winning.
I like it because it's a good guessing game. There are lots of good subjects.

SNAKE 2

I like it because it has bombs.
I like blasting holes in the other snake.
I like firing people.

HANGMAN

It's neat to guess out those little words. Once I guessed "farmer" and "airplane" and it was so hard.
I like to try to get the words right. It's fun. The person looks funny when he's hanging.
I like it when he hangs by his head.
I like getting the letters and putting the tape in.
It's fun for us to try to guess.
I like winning.
---
It's not much fun to sit around and try to guess words. I don't like word games that much.
It's hard to guess the names.
It was boring. I would play it at home with my brother or mother.

LEMONADE

I like it that you learn how to count your money. You can tell whether the computer is right or wrong, and you can tell how many lemonades you want to sell.
I like making the lemonade and telling the computer how much glasses.
I like making money.

**Table 6 (Cont.)**

I like it that you earn money.

---

It lasted too long. I liked it at first, but not since I played other games.

It was boring. I wasn't interested.

GOLD

I like it that you get to write your own stories. You don't have to do what it tells you.

---

It's boring.

BREAKOUT

I like it that I am good at it and that you can use different colors.

It's challenging.

It sometimes is a challenge. It's good practice to keep your eye on the ball.

I like trying to get the ball and to break out. I like seeing how many points I got and how many times the holes get blank.

---

I don't like the colors.

I used to like it but I played too much. I don't like that the ball can only hit one side each time.

SNOOPY

I like that it's so easy. You alway get a hit.

---

I don't like it because I don't like math.

I don't understand it. I have trouble playing it.

It's too easy.

It's too simple.

I don't like that it's so easy.

PETBALL

It's fun.

I like pinball machines.

I just like it.

I like it that sometimes you can get a high score very fast. It has a bigger padle than regular pinball. It's easy to get bonuses. I like to win; I'm a sour loser.

It's just enjoyable.

I like regular pinball. It's good thay can make something like this on the computer.

I like collecting bonuses and getting free balls.

I like that it's fast, exciting, and a challenge. They keep the high scores on the board. The rules are fairly complicated, but once you learn them it makes the game fun.

## Discussion

At one level, these results are of interest simply as market research. To the best of my knowledge, no one before has systematically compared the popularity of computer games except in terms of overall sales. The interview technique used here provides a more detailed understanding of game preferences because: (1) it weights people equally rather than by the number of times they play the game, and (2) it counts only people who have actually played the games rather than those who may have been attracted by names or packaging.

This study also begins to answer deeper questions that any instructional game designer must deal with. First of all, it is clear that there are big differences between people in the kinds of games they like. No single instructional game can be expected to appeal to everyone. There are, however, some tantalizing indications of the kinds of features that are important in general. Most surprising, in a way, is the importance of having a goal. This theme will reappear several times in the studies and discussions below.

One seemingly contradictory result is that even though fantasy is not correlated with game ratings, it is the most frequently mentioned reason for liking a game. One possible explanation for this result would be that there were large differences between people in their fantasy preferences. If the same fantasies are liked by some people and disliked by others, then the overall correlation of fantasy with preference could be low even though fantasy was still an important factor in preference. The features with high overall correlations are those that are not only important, but important in the same way for most people. There is, in fact, some evidence of large differences between people in the fantasies they find appealing. The games in Table 4 for which individual differences were significant all involved fantasy. And in Study 3 below there is a significant individual difference in fantasy preference. In other words, fantasy may be important in game preference, as indicated by the students' comments, but not have a high overall correlation because of differences among people in the fantasies they like.

This study does not say much about the issue of changes in popularity over time. The most popular game, however, was Petball, a new game that had been introduced at the school only a couple of weeks before my survey. I think that if a followup survey had been done a month or two later, the novelty of Petball would have worn off and it would have migrated to a lower position in the list. Based on Eifferman's (1974) results described above, we would expect some computer games to be steady favorites, others to have recurrent waves, and still others to be sporadic or one-shot sensations. Since Petball has a score-keeping mechanism that can provide challenges at many skill levels, I would expect it to be a steady favorite, but not consistently at the top of the list.

There are, of course, large problems with trying to draw strong conclusions from the kind of correlational study I have described here. It is impossible to know whether the factors I measured actually caused the effects I attributed to them. Among other things, the results depend entirely on the sample of games used. For example, if all the games in the study had had goals, the correlation between popularity and the presence of a goal would have been 0. And if I had included a number of totally uninteresting non-games in the survey, there might have been a much stronger consensus about which games were the most fun. In order to make stronger inferences, the other two studies I will describe each focus on a single game and systematically vary the features of the game by having different versions of the same game.

# Chapter III
## Study 2: Breakout - A motor skill game

The results of the previous study and other casual observations indicate that Breakout is one of the most popular computer games. Why is this game so popular? What is the "secret" of the success of Breakout? To try to answer these questions, I designed several degenerate versions of Breakout, each of which removed one or more of the features I thought contributed to the appeal of the game. Then I asked people to play with the different versions and say how much they liked them.

Figure 1 shows a typical screen display in the original Breakout game. The player uses a knob to control the position of the paddle on the left side of the screen. The paddle is used to bounce the ball against the wall of bricks on the right side of the screen. Each time the ball bounces off the wall, it knocks one brick out of the wall and adds to the score. The ultimate goal of the game is to knock out all the bricks.

One can easily generate a list of features of this game that might contribute to its appeal. In fact Breakout contains almost all the features analyzed above in Table 5:

(1) *Goal* - Breaking out all the bricks and getting a higher score than last time.

(2) *Score* - Depends on how many and which bricks are broken out.

(3) *Audio effects* - There are different tones for bouncing off a wall, a brick, or the paddle and for missing the ball.

(4) *Randomness* - The place and angle at which the ball first emerges from the wall are random.

(5) *Speed of responses counts.*

(6) *Visual effects* - The motion of the ball, the appearance of the wall, and the breaking out of the bricks.

(7) *Competition* - Players can compete with each other or with themselves to get a high score.

(8) *Variable difficulty level* - When the player hits the ball correctly six times in a row, the ball automatically speeds up.

(9) *Fantasy* - There is a mild fantasy of destroying a wall (perhaps escaping from a prison).

The success of Breakout must be due, in part, simply to the fact that it includes so many of these motivational features. But which of these features are the most important to making it fun? One can imagine making up many new versions of Breakout by taking out each of these features (or

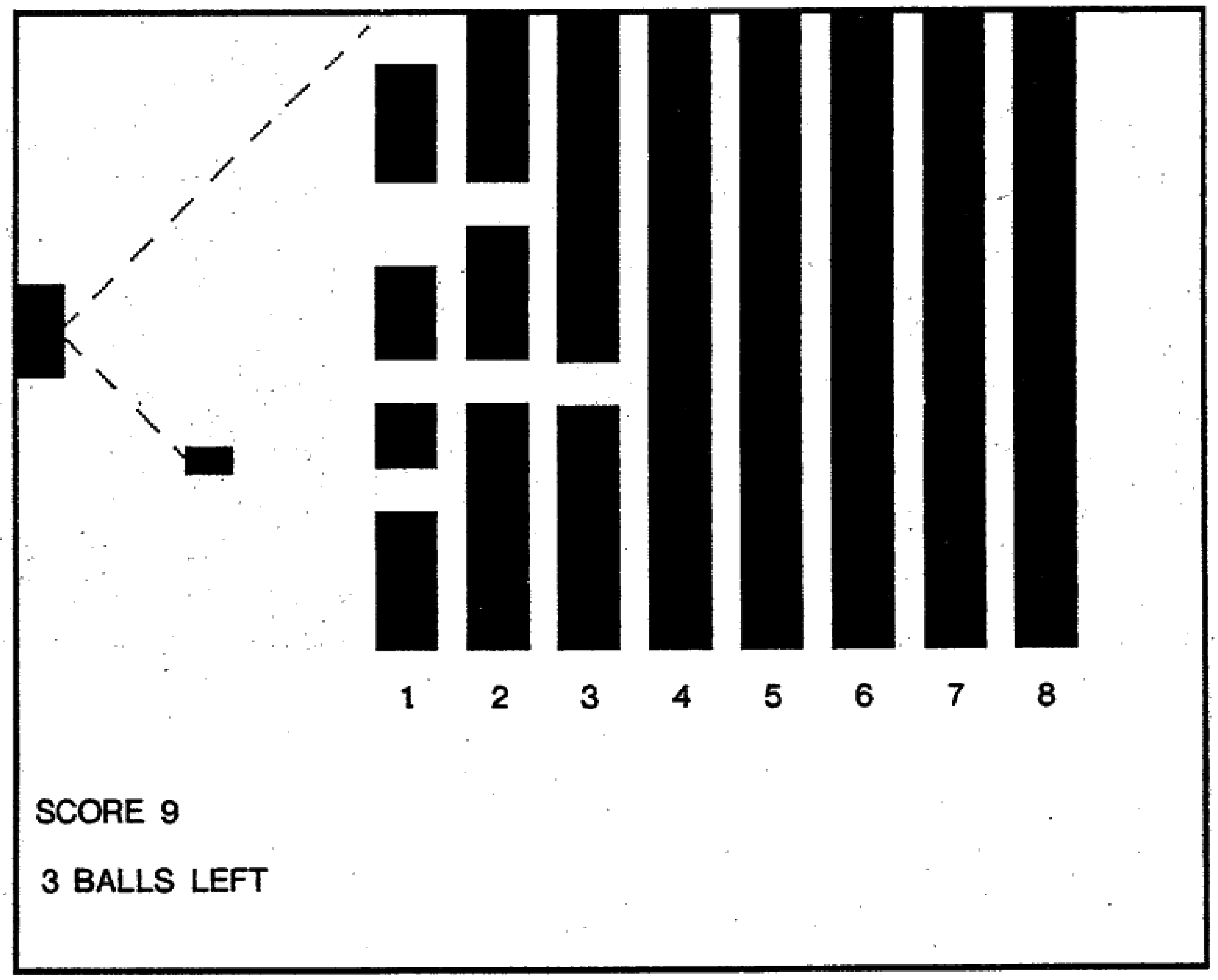


FIGURE 1. Breakout Display Format

others), separately or in various combinations. This can very quickly become unwieldy, however, and judgment is required to pick features to remove that seem important and interesting.

In my judgment, three features of Breakout seem to capture the most important aspects of its appeal: (1) the breaking out of the bricks, (2) the score, and (3) the ball bouncing off the paddle. In a sense, the essence of the game is that the ball bounces off the paddle, bricks are broken, and a score is kept. But it is not at all clear which of these is the most important. In my casual conversations with devotees of Breakout (and other similar games like Space Invaders), they nearly always mention their scores--usually their highest score. Is the challenge of getting a higher score than your own or someone else's previous record, the main captivation of Breakout? Is it the visual stimulation of watching the bricks break out? Or is it simply the enjoyment of the sensorimotor skill involved in putting the paddle in front of the moving ball? The experiment I conducted tries to answer these questions.

## Method

### *Subjects*

The subjects for this experiment were Stanford undergraduates who volunteered to participate in the experiment in their dormitories. There were 10 subjects, eight men and two women. All the subjects had played with computer video games before the experiment, but only five of them had played Breakout before.

### *Conditions*

There are 8 possible combinations of the 3 features listed above. Two of these combinations are indistinguishable from the others, since if the ball doesn't bounce off the paddle, one cannot tell whether bricks get knocked out or not. Figure 2 shows the 6 distinguishable combinations that were used in the experiment. Version 1 is the original Breakout game. Each ball keeps going until the player misses it. There are five balls in a game. Each brick scores the number of points at the bottom of its column on the screen. In Versions 2 and 5, the balls bounce back and forth between the paddle and the wall without ever breaking out any bricks. Each bounce counts 1 point. In Versions 3 and 6, the player catches a ball with the paddle and then another ball appears until the player has missed 5 times. Each catch counts 1 point. Versions 4, 5, and 6 are just like Versions 1, 2, and 3 respectively except that the scores are omitted.

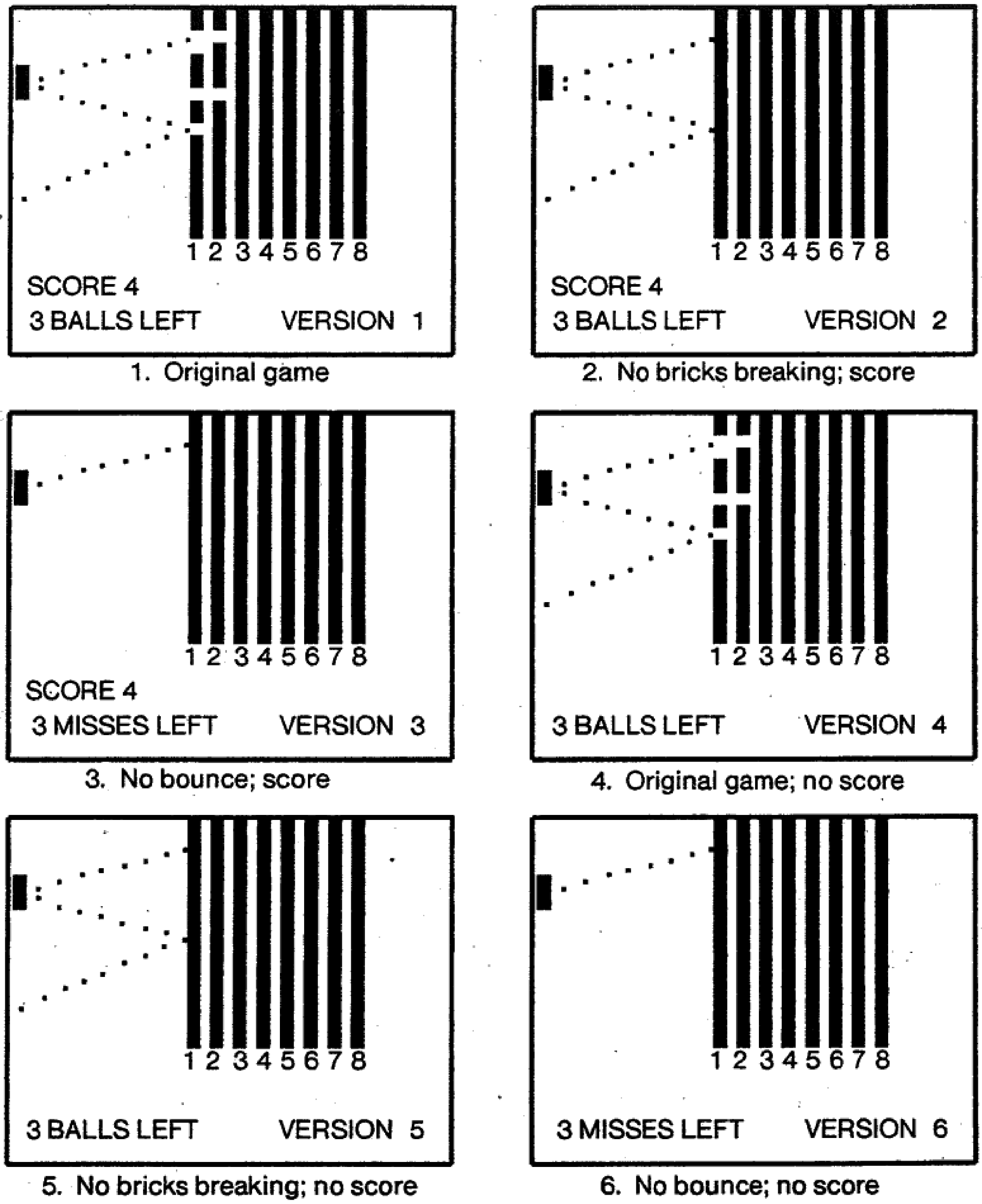


FIGURE 2. Different versions of the Breakout game.

The distance from the paddle to the wall in the "catch" versions was adjusted during pilot testing to make all the versions seem equally difficult. This adjustment was apparently successful, since 5 of the 10 subjects thought the versions were equally difficult and the other 5 had no consensus about which versions were more difficult. In all versions, including the "catch" versions, the ball speeds up after six correct hits or catches.

*Procedure*

Each subject played with each of the six versions of the game for about 3 minutes and then was able to play with any of the versions for the remainder of the 30 minute session. Half the subjects saw the versions in one random order, the other half saw the versions in the reverse order.

At the end of the session, the subjects were asked to rate each version on a scale with 5 intervals. They were reminded of the versions by a chart like that shown in Figure 2. The version or versions they liked least were rated at the left end of the scale and the version or versions they liked most were rated at the right end of the scale. The other versions were rated anywhere in between. This rating method was used to preserve the interval, rather than just ordinal, properties of the scale while emphasizing the differences between versions as much as possible.[1] After the subjects rated the six versions of the game, they were interviewed about (1) why they chose their most and least favorite versions, (2) how important the different features were to them, (3) whether any of the versions were more difficult than the others, and (4) what they thought made good computer games, in general.

The subjects who had never played Breakout before received the following special instructions. When they started playing they were told that it takes a long time to get used to the paddle so they shouldn't worry if they had trouble at first. When they played the first version of the game in which the bricks broke out, they were told that the object of the version was to destroy all the bricks in the wall. These instructions were added after the first three subjects who had not played Breakout had difficulty learning to play the game. These three subjects were discarded from the analysis and were not included in the total of ten subjects in the experiment.

## Results

Table 7 shows the two measures of how interesting the different versions of the game were: average rating on the questionnaire and time spent in the free play period. Since only two of the

[1] This rating method was suggested by Brian Ross.

## Table 7

## Appeal of different versions of Breakout

| *Version* | *Features* | | | *Average rating* | *A posteriori contrasts** | | | *Total time in free play (mins)* |
|---|---|---|---|---|---|---|---|---|
| | *Break bricks* | *Bounce from paddle* | *Score* | | | | | |
| 1 | x | x | x | 4.8 | │ | | | 66 |
| 4 | x | x | | 4.1 | │ | │ | | 17 |
| 2 | | x | x | 3.3 | | │ | | 3 |
| 3 | | | x | 2.1 | | | │ | 0 |
| 5 | | x | | 2.0 | | | │ | 0 |
| 6 | | | | 1.4 | | | │ | 2 |

*Note: The versions that have vertical lines in the same column were not significantly different from each other using *a posteriori* contrasts.

versions received a non-trivial amount of time in the free play period, the primary analyses will focus on the questionnaire ratings. A four-way analysis of variance predicting questionnaire rating from order of presentation, sex, amount of computer game experience, and version, found a significant effect only of version ($F(5,24) = 25.84$, $p < .001$). Not surprisingly, the original version of the game was more fun than any of the degenerate versions. It received much more time in the free play period and was shown by *a priori* contrasts of the questionnaire ratings to be significantly more fun than all the other versions. Using Tukey's HSD *a posteriori* contrasts at the .05 level, the questionnnaire ratings for versions 3, 5, and 6 were found to be significantly worse than the others. In other words, when there is no breaking out of bricks and no scoring, the game is much less fun. It is also less fun when there is no bouncing off the paddle even if there is scoring.

Table 8 shows the results of a multiple regression predicting questionnaire ratings from the features in the versions. The most important feature in determining whether the game is liked is the breaking out of bricks. According to the regression, the bouncing from the paddle and the score are approximately equal to each other and both are much less important than breaking out the bricks. The ordering of the conditions, however, suggests that score may be more important than bouncing from the paddle (since both non-breaking-out versions *with* scores came before both non-breaking-out versions *without* scores).

**Table 8**
**Importance of game features in preference for Breakout**

| *Feature* | *Beta in multiple regression* |
| --- | --- |
| Breaking out bricks | .77 |
| Score | .32 |
| Bounce from paddle | .30 |
| Multiple R | .87 |

About 57 percent of the reasons given for liking or disliking the versions involved challenge, goals, or scoring. The other 43 percent of the comments dealt with various other topics like the uneven motion of the ball.

## Discussion

The results of this study suggest that the "secret" of Breakout's success has more to do with the breaking out of the bricks than with the challenge of the scoring mechanism or the basic motor skill of hitting the ball with the paddle. Why is the breaking out of the bricks so appealing? The data from this experiment do not answer that question, but the analysis begun above suggests a number of possibilities. A partially destroyed wall of bricks presents a visually compelling goal and at the same time is a graphic score-keeping device telling how close the player is to attaining that goal. It thus provides a goal, a visual effect, and scoring all at the same time. In fact, the structure of the wall suggests all sorts of goals at different levels: knocking out a brick in the third row, destroying the first row completely, etc.

The results also show that when both the score and the brick destruction are removed, the game is significantly less fun. Without either of these features, the only goal is a rather vague "keep the ball going as long as possible", and players have no way (except for counting to themselves) to tell how well they are doing. Without a clear goal, the game is not really a game at all.

Certainly the results of this short experiment do not definitively reveal the "secret" of Breakout. Varying a different set of features would have produced a different set of insights. These results do, however, illuminate the importance of a clever combination of challenge and visual effects in the design of Breakout. I believe a similar combination is important in the success of a number of other games like Space Invaders, Snake2, and Petball.

Even though there is learning taking place in the Breakout game, it is learning of a sensorimotor skill not a cognitive skill like the skills emphasized in schools. In the last experiment of this series, I will examine the motivational features of a game that involves bona fide academic skills--estimating magnitudes on a number line and expressing them as mixed numbers.

# Chapter IV
## Study 3: Darts - A cognitive skill game

How can games be used to teach academic skills? What makes an instructional game fun? To try to answer these questions for a game with clear academic relevance, I studied a game called Darts that was designed to teach elementary students about fractions (Dugdale & Kibby, 1975).

In the version of the game used, three balloons appear at random places on a number line on the screen and players try to guess the positions of the balloons (see Figure 3). They guess by typing in mixed numbers (whole numbers and/or fractions), and after each guess an arrow shoots across the screen to the position specified. If the guess is right, the arrow pops the balloon. If wrong, the arrow remains on the screen and the player gets to keep shooting until all the balloons are popped. Circus music is played at the beginning of the game and if all three balloons in a round are popped in four tries or fewer, a short song is played after the round.

This game typifies, in my opinion, the best kind of highly motivating instructional computer games I have seen. Though my study focuses on the motivational rather than the educational aspects of the game, the game has a great deal of face validity as a way of teaching about estimating distances on a number line and expressing the results as mixed numbers. More importantly for my purposes here, the game embodies a number of generalizable motivational features.

*Motivational features of the Darts game*

One relatively easy way to try to increase the fun of learning is to take an existing curriculum and overlay it with a game in which the player progresses toward some fantasy goal, or avoids some fantasy catastrophe, depending only on whether the player's answers are right or wrong. To a great degree, the fantasies used in this kind of game are interchangeable across subject matters. For example, Baseball and Hangman fantasies could just as well be used for arithmetic problems as for spelling problems, with people being hung or advancing around a baseball diamond depending on whether or not the arithmetic problems are worked correctly.[2] I would like to call this kind of arbitrarily interchangeable fantasy *extrinsic fantasy* and contrast it with *intrinsic fantasy* that depends crucially on the skill being used.

Darts is a good example of an instructional game with an intrinsic fantasy. The relative sizes of numbers are intimately related to the positions of the arrows and balloons in the fantasy

[2] For those readers who are not familiar with the computer games I use as examples, Table 3 and the appendix contain brief descriptions of all the games mentioned.

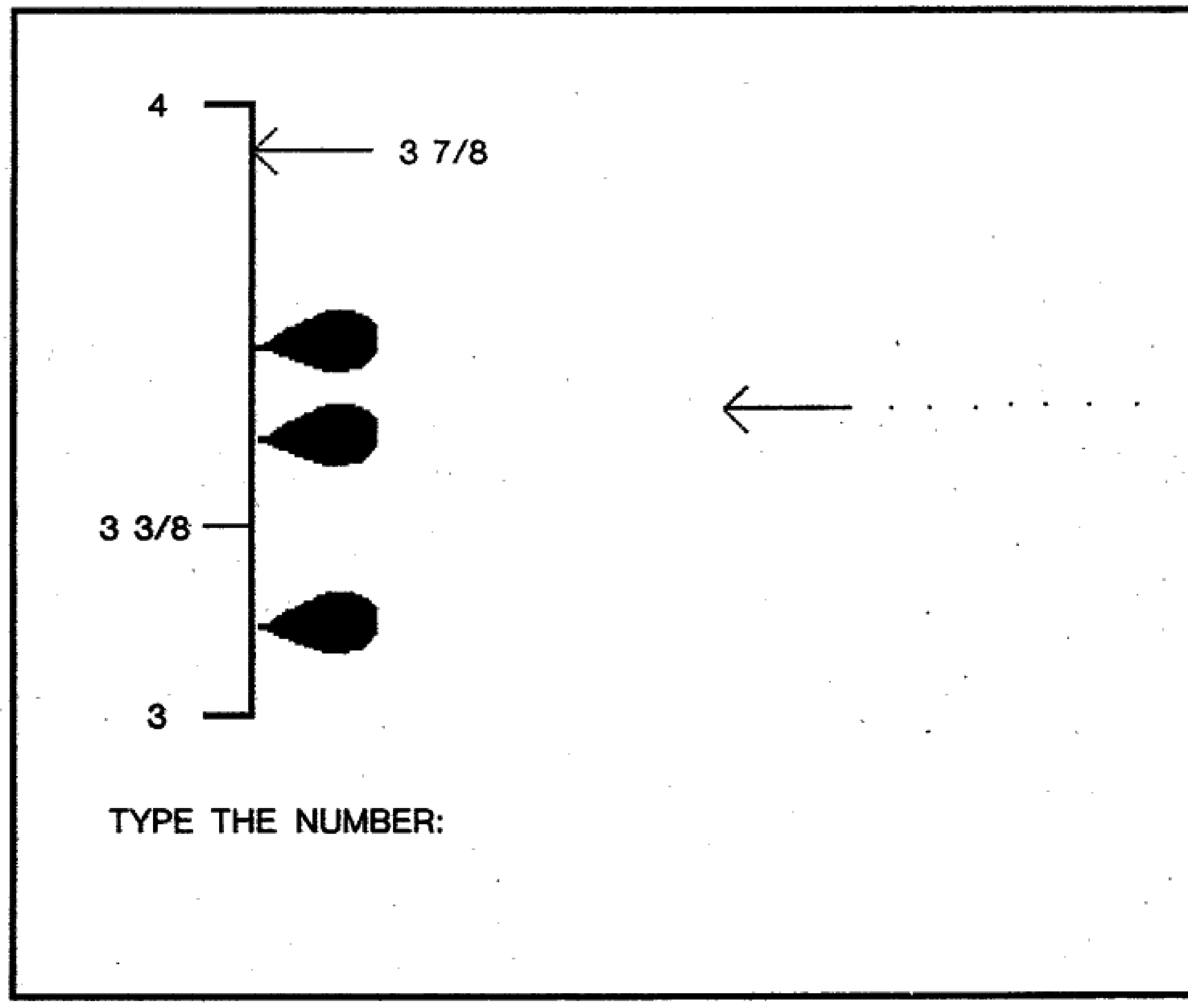


FIGURE 3. Darts Display Format

representation. Other intrinsic fantasies in math games include the search for a hidden animal in the Hurkle game and Snoopy shooting at the Red Baron in the Snoopy game. The Adventure game in which a vast underground cavern system is explored in response to the players' commands can be considered an intrinsic fantasy for the skills of reading (the cave descriptions) and writing (the commands). Hammurabi and Lemonade are both simulations in which a fantasy is intrinsic to the social science concepts being taught. I will give a more detailed analysis of the distinction between intrinsic and extrinsic fantasies in Chapter 5.

Darts has a number of other motivational features besides the intrinsic fantasy. When an arrow misses a balloon, the player not only sees that the answer was wrong (*performance feedback)* but also whether it was too high or too low (*constructive feedback).* The constructive feedback is provided in this case by the *graphic representation* of the arrows and balloons, but it could have been provided separately. Music is used both as decoration (the circus music at the beginning) and as a reward for good performance. Finally, the number of balloons popped and the number of incorrect arrows on the screen provide a simple *scoring* device.

The conditions in this study are chosen to illuminate the separate contributions of each of these elements to the appeal of the game: the performance feedback, the attractiveness of the balloon-popping fantasy by itself, the constructive feedback and scoring aspects of the graphic representation, the music, and the additional value of having all these kinds of information combined in a single intrinsic fantasy. The conditions are arranged in a rough continuum with each successive condition containing one more presumably motivational feature than the last condition. When the introduction of a new feature in a condition makes the information of an old feature redundant, the old feature is dropped.

To eliminate the possibility of "contamination" between versions, each subject sees only one version of the game. If each subject saw several versions of the game, then subjects who saw balloons popping in one version, say, might imagine balloons popping in later versions that did not actually show the balloons. Furthermore, it would be difficult to control for other effects of the order of presentation such as boredom with later versions or heightened contrasts between similar versions. Finally, it would be impossible to tell directly which versions contributed to what the subjects learned from playing the game. By comparing averages between groups of subjects who each see only one version, all these problems are eliminated. This design thus tests how important different features would be in natural situations where there is only one version of each game.

An alternative to this design was illustrated by the Breakout study. There each subject saw all the versions of the game and the "contamination" effect was partially controlled for by showing the versions in opposite orders to the two groups of subjects. This within-subjects design provided a powerful statistical test using only a small number of subjects, but it was not as "clean" a comparison of the versions as the between-subjects design used here.

## Method

### *Subjects*

There were 80 subjects in this experiment, 10 assigned randomly to each of the 8 conditions. There were 36 boys and 44 girls. All were fifth grade students at public schools in the Palo Alto area. Half were from a school in a predominantly low-income minority neighborhood; the other half from a school in a predominantly middle or upper-middle class neighborhood. To as great an extent as possible, the number of subjects of each sex from each school was kept constant over conditions.

### *Conditions*

As illustrated in Figure 4, the following conditions are used:

(1) *Non-interactive drill.* A number line is shown on the screen and a position is marked on the line by a small rectangle. The student types in a mixed number specifying the position on the line. Then the screen is cleared and the next problem is presented. There is no feedback about whether the guesses are right or wrong.

(2) *Add performance feedback.* After each try the student is told whether the answer was right or wrong. The last answer remains on the screen until a new answer is typed. After 3 incorrect tries, the correct answer is printed and the next problem is presented.

(3) *Add scoring.* The problems are grouped into "rounds" consisting of three problems each. A scoreboard at the bottom of the screen tells the round number, the number of tries in the round, and the number of correct answers in the round.

(4) *Add constructive feedback.* After each incorrect try the student is told in which direction and by approximately how much the answer was wrong (e.g., "A little too high", "Way too low", etc.). If there are 15 incorrect tries in a given round, the correct answer is printed and the next problem is presented.

(5) *Add extrinsic fantasy.* At the beginning of each round, three balloons are pictured on the screen. Each time the student gets a correct answer, an arrow moves across the screen and pops one of the balloons. The number of correct answers is omitted from the scoreboard since it is implied by the number of balloons popped.

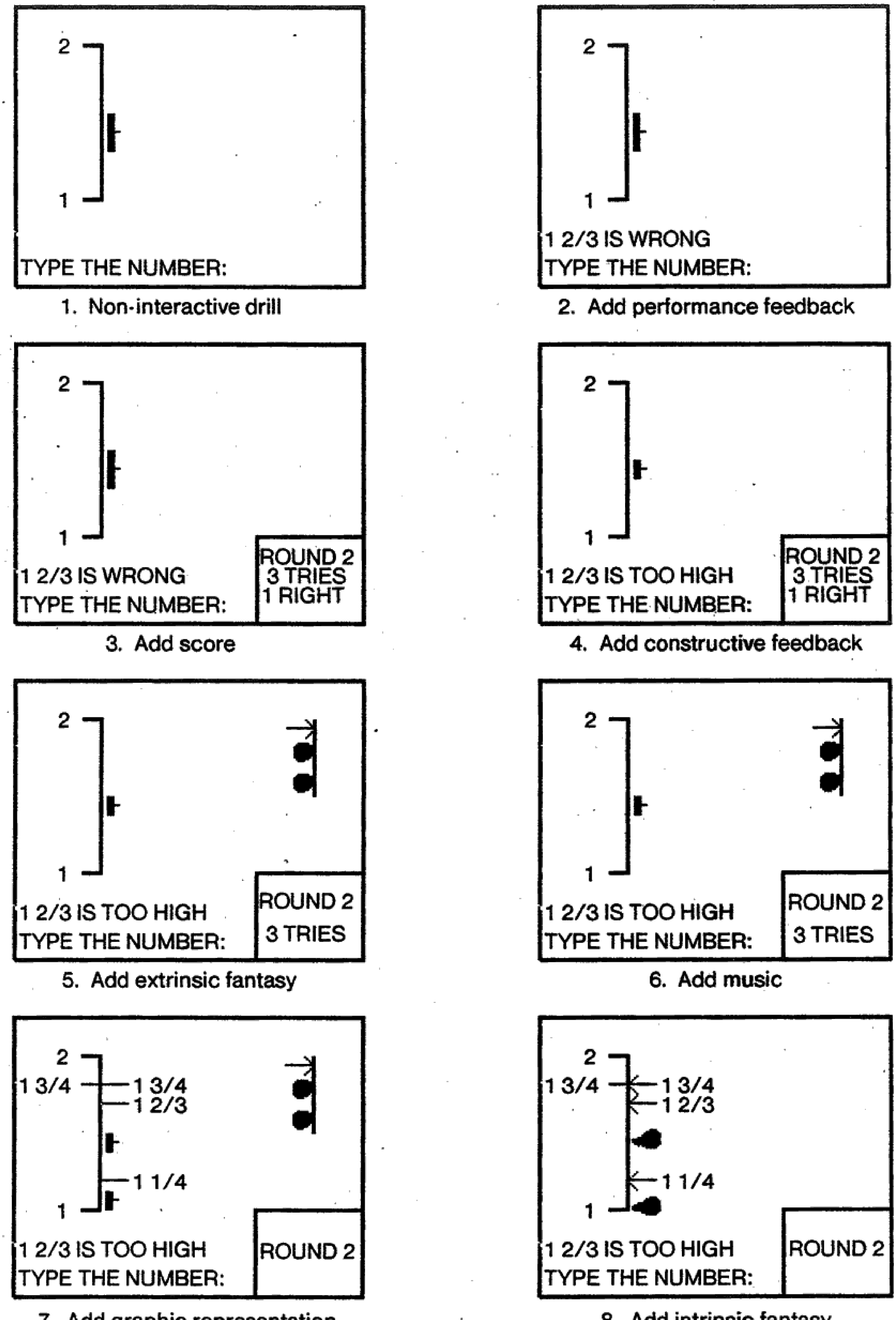


FIGURE 4. Different versions of the Darts game.

(6) *Add music.* Circus music is played at the beginning of the game, and a song is played after each round in which the student guesses all three numbers in four tries or fewer.

(7) *Add graphic representation.* All three rectangles for a given round appear on the number line at the same time, and all correct and incorrect answers are marked by short lines that remain on the line for the entire round.

(8) *Add intrinsic fantasy.* The standard Darts game is used with arrows popping balloons on the number line. The balloons for the extrinsic fantasy are omitted.

The sizes of the rectangles in each condition were adjusted to try to make the probability of success (number of correct answers / number of tries) approximately the same in all conditions.

*Procedure*

Each student was assigned to one condition and was allowed to choose freely between the version of Darts in that condition and a version of the Hangman computer game that was the same in all conditions. In the Hangman game, students try to guess a word that is specified by blank spaces corresponding to the letters in the word. Each time they make an incorrect guess, one more body part (e.g., head, arm, leg) is added to a picture of a man being hung. The object of the game is to guess the word before the man is completely "hung". (In the version of Hangman used in this experiment, students can choose whether they want to guess one letter at a time or the whole word at a time, whether they want easy words or hard words, and whether they want the picture of the man being hung to be displayed. If they guess one letter at a time, then each correct letter guessed is displayed in its proper place in the word. If they choose to guess the whole word at a time, each incorrect guess is followed by a "free" letter being displayed in the word. Then if the student does not guess the word before the last letter is filled in, the man is "hung".)

Each student played with the games for two 20 minute sessions. For most subjects, the two sessions were separated by 1 to 3 days. Within each session, the times when students changed back and forth between the games were recorded.

At the beginning of the first session, students were asked to rate how well they liked reading, mathematics, and spelling on a scale from 1 ("don't like") to 5 ("like a lot"). They were also asked to rate how well they thought they did in those subjects on a scale from 1 ("not very well") to 5 ("very well"). Then they were given the following instructions: "I have two games here for you to play with: Darts and Hangman. We're going to start out with Darts, and then you can change back and forth between the two games whenever you want to. If you ever want to change games, and you don't see how, just ask me." The beginning of the Darts game had a set of instructions and two sample problems. If the children appeared to not understand the instructions or the sample problems, they were given help, but they did not receive any help on the other problems.

At the beginning of the second session, the children were told, "Now remember there are two games here: Darts and Hangman. Which one would you like to start out with today?" At the end of the session, they were asked to say which game they liked best and to rate how well they liked the two games and how well they thought they did in each game on 5 point scales. They were also asked what they liked about their favorite game and what they disliked (or liked) about the other game.

For each class that had students in the study, a pretest was given in class before any students had a session with the games and a posttest was given after all students had completed both sessions. The pre- and posttests consisted of two kinds of problems: (1) given a number line and a mixed number, put a mark on the number line where the mixed number should be, and (2) given a number line with a mark on it, write the mixed number specified by the mark. In grading both parts of the test, I used an arbitrary tolerance for correctness of plus or minus 1/12 of the range of the number line. This was approximately the tolerance for correctness in the Darts game itself.

*Equipment*

The different versions of the Darts game and the Hangman game were programmed in BASIC on an Apple II personal computer. The first ten problems in Darts were the same for all students. For the few students who worked more than ten problems, the additional problems were generated randomly. Each guess the students made was recorded on a diskette in the Apple. These protocols were later transferred over a link to a PDP-10 for analysis.

For most of the sessions, two students were working on separate computers at the same time. Both students were in the same room, but they faced away from each other and their starting times were staggered to minimize distractions.

## Results

*Effects of game features on interest*

There were three measures of how interesting subjects found the Darts game: (1) how long they played with Darts in preference to Hangman (up to a maximum of 40 minutes), (2) how well they said they liked Darts (on a scale from 1 to 5), and (3) which game they said they preferred (Darts or Hangman). All three measures were significantly correlated with each other ($r_{12} = .30$, $r_{13} = .45$, $r_{23} = .69$; each $p < .01$). The amount of time spent on Darts had a higher variance in proportion to its mean and was the most sensitive of the three measures.

A separate three-way analysis of variance (using condition, school, and sex as independent variables) was performed for each of the three measures of interest. Both time spent on Darts and preference for Darts revealed significant effects of condition ($F(7,48) = 4.90$, $p < .001$; and

$F(7,48) = 2.21$, $p < .05$). There was also, surprisingly, a highly significant interaction between condition and sex in determining time spent on Darts ($F(7,48) = 4.84$, $p < .001$).

Because each pair of adjacent conditions differs by only one feature, *a priori* comparisons were planned between each adjacent pair of conditions. Table 9 shows the average values and the significant differences between conditions for the three interest measures. Because of the significant interaction between sex and condition on the time measure, these comparisons were done separately for boys and girls on that measure.

The most surprising result in Table 9 is that the standard version of Darts (condition 8) is significantly *less* interesting for girls than the version in which the intrinsic arrows and balloons fantasy is replaced by an extrinsic version of the same fantasy (condition 7). The table also shows that boys like the arrows and balloons when introduced as an extrinsic fantasy (condition 4 vs. 5) and dislike being told in words that their guess is too high or too low (condition 3 vs. 4), and that girls like the music (condition 5 vs. 6). In fact, even though not all the differences are significant, in every case where boys like a feature, girls dislike it, and vice versa (that is, all changes between adjacent conditions are opposite in sign for boys and girls).

The planned comparisons between adjacent conditions evaluate a feature using only the condition in which it is first introduced. Since each feature appears not only in the condition in which it is introduced but also in all subsequent conditions, a potentially more powerful test can be made using regressions. Table 10 shows the results of regressions that use the features present in each version to predict the time spent on that version. Two alternative definitions of the features are used. The first definition embodies the conceptual assumptions made in the design of the experiment--that a feature is present in all conditions after it is introduced even though its form may change. For example high/low constructive feedback is assumed to be present in both the conditions where it is given in words and in those where it is given graphically. With this definition, the same features are significant as with the planned comparisons. The second definition embodies a more "naive" view of what the features really are--that they are exactly what appears to the student. For example, with this "naive" definition, the verbal high/low feedback is assumed to be a different feature from the graphic feedback. This definition also assumes that the "score" feature is present in different intensities (proportional to the number of lines in the scorebox). Using this "naive" definition of the features, the verbal high/low feedback is no longer significantly disliked by the boys, but the other significant features are the same. The regressions based on both definitions fit the data equally well.

*Effects of personal characteristics on interest*

Table 11 shows the relationships between interest in the game and several personal attitudes or skills. As noted above, there is a strong positive relationship between the different measures of interest in the Darts game and a negative relationship between these measures and interest in the Hangman game. The table also shows that interest in the Darts game is positively correlated with

**Table 9**
**Interest in different versions of the Darts game**

| ***Condition*** | ***Interest Measures*** | | | |
|---|---|---|---|---|
| | *Time playing Darts (0 - 40 mins.)* | | *"Like Darts"* | *"Prefer Darts to Hangman"* |
| | *Boys* | *Girls* | *(scale from 1 - 5)* | *(percent of subjects)* |
| 1. Non-interactive drill | 20.5 | 15.5 | 3.2 | 10 |
| 2. Add performance feedback | 18.8 | 20.2 | 3.4 | 20 |
| 3. Add scoring | 24.2 | 19.8 | 3.2 | 20 |
| 4. Add constructive feedback | 16.2 * | 22.2 | 3.1 | 30 |
| 5. Add extrinsic fantasy | 25.8 * | 20.8 | 4.5 * | 50 |
| 6. Add music | 21.8 | 30.0 * | 4.0 | 50 |
| 7. Add graphic representation | 28.3 | 29.8 | 4.0 | 60 |
| 8. Add intrinsic fantasy | 34.5 | 19.8 ** | 3.9 | 70 |
| Average | 23.4 | 22.0 | 3.7 | 39 |

* $p < .05$, for comparison with previous condition
** $p < .01$, for comparison with previous condition

Table 10

Importance of game features in determining interest in Darts versions

| *Feature* | *Boys* Beta in multiple regression | *Boys* F(1,27) | *Girls* Beta in multiple regression | *Girls* F(1,35) |
|---|---|---|---|---|
| *"Conceptual" definitions* | | | | |
| Performance feedback | -.08 | 0.20 | .23 | 1.91 |
| Scoring | .32 | 2.20 | -.02 | 0.01 |
| Constructive feedback | -.54 | 5.33 * | .17 | 0.42 |
| Extrinsic fantasy | .67 | 6.75 * | -.10 | 0.15 |
| Music | -.27 | 1.23 | .63 | 5.90 * |
| Graphic representation | .37 | 3.29 | -.01 | 0.00 |
| Intrinsic fantasy | .27 | 2.60 | -.49 | 8.77 ** |
| Multiple R | .74 | | .66 | |
| *"Naive" definitions* | | | | |
| Performance feedback | -.10 | 0.20 | .29 | 1.91 |
| Scoring | .28 | 2.20 | -.02 | 0.01 |
| Constructive feedback | -.67 | 3.51 | .47 | 2.00 |
| Extrinsic fantasy | .80 | 8.63 ** | -.11 | 0.16 |
| Music | -.27 | 1.23 | .63 | 5.90 * |
| Graphic representation | -.09 | 1.23 | .43 | 1.42 |
| Intrinsic fantasy | .27 | 2.60 | -.49 | 8.78 ** |
| Multiple R | .74 | | .66 | |

* $p < .05$
** $p < .01$

**Table 11**

**Correlations between measures of interest, attitude, and skill**

| *Attitudes and skills* | *Interest Measures* | | |
|---|---|---|---|
| | *Time playing Darts* | *"Like Darts"* | *"Prefer Darts to Hangman"* |
| *Attitudes before playing* | | | |
| Like math | .14 | -.08 | .06 |
| Do well in math | .28 * | .17 | .28 * |
| Prefer math to other subjects | -.04 | -.04 | -.00 |
| *Attitudes after playing* | | | |
| Liked Darts | .30 ** | -- | .69 ** |
| Liked Hangman | -.31** | -.52 ** | -.81 ** |
| Did well in Darts | .21 * | .28 ** | .34 ** |
| Preferred Darts to Hangman | .45 ** | .69 ** | -- |
| *Skills* | | | |
| Pretest score | .15 | .33 ** | .26 * |
| Percent of correct guesses in Darts | -.13 | .12 | .07 |

* $p < .05$
** $p < .01$

how well the students think they do in math and with how well they think they did in the game, but it is unrelated to how well they actually did in the game. In other words, students who *thought* they were good at the game liked it, but those who were *actually* good at the game didn't like it any better than those who weren't.

*Learning*

As noted above, the primary goal of this experiment was to study what made Darts interesting, not what made it educational. Accordingly the experiment was not designed to optimize the measurement of learning. For example, the pre- and posttests were separated from each other by several weeks, with each student receiving an average of 23 minutes exposure to the Darts game sometime during that period.

As expected, this brief exposure did not produce any measurable learning. First, the posttest scores were not significantly higher than the pretest scores ($z = 1.24$, N.S.). Next, an analysis of covariance was performed to predict posttest score from school, condition, and sex, with pretest score and time spent on Darts as covariates. A significant effect of condition in this analysis would have indicated that some learning was attributable to different versions of the game independent of the classroom learning. In fact, no such effect was found. The only significant variable in predicting posttest score was pretest score ($F(1,45) = 65.24$, $p < .001$). Finally, an analysis of variance was performed on the proportion of correct answers during the course of the game. Since students in all conditions saw the same problems, a significant interaction between problem and condition would have indicated that students in some conditions were improving at a different rate than others. Again, no such effect was found. In predicting the proportion of correct answers, there were, however, significant effects of problem and of the interaction between sex and condition ($F(4,155) = 45.21$, $p < .001$; and $F(7,155) = 4.05$, $p < .001$; respectively, for students who worked all of the first 5 problems). The pattern of these interactions was complex and not easily interpretable and, in fact, it changed for different samples of the problems so it was not analyzed further.

*Factors affecting the decision to change games*

So far, only the effects of overall characteristics of the games and subjects have been presented. However, because detailed protocols of each student's interactions with the computer were recorded, it was also possible to analyze several micro-level factors affecting when the students decided to change games.

First of all, there was some tendency for subjects to change games at the end of a round rather than in the middle. For subjects playing the Darts game, a total of 454 rounds were recorded that were not interrupted by the end of a session. Subjects chose to change games after 17 percent of these rounds. If the decision to change games were totally random, we would expect very few of the changes to occur exactly at the end of a round because when a round is completed, subjects ordinarily begin working on the next round almost immediately. In fact over half of the game changes (53 percent) occurred after one round was complete and before the next one began.

Another obvious factor that might affect the decision to change games is how long the subject has been playing the game. Figure 5 shows the distribution of times for uninterrupted periods of playing the Darts game. Periods that were interrupted by the end of a 20 minute session, rather than by the subject deciding to change games, are omitted from this graph. If there were a constant tendency to change games at any time (in other words if game changing were a Poisson process), this graph would have the form of a falling exponential curve. In fact, it is closer to a normal distribution, suggesting that each time students start playing Darts, there is a tendency for them to play for some average amount of time before changing to Hangman. Inspection of the first and second sessions separately showed the following major differences: 35 percent of the subjects spent all of the first session playing Darts, and 23 percent of the subjects did not play Darts at all in the second session. However, all of the subjects spent at least some time playing Darts, and only 2 of the 80 subjects spent both sessions entirely on Darts.

An even more important factor affecting game-changing is how well the subject is doing. A regression was performed to predict whether the subject continues Darts after a round depending on how well the subject is doing and on how long the subject has been playing. Since exact times were not recorded at the end of each round but only when subjects changed games, two kinds of substitute measures were used in this regression. The amount of time spent playing Darts before a given round was approximated by the number of previous guesses and by the number of previous rounds.

Altogether 6 independent variables were included in the regression to predict game changing after a round: (1) score on the current round, (2) score on the previous round, (3) number of rounds in this period (i.e., since the last game change), (4) number of guesses in this period, (5) number of rounds altogether for the subject, (6) number of guesses altogether for the subject. Score on the current round was a very strong predictor of game-changing ($F(1,454) = 12.6$, $p < .01$), and in fact was the only significant variable of the ones included. Students who did well in a round were much more likely to continue the game than students who did poorly. To interpret this result, one must bear in mind that the linear regression used was only a test of the linear effects of the variables. Figure 5, above, shows that the effect of time on game-changing is curvilinear rather than linear, but the effect still appears to be fairly weak. Inspection of the surrogate time measures used in the regression revealed a similar curvilinear effect.

Inspection of the results shows that score has a positive effect on continuing the game thoughout the range of the scores. Students who got nearly perfect scores were the most likely of all to continue. This result is true, not only for all problems considered together, but also for each problem considered separately. At first glance, this result appears to be a disconfirmation of the

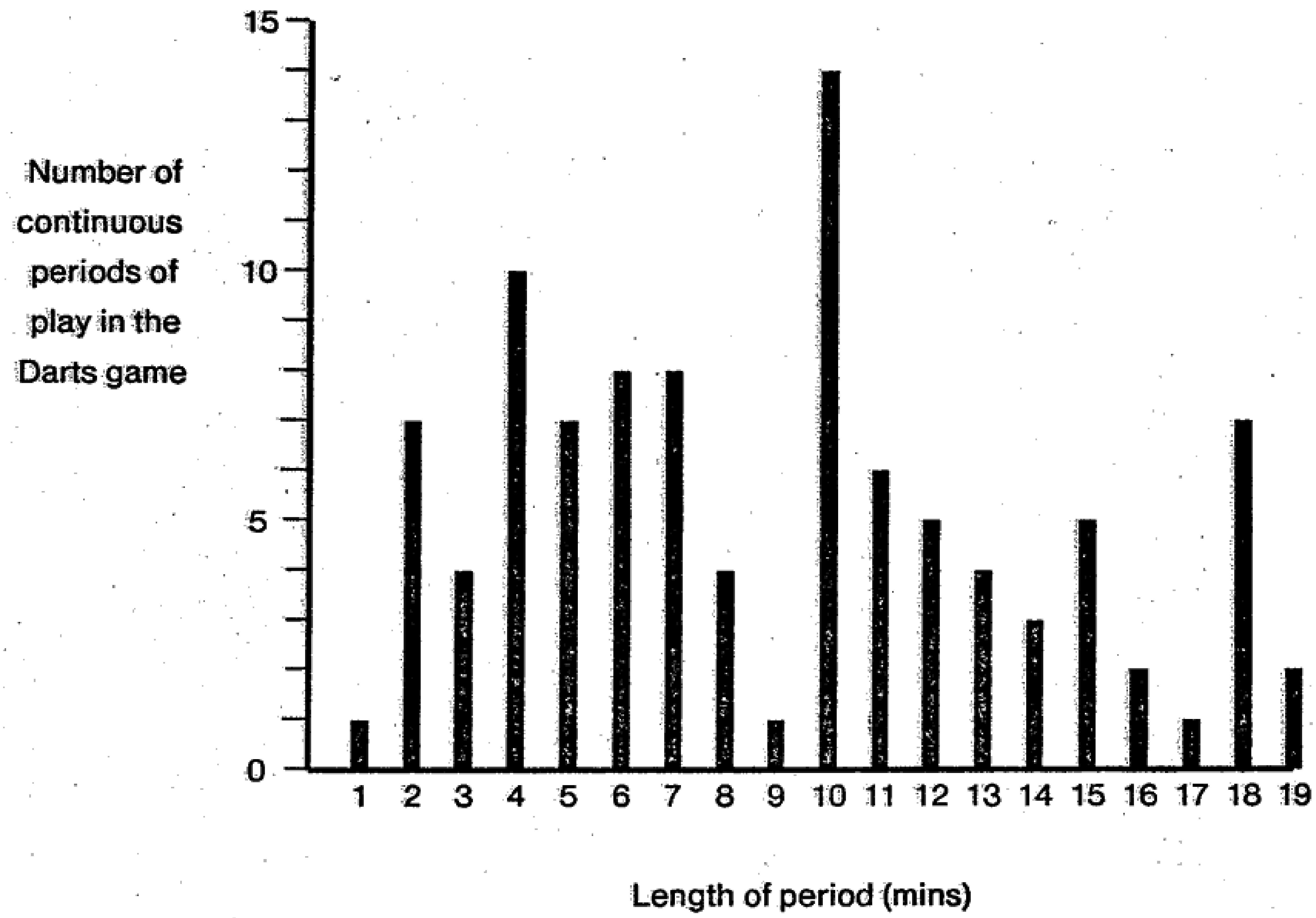


FIGURE 5. Distribution of playing times of the Darts game.

hypothesis that people prefer an optimal level of challenge, neither too hard nor too easy. If the optimal level hypothesis were correct, the relationship between difficulty and interest should be an inverted "U" rather than the monotonically increasing curve found here. But if the range of students sampled includes only those in the lower half of the curve, then a monotonically increasing curve like that found here would result. If the sample had included a much wider ability range (perhaps up to high school or college students), those at the high end of the range would presumably have done so well that the activity would have quickly become uninteresting for most of them. This would have given rise to an inverted "U" curve in terms of underlying ability level, even though the score on the Darts game might not have been able to measure differences in the upper part of the range. In other words, the results are consistent with an optimal level of challenge hypothesis, if we assume that the Darts game is challenging even for the fifth graders who do very well on it. My casual impressions of the students working on the game are consistent with this assumption.

## Discussion

In this study, as in the study of Breakout, I started with a popular game and then designed a number of degenerate versions of the original game. It would have been no surprise to find, as in Breakout, that each time a feature was removed, the game decreased slightly in appeal. In fact not only did removing some of the features actually increase the appeal of the game, but the original game itself turned out to be significantly less appealing for girls than one of the "degenerate" versions. Why should this be so?

Before discussing these results further, a comment is in order about the implications of the differences between boys and girls. There is a danger, in reporting these results, of helping to perpetuate stereotypes of human beings on the basis of their gender. This is certainly not my intention. There is no reason to believe, on the basis of these results, that the sex differences in game preferences reflect anything other than differences in the ways boys and girls are now socialized in our culture (see Maccoby & Jacklin, 1974). It seems likely that game preferences are affected just as much or more by other cognitive or personality differences I did not record as they are by gender, which I did record.[3] But even if gender is only one of many determinants of what children find interesting, it is still important to understand this effect. For example, if mathematics games like Darts are unintentionally designed in a way that appeals more to boys than to girls in our present society, then sex differences in attitudes toward mathematics may be unwittingly perpetuated. In this sense, then, understanding existing differences may help remove future differences.

[3] There is an interesting parallel here between scientific perception through experiments like this one and ordinary interpersonal perception. I chose to record the sex of my subjects because it was easy to do, but not to make more difficult assessments of personality or cognitive differences. In the same way, we often judge people in ordinary life on the basis of easily perceived differences like gender rather than on the basis of other, usually more important, personal characteristics.

Now, why did the girls dislike the standard version of Darts in comparison to the version with an extrinsic fantasy? The simplest explanation would be that, for some reason, girls prefer extrinsic to intrinsic fantasies in general. However, I think there are some more plausible explanations. The principal difference between Conditions 7 and 8 is whether the fantasy is intrinsic or extrinsic. But there are subtle differences in the implementations of the two conditions. In Condition 7, the player's guess is marked immediately on the number line, and an arrow goes across the screen only if the guess is right. In Condition 8, an arrow goes across the screen after every guess, and there is a moment of suspense before the player can tell whether the guess is right or wrong. These subtle differences suggest several possible explanations for the girls' preference of Condition 7:

(1) The girls preferred Condition 7 because they were more impulsive or achievement-oriented than the boys and did not like having to wait for the arrow to travel across the screen after every guess. (In Condition 8, it took about 6 seconds for the arrow travel and printing after a wrong answer; in Condition 7, it only took 3 seconds to mark and print the wrong answer. Both conditions took about 8 seconds after a right answer.)

(2) The girls preferred Condition 7 because they did not have to wait as long to find out if their guesses were right or wrong. (They had to wait about 3 seconds in Condition 8 and 1 second in Condition 7.)

(3) The girls preferred Condition 7 because they disliked the fantasy of arrows and balloons in the first place and the fantasy was more salient in Condition 8. (In Condition 7, they saw arrows only after right answers, that is, only about 40 percent of the time.)

Of these possible explanations, I prefer the last one for several reasons. First of all, the girls in Condition 7 made slightly fewer guesses per minute than the girls in Condition 8. If they had preferred Condition 7 because it allowed them to guess faster, we would have expected them to make more guesses per minute. More importantly, there are no good *a priori* reasons to expect a difference between boys and girls in their impatience to work more problems or to find out whether their guesses were right or wrong. After an extensive review of psychological studies of sex differences, Maccoby and Jacklin (1974) found no consistent differences between boys and girls in either impulsivity or achievement motivation.

There are several reasons, however, for thinking that girls did not like the arrows and balloons fantasy. When the arrows and balloons fantasy was first introduced in Condition 5, the girls liked it less than the previous condition though this difference was not statistically significant. Rosenberg and Sutton-Smith (1960) in a study of sex differences in children's game preferences found that boys (age 9 - 11) liked games that involved propelling objects through space (including darts) and girls did not. Finally there is anecdotal evidence that the girls did not like the Darts fantasy. One little girl, in the post-experimental interview, said, "Darts is more like a boys' game." When I went back to the classes where I had done the experiment to tell them about the results, I first explained the conditions, said that there were differences between boys and girls in what they liked, and then asked them to guess what the differences were. Most of the classes guessed that girls would have liked music and boys would have liked exploding the balloons.

For all these reasons, I think that the girls disliked the intrinsic fantasy because the Darts fantasy--which they disliked in the first place--was more salient in the intrinsic version. I think that if a game like Darts were designed with a fantasy that appealed to girls, the girls would like the intrinsic version better than the extrinsic version. This is what happened for the boys with the Darts fantasy, though the difference was not significant.

If it is true that boys like the arrows and balloons fantasy and girls do not, why should this be so? As noted above, boys like the non-computer darts game better than girls do. To the extent that both the non-computer game and the computer Darts game involve destroying balloons with weapon-like objects, they may be considered aggressive. Maccoby and Jacklin (1974) found convincing evidence from an extensive review of psychological studies that boys are more aggressive than girls. Thus a possible explanation of the sex difference in preference for Darts lies in the aggressiveness of the fantasy.

In summary, the primary result of this experiment is that there is a significant difference in what boys and girls like about the Darts game. Boys like the fantasy of arrows popping balloons and girls apparently dislike this fantasy. The implication of this finding is *not* that boys should be given one kind of fantasy and girls should be given another. Even if some fantasies appeal more to most boys and others appeal more to most girls, I see no reason at all why the fantasies should be labelled as boys' and girls' versions. It would be better, I think, to let each person choose whichever fantasy seems most appealing at the time. These choices will presumably depend on many factors besides gender.

I think the most important implication of these results is that fantasies can be very important in creating motivating instructional environments but that, unless the fantasies are carefully chosen to appeal to the target audience, they may actually make the environment less interesting rather than more.

Two other features also significantly affect the appeal of the Darts game. Girls like the music, and boys do not like the verbal constructive feedback. Since the boys' dislike of verbal constructive feedback was not statistically significant in the regressions with "naive" feature definitions, it seems less reliable than the other results.

One of the reasons that is often given for why computer games are so captivating is that they are responsive, that they provide feedback about what the person is doing. This experiment allows a partial test of that hypothesis since Condition 1 provides almost no feedback and all the other conditions provide at least right/wrong feedback. If the mere presence of feedback were the most important aspect of the success of Darts, then the difference between Conditions 1 and 2 should have been greater than any other differences between adjacent conditions. In fact, fantasy and music both appear to be more important than feedback in making this game appealing. But the fantasy in computer games is a unique form of responsive fantasy. The viewers of movies and books are passive observers of the fantasies that are depicted. The players of computer games, on the other hand, are active participants in the fantasy worlds created by the games.

# Chapter V

# Toward a Theory of Intrinsically Motivating Instruction

Several of the theorists discussed in Chapter 1 (e.g., Piaget, 1951; Bruner, 1966; Berlyne, 1965; Moore & Anderson, 1969) deal with intrinsically motivated learning, and several others (e.g., Csikszentmihalyi, 1975, 1978; Eifferman, 1974) deal with intrinsic motivation in general. But none of the theories deals satisfactorily with all three of the major kinds of motivation discussed above: challenge, fantasy, and curiosity. Csikszentmihalyi, for example, presents a detailed analysis of the role of challenge in intrinsic motivation, but since he is not dealing specifically with learning he does not mention curiosity, the most obvious intrinsic motive for learning. Similarly, Berlyne analyzes curiosity in some detail, but neglects challenge and fantasy altogether. Bruner perhaps comes closest to the taxonomy presented here by giving prominent roles to challenge and curiosity, but he does not develop the implications of either in much detail, and he does not mention fantasy. Piaget does a very admirable job of synthesizing all three elements into a coherent theory. To greatly oversimplify his theory for the purpose of comparison, he claims that people are driven by a will to mastery (challenge) to seek optimally informative environments (curiosity) which they assimilate, in part, using schemas from other contexts (fantasy). But though a number of people have applied Piaget's ideas to educational practice (e.g., Furth, 1970; Kamii & DeVries, 1977) the implications of his theory for instruction are often ambiguous or extremely general (Groen, 1979).

In short, none of the theories is satisfactory as a basis for instructional design that captures what seem to be the most important aspects of the computer games studied above and other well-known computer games (e.g., Ahl, 1973, People's Computer Company, 1977). Using these computer games as inspiration, I will suggest in this chapter how a more comprehensive theory of instructional design might be developed based on the three categories: *challenge, fantasy,* and *curiosity.* This chapter will be devoted to a theoretical analysis of instructional environments in general, but the primary goal of the analysis is to guide the design of computer-based instructional environments. In the next chapter, I will present a more specific set of heuristics for the design of instructional computer games.

## Challenge

A number of writers have noted that in order for an environment to be challenging, it must provide *goals* whose attainment is *uncertain* (e.g., Kagan, 1978, p. 157; Eifferman, 1974). A careful analysis of the computer games studied above shows that there are at least four general ways that the attainment of a goal can be made uncertain for a wide range of people or for the same person at different times:

(1) *Variable difficulty level*

(2) *Multiple level goals*

(3) *Hidden information*

(4) *Randomness*

I will now discuss each of these factors in more detail from the perspectives of several psychological theories and two formal models: mathematical game theory and information processing models of problem solving.

### *Goals*

There are several reasons for believing that goals are important to intrinsically motivating environments. In Study 1, the single feature of the computer games that correlated most strongly with preference was whether or not the game had a goal. In a sense, the very notion of "game" implies that there is an "object of the game."

In mathematical game theory (see, e.g., McKinsey, 1952), the object of a game is represented by assigning utilities (or at least a preference ordering) to all the possible outcomes of the game. There is no requirement in game theory, or indeed in the theory I am proposing here, that there be only two outcomes of a game (e.g., win or lose). But in games with a large number of possible outcomes, there seems to be a motivational advantage to converting a continuous utility scale into a discontinuous goal by setting a criterion level. For example, players in a game where a score is kept (like Breakout) often have a goal of beating their own or someone else's previous record. In other words, the continuous point scale has been mapped into a discontinuous utility scale with point scores below the goal (in this case, the previous record) having a low utility and point scores above the goal having a high utility. (Note that the utility scale might not actually be discontinuous if "almost" reaching the goal is "almost" as valuable as completely reaching it. The utility curve would, however, still be very steep and inflected near the goal.)

Bandura and Schunk (1980) have carefully explored the effects of this kind of goal-setting on performance and motivation in long term activities like mastering many units of an arithmetic curriculum. They found that *proximal* (i.e., short-term) goals were significantly superior to no goals or *distal* (long-term) goals in sustaining performance and interest in the task. Though Bandura and Schunk interpret their results in terms of social learning theory concepts like self-efficacy expectations, the analysis here suggests that the results can just as well be interpreted as evidence for the importance of goals and challenge in intrinsically motivating environments.

There seem to be other aspects of goals that affect their motivational value as well. A study by Morozova (1955) gives some tantalizing suggestions about what some of these aspects might be. In this study, children read several variants of a text passage about latitude and longitude. The version in which a child hero was faced with the practical problem of finding his location was much more interesting (and understandable) to the children than the other versions. The goal in this version had several intriguing qualities: (1) Using the skill being taught was a means to achieving the goal, but it was not the goal in itself. (2) The goal was part of an intrinsic fantasy as discussed below. (3) Because of the child hero, the goal was presumably one with which the child readers could identify. It is, of course, not clear without further study which of these aspects of the goal is most important.

Another aspect of goals is highlighted by Csikszentmihalyi's (1975) distinction between *fixed goals* and *emergent goals*. He defines fixed goals as those that are predetermined by cultural convention (like winning a game) while emergent goals arise out of the interaction between a person and the environment (like drawing a certain kind of picture). Csikszentmihalyi would claim that there should at least be easily generated emergent goals in intrinsically motivating environments. The correlational results in Study 1 above suggest (though do not prove) that, for these young computer game players, emergent goals like those in the story completion program and the drawing program were not as motivating as the fixed goals in games like Petball and Breakout. Clearly there is room for further experimental clarification here.

*Uncertain outcome*

An environment is not challenging if either the person is certain to reach the goal or certain not to reach the goal. From the perspective of mathematical game theory, McKinsey (1952, p. 126) remarks that, ". . . after optimal strategies for a game are known, it ceases to offer any intellectual challenge, and people stop playing it." This factor, together with randomness and hidden information, gives rise to the three ways the outcome of a game can be uncertain:

1. *Chance plays a role in the game.* For example, in card games the cards are usually dealt randomly to players and this introduces uncertainty into the outcome. (It is interesting to note that while randomness affects the certainty of the outcome of a game, it does not affect whether there is a simple optimal strategy for the game. That is determined by the next factor--the availability of information.)

2. *There is hidden information.* For example in Kriegspiel chess, neither player knows where the other player's pieces are located unless a hidden piece captures a piece, is captured, or prevents an attempted move. (This game requires two chess boards and a referee). In game theory, this is called imperfect information and it implies that the optimal strategy may be a random mixture of simple strategies rather than a single pure strategy. The randomness introduced by the players' strategies thus makes the outcome uncertain. Hidden information can also make the outcome of a game uncertain even when it does not lead to mixed strategies. For example, hidden information in one-person guessing games can make outcomes uncertain even given a constant difficulty level.

3. *Cognitive limitations of the players prevent them from knowing the optimal strategies.* For example, since chess is a game of perfect information there must, according to game theory, exist an optimal strategy for playing it. But since no known intelligence (either human or machine) can compute this optimal strategy, chess remains an interesting game whose outcome is uncertain for evenly matched players. In Tic Tac Toe, on the other hand, the optimal strategy is known to adult players, the outcome is certain, and therefore the game is uninteresting.

To be more specific about how the cognitive abilities of the players affect the outcome of a game, I will use a formalism developed in studying problem-solving.

*An information processing analysis of challenge*

A very large and interesting class of intellectual activities, whether performed by people or machines, can be characterized in terms of a current information *state*, a desired information state or *goal*, a set of *transformations* for changing one state into another, and a body of *search control knowledge* for deciding which transformations to apply in order to change a current state into a more desirable one (Newell & Simon, 1972; Newell, 1979).

One of the most common examples analyzed in these terms is the Towers of Hanoi puzzle. In this game, there are three pegs and a number of disks of different sizes that fit on the pegs. The *state* at any time is the configuration of disks on the pegs. The *initial state* of the puzzle has all the disks arranged on one peg in order of size with the largest on the bottom and the smallest on the top. The *goal* is to get all the disks on another peg, arranged in the same way. The possible *transformations* consist of moving a disk from one peg to another, subject to the *constraints* that only the top disk on a peg can be moved and a disk can never be moved to a peg that has smaller disks on it. The *search control knowledge* determines which disk to move when. The *problem space* for this puzzle consists of all the possible states connected by the transformations that change one state into another one. (Simon (1975) and others (e.g., Nilsson, 1971) present much more complete analyses of this problem. The simple description here is intended merely to introduce the model.)

Now, what makes a problem interesting in terms of this model? First of all, the importance of having a *goal* in a challenging environment is nicely represented by the fact that a goal is an essential part of the problem-solving model. Two ways of making an outcome uncertain also have interesting interpretations in this model:

(1) *Variable difficulty level.* The difficulty of solving a problem depends on a number of factors, including the amount of search required to reach the goal, the effort required to apply the transformations, the memory capacity required to carry out the search, etc. An environment with a variable difficulty level thus includes a family of problems that vary in difficulty for one or more of these reasons.

(2) *Multiple level goals.* There are at least two kinds of multiple level goals:

(a) In the first kind, all the goals are of the same type, but they vary in difficulty. For example, in Breakout, the goal of destroying all the bricks in the first row, is different in difficulty but not different in kind from the final goal of destroying all the bricks. The chief advantage of this type of multiple level goal seems to be simply that it provides a variable difficulty level within a fixed problem environment.

(b) The second kind of multiple level goal is more subtle. In the Darts game, for example, the high level goal is not just to pop all the balloons, but to pop them in as few tries as possible. High level goals, in other words, often deal with solving problems faster or with fewer steps. In terms of the problem-solving model, this implies that the search control knowledge is becoming more efficient based on experience (see Anzai & Simon, 1979), or that the execution of the transformations is becoming faster (e.g., "automatized", see LaBerge, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). In this sense, multiple level goals truly are at different levels. The goal of making the search control knowledge more efficient is at a fundamentally different level from, say, the simple goal of moving all the disks to another peg. The implication here is that *well-designed instructional environments, by providing high level goals, can take advantage of a "natural" cognitive motivation to optimize existing mental procedures.* This is, of course, a testable hypothesis.

Apart from the high level motivation to optimize existing procedures, we are left with the question of why goals of varying difficulty should be motivating. The problem-solving model has little to say about this question. To answer it, we need a theory of why the problem solving process is invoked in the first place. One way of addressing this issue is to assume that people try to pick a goal at a difficulty level that maximizes some function of the probability of success and the value of success. This is the approach taken by most theories of achievement motivation (e.g., Atkinson, 1964). Another way of addressing the issue is to assume that people pick goals that will give them the most information about themselves, thus satisfying their curiosity. In fact the two approaches are closer than they seem. Studies of achievement motivation find that people often pick goals for which their probability of success is near 0.5 (see Weiner, 1980). But these are exactly the goals that are most informative in the technical sense of information theory since their outcome is most uncertain. In either case, as people's abilities increase, the absolute difficulty level they find most challenging will also increase and therefore an intrinsically motivating environment should provide this increasing level of difficulty.

The problem solving model illuminates some even more subtle features of the *structure of the* *problem space* in intrinsically motivating environments. As noted above, problems can vary in difficulty because of differences in memory capacity used, the amount of search required, and so forth. One particularly interesting kind of difficulty in searching problem spaces has to do with how straightforward the solution strategy is. Many puzzles (e.g., Towers of Hanoi and Missionary and Cannibals--see Glass, Holyoak, & Santa, 1979, pp. 409-420) cannot be solved by a simple strategy in which one is always clearly getting closer to the final goal. For example, one cannot just move the disks directly to the target peg, one at a time, in the Towers of Hanoi problem. Instead, one sometimes has to move disks *away* from the target peg in order to eventually reach the solution. In other words, a simple "hill climbing" strategy--where one always advances directly toward the solution--will not work, and a more sophisticated strategy is necessary. This subtlety in the problem-solving strategy may contribute to the interest of many puzzles.

There is an important distinction here between *puzzles* and *tools.* Straightforward hill climbing strategies usually do work in the problem spaces defined by well-designed tools like computer text editors. For example, to make a set of corrections in a manuscript, one usually applies a series of editing commands, one at a time, and each command makes the manuscript more like the desired error-free version.[4] One paradoxical implication of this observation might be that tools like text editors could be made more game-like by making them less straightforward to use. But in the case of text editors, the central problem is not how to use the editing commands, but how to improve the document being edited. This problem is already uncertain in its own right, and subgoals involving how to use the text editing tools seem to be frustrating distractions, rather than interesting additions to the problem space. It is not yet clear how to distinguish *a priori* between these two kinds of goals. One kind of goal is involved in puzzles and games and its interestingness is enhanced by the uncertainty of its outcome (either because the solution path is not straightforward or because of randomness). The other kind of goal is achieved by using tools, and uncertainty in reaching this kind of goal is usually frustrating.

It is, of course, easy to create problem spaces that are so far from being straightforward that they are too difficult to be interesting. Two professional game designers (Abbot, 1975; Solomon, 1977) have pointed out the importance of balancing the number of possible successor states for each state of the game. According to Solomon (p. 15), "If there are too many, analysis of play may be difficult or

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4 I am indebted to Tom Moran for pointing this out.

'shallow'. If there are too few, analysis may be carried out to a great depth and victory will probably go to the most painstaking player." While it is not clear that this conclusion is correct, the approach of analyzing games in terms of the abstract structure of their problem spaces may help illuminate certain aspects of their appeal.

*Self-esteem*

Goals and challenges are captivating because they engage a person's self-esteem. Success in an instructional environment, like success in any challenging activity, can make people feel better about themselves. The opposite side of this principle is, of course, that failure in a challenging activity can lower a person's self-esteem and, if it is severe enough, decrease the person's interest in the instructional activity. The complexities of this relationship between self-esteem and achievement have been extensively studied by attribution theorists and others (see Weiner, 1980, for a comprehensive review). One simple implication of this relationship is that instructional activities should have a variable difficulty level so learners can work at an appropriate level for their ability (leaving aside for the moment the often difficult questions of how ability level is determined). Another implication might be that performance feedback should be presented in a way that minimizes the possibility of self-esteem damage. Note that there is a tension here between the need to provide clear performance feedback to enhance challenge and learning, and the need not to reduce self-esteem to the point where the challenge becomes discouraging rather than inviting.

## Fantasy

Fantasies can make instructional environments more interesting and more educational. I define a fantasy-inducing environment as one that evokes "mental images of things not present to the senses or within the actual experience of the person involved" (American Heritage Dictionary). These mental images can be either of physical objects (e.g., darts and balloons) or of social situations (e.g., being the ruler of a kingdom).

*Intrinsic and extrinsic fantasies*

As discussed in Chapter 4, fantasies can be either *intrinsic* or *extrinsic* to the skill being used in the environment. Figure 6 illustrates the logical dependencies in the two cases. In an extrinsic fantasy,

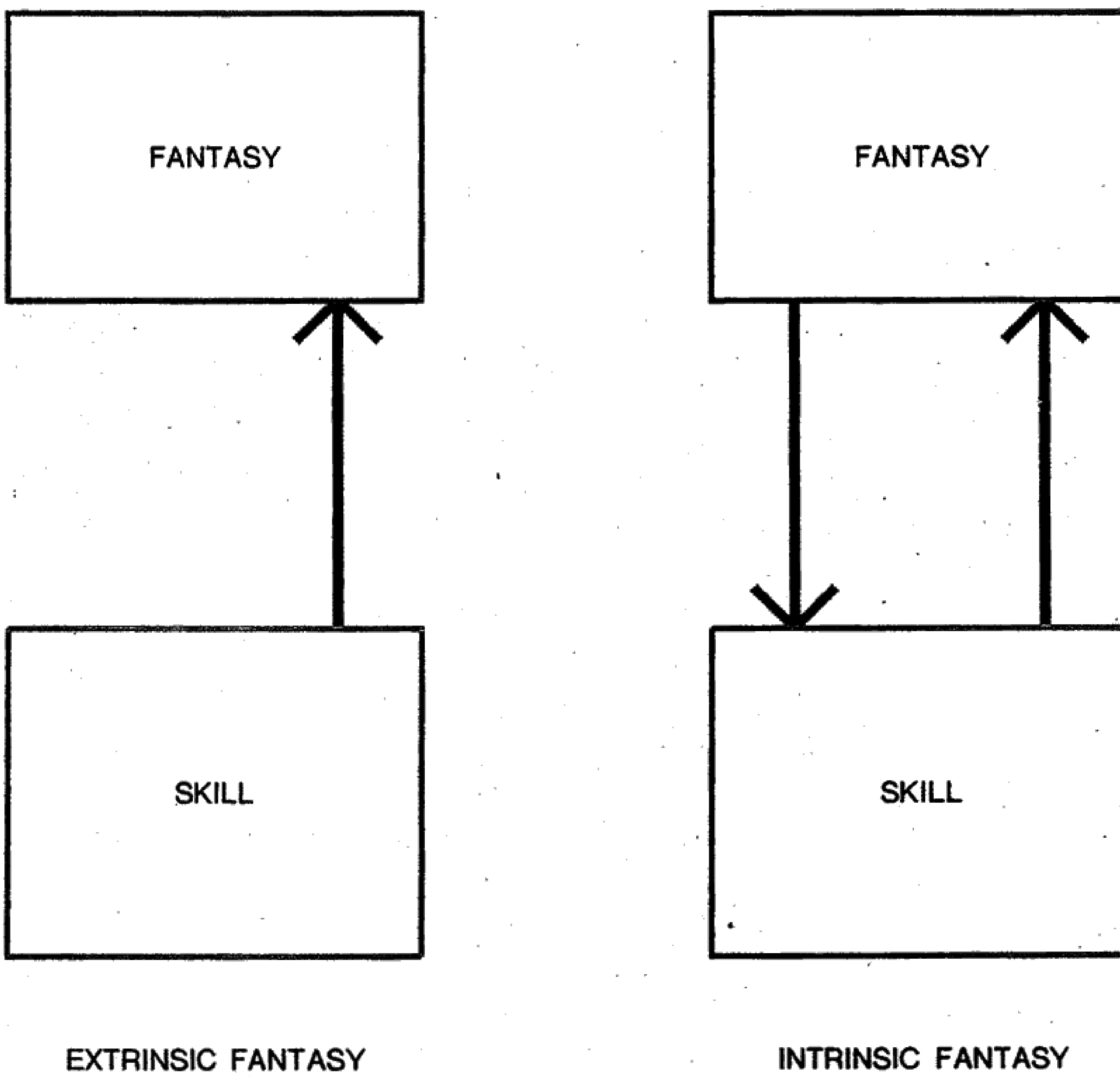


FIGURE 6. Logical dependencies in intrinsic and extrinsic fantasies

the fantasy depends on the use of the skill but not vice versa. Most extrinsic fantasies depend on whether or not the skill is used correctly (i.e., whether the answer is right or wrong), but other factors like how quickly the answer is given or how close the answer is to being correct can also affect extrinsic fantasies. For example, a classroom "Baseball" game where students advance to bases around the room depending on whether or not they spell words correctly is an extrinsic fantasy. So is a computer "race car" game in which students' cars move along a race track depending on how fast they answer arithmetic problems. In none of these cases, however, does the exercise of the skill depend in any way on the fantasy. The same arithmetic or spelling problems could be given with different fantasies or with no fantasies at all.

In intrinsic fantasies, on the other hand, not only does the fantasy depend on the skill, but the skill also depends on the fantasy. This usually means that problems are presented in terms of the elements of the fantasy world. For example, in Darts, the skill of estimating distances is applied to the fantasy world of balloons on a number line. The use of the skill then affects the fantasy world by shooting arrows and popping balloons. In intrinsic fantasies, the events in the fantasy world usually depend not just on whether the skill is used correctly, but on how its use is different from the correct use. For example, players of the Darts game can see graphically whether their answers are too high or too low and if so by how much. All the classroom simulation games like the Life Career Game and the Legislative Game (Boocock & Schild, 1968) are intrinsic fantasies for the various kinds of decision-making and role-playing skills they involve.

Notice that a fantasy is always intrinsic or extrinsic *with respect to* a particular skill. In most cases, there is one primary skill in an activity or the fantasy is intrinsic or extrinsic with respect to all the skills of interest. In these cases it is convenient to omit the mention of the skill and simply refer to the fantasy as being intrinsic or extrinsic in that environment.

I would like to claim that: *In general, intrinsic fantasies are both (a) more interesting and (b) more instructional than extrinsic fantasies.* This is, of course, a testable hypothesis. The experiment in Study 3 was intended, in part, to test the first part of this hypothesis, but the apparent unappealingness of the basic fantasy for girls prevented a strong test. One advantage of intrinsic fantasies is that they often indicate how the skill could be used to accomplish some real world goal. Simulations, like the Lemonade stand simulation, are obvious examples of this. More importantly, the cognitive advantages of fantasies discussed in the next section apply only to intrinsic fantasies, not to extrinsic ones.

*Cognitive aspects of fantasy*

As discussed above, Piaget assigns a central role to make-believe play in the development of symbolic representation skills in children. Some recent theorists (e.g., Petrie, 1979) go even further and claim that some kind of metaphor or analogy is epistemologically necessary for anyone to ever learn anything radically new because new knowledge can only be comprehended in terms of old knowledge. Even without making a claim of epistemological necessity, it is clear that analogies of the kind provided by intrinsic fantasies can often help a learner apply old knowledge in understanding new things. For example, players in the Darts game already know about physical objects (like arrows and balloons) being higher or lower than other objects. If they make the crucial connection between number size and position on the number line, then they are able to use this old knowledge in the new domain to make inferences about the relative sizes of unfamiliar fractions. Miller (1979) and VanLehn & Brown (1979) present two candidates for notations that might be used to specify in more detail the correspondences and inferences students would have to make when using intrinsic fantasies as productive analogies.

So far I have assumed that the fantasy world is more familiar to the student than the skill being learned. In the case of simulations, the purpose may be just the opposite. Students may be learning a skill in a partly imaginary simulation that they will later need to transfer to a real world situation. The cognitive advantages of having the intrinsic fantasy approximate the situation in which the skill will be applied are obvious. In some cases, however, giving a fantasy a great deal of mundane realism (e.g., a flight simulator for pilots) may detract from wish fulfillment or other emotional advantages of fantasy.

The final cognitive advantage of intrinsic fantasies is simply that, by provoking vivid images related to the material being learned, they can improve memory of the material (Bower & Winzenz, 1969; Bower, 1972; Paivio, 1971).

*Emotional aspects of fantasy*

In Chapter 1, I discussed several emotional functions of fantasy such as wish fulfillment and symbolic conflict resolution. These aspects of fantasy have been studied primarily in relatively unconstrained situations like dreams, daydreams, and projective tests. The fantasies were seen as being determined by pre-existing motivations. In designing intrinsically motivating instruction, we are concerned with almost the opposite question--not how does motivation affect fantasy but how does fantasy affect motivation, specifically motivation to learn? My hypothesis is that if the fantasies in instructional environments serve the same kinds of wish fulfillment and conflict resolution functions as other fantasies, then they can "harness" the pre-existing emotional motivations and use them to increase interest in learning.

There are several ways this might be done:

(1) By providing a single fantasy that is likely to be appealing to the target population.

(2) By providing several fantasies for the same instructional material and letting students choose their favorite fantasy.

(3) By providing an environment into which students can project their own fantasies in a relatively unconstrained way. For instance, one could let students name imaginary participants in a computer game.

Clearly these things are much easier said than done. The unexpected difference between boys and girls in the Darts experiment illustrates the difficulty of predicting what kinds of fantasies will be appealing to different people. There are also difficult questions about whether it is sometimes bad to encourage certain fantasies. For example, if a computer game provides an outlet for aggressive fantasies, will players become more or less aggressive in real life? (See Liebert & Poulos, 1976, for a related review of empirical studies on the effects of television violence.)

## Curiosity

As discussed in Chapter 1, environments can evoke a learner's curiosity by providing an *optimal level of informational complexity* (Berlyne, 1965; Piaget, 1952). In other words, the environments should be neither too complicated nor too simple with respect to the learner's existing knowledge. They should be *novel* and *surprising,* but not completely incomprehensible. In general, an optimally complex environment will be one where the learner knows enough to have expectations about what will happen, but where these expectations are sometimes unmet.

There are a number of parallels between challenge and curiosity:

(1) Challenge requires an optimal level of difficulty in reaching a goal; curiosity requires an optimal level of complexity in what is to be learned. For this reason, both challenge and

curiosity often depend on adjusting the level of the environment to the level of the learner's ability or understanding.

(2) Challenge involves reducing uncertainty about one's own ability to reach a goal; curiosity involves reducing uncertainty about the state of the world. Both depend on feedback to reduce uncertainty.

Not only are the two concepts parallel, but in a way, either concept could subsume the other. Challenge could be explained as curiosity about one's own ability. Curiosity could be explained as a challenge to one's understanding.

In spite of these similarities between challenge and curiosity, however, I think it is useful to separate the two concepts. While the notion of self-esteem is central to the idea of challenge, self-esteem is not involved in most curiosity. Similarly, the cognitive models of curiosity I will sketch below, while provocative in their implications for curiosity, have little to contribute to an understanding of challenge. In other words, there seem to be a number of theoretical advantages to analyzing the two concepts separately.

It is also useful, in the following discussion, to distinguish between two kinds of curiosity--*sensory curiosity* and *cognitive curiosity*--depending on the level of processing involved.

*Sensory curiosity*

Sensory curiosity involves the attention-attracting value of changes in the light, sound, or other sensory stimuli of an environment. Mander (1978) proposes an extremely interesting hypothesis about how television artificially manipulates the sensory curiosity of its viewers to give television a kind of "counterfeit" interest value. He defines a "technical event" as a change of camera angle, a zoom, or some other similar technical change in the image being presented. He claims that these technical events artificially capture our attention independent of the content of the television program. According to his observations, television commercials average 20 to 30 technical events per minute, regular programming averages 8 to 10 technical events per minute, and public television averages only 2 to 3 technical events per minute.

One implication of this observation is that educational television could be made more interesting simply by increasing the frequency of technical events. In fact, educational television shows like *Sesame Street* seem to take advantage of this and other techniques of commercial television. More generally, there is no reason why educational environments have to be impoverished sensory environments. Colorfully illustrated textbooks and tactile teaching devices (e.g., Montessori, 1912) demonstrate this point, and as discussed in the next chapter, computers provide even more possibilities for audio and visual effects.

*Cognitive curiosity*

In contrast to the perceptual changes that evoke sensory curiosity, cognitive curiosity is evoked by the prospect of modifying higher level cognitive structures. Though I will not pursue the subject in great detail here, it may prove fruitful to investigate how this intrinsic motivation for learning is related to information processing representations of the learner's knowledge and skills. In general, curiosity can be thought of as a desire to bring better "form" to one's knowledge structures. In particular, I claim that people are motivated to bring to all their cognitive structures three of the characteristics of well-formed scientific theories: *completeness, consistency,* and *parsimony.* According to this theory, the way to engage learners' curiosity is to present just enough information to make their existing knowledge seem incomplete, inconsistent, or unparsimonious. The learners are then motivated to learn more in order to make their cognitive structures better-formed. For example:

(a) *Completeness.* If you have just read all but the last chapter of a murder mystery, you have a strong cognitive motivation to bring completeness to your knowledge structure by finding out who the murderer was. This motivation to bring completeness to cognitive structures is closely related to the tendency to return to, and remember better, activities that are interrupted before completion (Ziegarnik, 1927; Osvianka, 1928).

As another example, Berlyne describes an experiment by Maas (cited by Peel, 1961) in which subjects were shown "exotic" objects borrowed from a museum. The subjects saw the objects three times, each time receiving more information about the objects. After each viewing the subjects rated to what extent they wanted to know more about the objects, and there was a significant tendency for curiosity to increase with successive presentations. Berlyne's interpretation of this experiment is the following (p. 262-263):

> "Once again, we have some indication that epistemic curiosity is not at its maximum with complete ignorance but increases, up to a point, with increasing knowledge. As long as knowledge is *incomplete*, the more there is of it, the more scope there presumably is for conflicting symbolic response tendencies." [my italics]

A much more natural explanation, it seems to me, is simply to use Berlyne's own word and call this experiment a demonstration of how incomplete knowledge structures induce curiosity.

(b) *Consistency.* Morozova (1955) suggests that a topic can be made more interesting by creating inconsistencies in a learner's knowledge. For instance, students may be told that plants require sunlight for the photochemical processes on which they depend, but that some plants, namely fungi, can live in the dark.

(c) *Parsimony.* One way of stimulating curiosity by appealing to parsimony is to give a number of examples of a general rule before showing how (or letting students discover that) all the examples can be explained by the single new rule.

In order to develop this theory of cognitive motivation, I think it would be important to try to define completeness, consistency, and parsimony more carefully in some knowledge representation formalism. For example, the notion of completeness seems to imply that the frames (Minsky, 1975) invoked in an understanding process are completely filled in. In the murder mystery example, you have a strong cognitive motivation to complete your "murder frame" by filling in the slot for the murderer. Another possibility for developing the theory would be to sharpen the concepts in terms of laboratory experiments. For instance, I would predict that subjects in traditional concept learning experiments will be more interested and curious at points where they have just been surprised by an inconsistency between their predictions and the correct answer.

Still another possible approach to this problem is suggested by Schank (1979). Schank's problem is to restrict the explosion of possible inferences made by a language understanding program to those that are "interesting". His notions of interestingness are partly a reflection of those discussed here. For example, "unexpected events" are a prime signal of interestingness. Another important factor affecting interestingness is how related the event is to the reader. Schank also proposes a number of specific concepts like death, danger, sex, and destruction as being interesting in general. Though Schank does not do this, the interestingness of many of these specific concepts could presumably be explained in terms of the emotional aspects of fantasy discussed in Chapters 1 and 6.

The important point here is that theories about what is "interesting" to automated text understanders can also be viewed as theories of what is interesting to human learners. The theories can then be used to design interesting instructional environments that take advantage of the learners' natural curiosity. In a computer-based environment for example, the same knowledge about interestingness that Schank represents in a story understanding program to control inferences, might be used in a story generating program to create interesting stories for students to read.

## Summary

In this chapter, I have suggested a coherent framework for a theory of intrinsically motivating instruction. I have also described a number of ways this theory can be developed and related to other theoretical systems. It is clear that this is not yet a fully developed formal theory. But I believe the framework I have outlined here is already useful in at least two ways. First, the framework helps direct attention to what seem to be the most important aspects of intrinsically motivating instruction. For instance, I think the potential value of fantasy in creating motivating instructional environments has often been overlooked. As evidence of the usefulness of this framework, the next chapter illustrates how the theory can be applied to instructional computer games. The second use of the framework is as a taxonomy of intrinsic motivation that can help clarify theoretical distinctions, For example, one might expect very different factors to be operating in activities that depend primarily on challenge for their appeal than in activities that depend primarily on fantasy or curiosity.

I have focused in this chapter, and indeed in most of this report, on features that can be present in all learning environments, neglecting phenomena, like cooperation and competition, that emerge only in situations involving more than one person. It seems clear, however, that interpersonal motivations are often very important in learning. A number of sources suggest how a theory including these motivations could be developed. For example, Bruner (1966) points out the importance in instruction of social processes like *reciprocity* (by which he means cooperation) and *identification* (or modeling one's self after some respected other person). DeVries and Slavin (1978) and Allen and Ross (1977) describe how competitive academic games can be used to stimulate both interest and learning. Finally, Cole (1979) and Levin and Kareev (1980) have begun to perform detailed cognitive analyses of how children cooperate in learning to solve new problems. Clearly a complete theory of intrinsically motivating instruction should suggest ways that learning can be fostered by interpersonal--as well as individual--motivations.

# Chapter VI
# Heuristics for Designing Instructional Computer Games

In the previous chapter, I presented the ingredients of a theory about what makes instructional environments intrinsically motivating. In this chapter, I will be more specific about how this theory can be applied to instructional computer games. My primary goal is to provide a set of guidelines or heuristics for the designers of instructional computer games. To demonstrate the usefulness of these principles, I have described several possible applications to actual or proposed instructional games. Throughout the chapter I emphasize games with educational uses, but I focus on what makes the games fun, not on what makes them educational. I have also chosen to focus on game-like educational environments, but, of course, not all intrinsically motivating educational environments are games.

The principles in this chapter are organized in the same three categories as used in the previous chapter: *challenge, fantasy,* and *curiosity.*

## Challenge

*Goal.* The first implication of the theory is that even rich, responsive environments may be unappealing unless they provide an appropriate goal. More specifically:

1. Simple games should provide an obvious goal. Usually the more obvious and compelling the goal is, the better. Goals can be made obvious or compelling by the use of visual effects (Breakout) or fantasy (Hangman).

2. A complex environment without built-in goals should be structured so that users will be able to easily generate goals of appropriate difficulty. For example, one of the nice things about a programming system like Logo is that it is often easy to think of things for a moving "turtle" to do. But unless beginners have some suggested projects of the right difficulty level, they might easily pick tasks that are discouragingly difficult.

3. The best goals are often practical or fantasy goals (like reaching the moon in a rocket) rather than simply goals of using a skill (like doing arithmetic problems).

4. The players must be able to tell whether they are getting closer to the goal. This *performance feedback* may or may not be the same as the *informative feedback* discussed below.

*Uncertain outcome.* A computer game is not challenging if the player is either certain to win or certain to lose. There are four ways to make the outcome uncertain for players over a wide range of ability levels:

1. *Variable difficulty level.* Good computer games should be playable at different difficulty levels. The choice of difficulty level can be either:

(a) determined automatically by the program according to how well the player does (Breakout, drill-and-practice),

(b) chosen by the player (perhaps with ego-involving labels like "Cadet", "Captain", "Commander" in Star Wars), or

(c) determined by the opponent's skill (chess, Chase, etc.). I think one of the important reasons that competition is motivating is simply that it often provides a challenge at an appropriate difficulty level. (Note that if the computer is the opponent, this case can be equivalent to either (a) or (b).)

2. *Multiple level goals.* Good computer games often have several different levels of goals. With this feature, players whose outcome is certain at one level of goal may still be challenged by another level of goal. In general, two levels of goals can be created by having a basic goal of accomplishing something in the game world (like popping balloons or destroying bricks) and then a metagoal of reaching the basic goal efficiently. At least two game features create this kind of metagoal:

(a) *Score-keeping.* With this feature, the metagoal is to get as high (or as low) a score as possible. The score can reflect the number of tries, the number of successes, the difficulty of the successes, the resources expended, etc.

(b) *Speeded responses.* With this feature, the meta-goal is to do something as fast as possible, or faster than a deadline, or faster than one's opponent.

Sometimes these features provide subgoals rather than metagoals. For example, in Breakout, one can play with a goal of simply getting a higher score for a long time before the goal of destroying all the bricks becomes reasonable. Some games, like Adventure, provide not just two, but a whole series of levels of challenge.

3. *Hidden information.* Many games, especially guessing games, make the outcome of a game uncertain by hiding information from the player or players and selectively revealing it. This feature seems to provoke curiosity and well as contributing to the challenge of the game.

4. *Randomness.* A final way of making the outcome of a game uncertain is to introduce randomness. Many gambling games seem to succeed almost entirely on the basis of this principle, and randomness can be used to heighten interest in many other kinds of games (Hammurabi, Adventure).

**Fantasy**

Fantasies often make computer games more interesting. In general, games that include fantasy show or evoke images of physical objects or social situations. These objects or situations may involve varying degrees of social or physical impossibility from completely possible (running a lemonade stand in Lemonade) to completely impossible (moving instantly from one barrier to another in Chase). Non-fantasy games involve only abstract symbols.

*Intrinsic and extrinsic fantasies.* As discussed in the previous chapter, when they are possible, intrinsic fantasies seem better than extrinsic fantasies. One way of creating an intrinsic fantasy for a given skill is to simulate a situation in which the skill might actually be used. Another way is to think of a situation (not necessarily a possible one) that involves useful analogies to the skill being used (e.g., Darts).

Because extrinsic fantasies are domain-independent, it is possible to say more about them in general. To spark the imagination of designers of extrinsic fantasy games, Table 12 presents a list of extrinsic fantasies that have been or could be used in instructional computer games. One potential problem with extrinsic fantasies involving a fantasy catastrophe (like a person being hung) is that the catastrophe may be so interesting that players try to get *wrong* answers so they can see it.

*Emotional aspects of fantasy.* As suggested in the previous chapter, fantasies in computer games almost certainly derive some of their appeal from the emotional needs they help to satisfy in the people who play them. It is very difficult to know what emotional needs people have and how these

**Table 12**

*Extrinsic fantasies in which a fantasy goal is approached:*

A train on a track is approaching a city

A rocket is passing the other planets of the solar system on its way to earth

A complicated building is being built, piece by piece

A fleet of space invaders is being destroyed, one by one

*Extrinsic fantasies in which a fantasy catastrophe is avoided:*

A man is hung, one body part at a time

A person advances toward the edge of a cliff, one step at a time

A time bomb is ticking toward an explosion needs might be partially met by computer games. It seems fair to say, however, that computer games that embody emotionally-involving fantasies like war, destruction, and competition are likely to be more popular than those with less emotional fantasies. In fact, a Freudian view that the two fundamental human drives are sex and aggression suggests that the current set of computer games based on aggressive fantasies may soon be joined by a whole new set of games based on sexual fantasies.

An obvious consequence of the importance of emotional aspects of fantasies, is that different people will find different fantasies appealing. As one example of this kind of individual difference, the boys in Study 3 seemed to like the fantasy of arrows popping balloons and the girls seemed to dislike it. Clearly the differences in fantasy choices may depend on many factors other than the simple sex difference found in Study 3. If computer game designers can create many different kinds of fantasies for different kinds of people, their games are likely to have much broader appeal. For example, one can easily envision a math game, in which different students see the same problems, but can choose which fantasy they want to see.

## Curiosity

Several specific principles for designing games follow from the ideas about curiosity in the previous chapter:

1. *Informative feedback.* One way of making environments interestingly complex is to make them responsive (see Moore and Anderson, 1969). In particular:

   (a) *To engage a learner's curiosity, feedback should be surprising.* The "easy" way to do this is by using randomness. A deeper way to do this is to have environments whose underlying consistency is revealed by things that seem surprising at first. For instance, "bugs" in a computer program produce surprising results that are nevertheless consistent with the underlying (incorrect) program.

   (b) *To be educational, feedback should be constructive.* In other words, the feedback should not just reveal to learners that their knowledge is incomplete, inconsistent, or unparsimonious, but should help them see how to change their knowledge to become more complete, consistent, or parsimonious.

One extremely powerful tool for tailoring feedback to specific learners is to maintain on-line cognitive models of the users (Burton & Brown, 1979). For example, with an on-line model of a student's knowledge, a program might be able to select information that would highlight an incompleteness or create an inconsistency. Then the program could take advantage of the curiosity this aroused in the student to present more information that removed the inconsistency or the incompleteness.

2. *Audio and visual effects.* Another way of making computer environments interestingly complex is by using sound and graphics. There are several different ways of using these effects:

(a) *As decoration.* When sound and graphics are used in a program regardless of what the player does, they can be considered "decorative" (e.g. circus music at the beginning of Darts). My conjecture is that this kind of effect will enhance the initial interest of a game, but will quickly become boring.

(b) *To enhance fantasy.* A special kind of "decorative" use of sound or graphics is to enhance the fantasy involved in a game (like the circus music mentioned above). In this case, the special effects are captivating not only in their own right, but also because of the fantasy associations they evoke.

(c) *As reward.* When sound or graphics displays are used to reward good performance, they can increase the salience of the goal and thus add to the challenge of the game. The challenge of reaching a goal, however, can sometimes distract people from exercising their curiosity, and so might decrease certain kinds of learning. (See Lepper & Greene, 1979, for an extensive review of research showing how rewards can sometimes undermine people's interest in a task and degrade their performance of it.)

(d) *As a representation system.* Perhaps the best use of sound and graphics in computer games is to represent and convey information more effectively than with words or numbers. For instance, the Darts game uses a graphic representation system for fractions, and the Breakout game signals bounces and misses of the ball with different tones.

## Combinations of features

One use of the above list of features is simply to suggest additions to existing or planned computer games. Almost no computer games include all the features mentioned above, and it is usually possible to think of ways that any given game could incorporate more of the features. For example, at least one fifth of the games in Study 1 do not have any way of varying the difficulty level and could probably be improved by adding this. Some computer games are successful because they are particularly strong on one of the above features, but most good computer games seem to have clever combinations of several of the features. For example, Breakout has a visually compelling graphic display that both presents a goal and serves as a score-keeping device.

One particularly interesting class of games uses a compelling visual goal to get players started and then keeps them interested with curiosity-arousing unexpected consequences. For example, in Darts, players are presumably first attracted by the goal of popping the balloons. But if they have a misconception about fractions, say that increasing the denominator makes the fraction larger, then they will be surprised when an arrow they thought would be higher on the line turns out to be lower. This surprising feedback seems likely to both arouse curiosity and provide constructive information for correcting the misconception.

## Toward a generative taxonomy of games

So far in this chapter, I have presented a set of principles for improving games for which a basic structure already exists. In this section, I will describe a way to generate ideas for new games based on analogies with old games. To do this, I will show how structural similarities can be found between games that seem on the surface to be very different. The equivalence classes that emerge from this analysis constitute a non-exhaustive taxonomy of common game families. I will discuss two such classes here and show how they can be used to invent new games with the same abstract structure as old games that are known to be popular. My examples will be chosen primarily from the domain of computer games, but most of the ideas are applicable to any kind of game. As indicated by the title, the ideas in this section are not yet complete; they merely point the way toward a useful way of thinking about games.

*A game taxonomy*

Though taxonomies seem to be an essential first step in the colonization of new scientific territory, the task of inventing a useful taxonomy is far from straightforward. The case of game taxonomies is no exception. Avedon and Sutton-Smith (1971, pp. 401-407) list at least five proposed ways of classifying games and include two different sets of structural dimensions for games (Redl, Gump, & Sutton-Smith, 1971; Avedon, 1971). The taxonomies generally involve classifications such as skill games, strategy games, and chance games while the structural dimensions include such elements as purpose of the game, skill requirements, and spread of winnership.

The problem solving perspective described in the previous chapter suggests that games can be analyzed in terms of the problems people solve in playing them. That is, games can be analyzed in terms of the state space, goal, transformations, and so forth, they imply. Once this analysis is done, then games can be classified into groups that are similar on most of these dimensions and differ on only a few of them. There is, of course, some arbitrariness in how to characterize the problem space of a game and how to group games using these dimensions. For example, should all games with the same goal be grouped together, even if they differ on the other dimensions, or should all games with the same state space and transformations be grouped together even if they differ in goals? This arbitrariness of classification exists in principle, but in practice several interesting game prototypes seem to emerge from problem space analyses. I will briefly describe two such prototypes here: guessing games and board games.

*Guessing games.* There is a large set of games in which the goal is to guess a target item in some representation system. In some cases, there are no clues to start with, and the guessing must proceed solely on the basis of feedback from guesses. In other cases, the game starts with a "hint" in either the target representation system or some alternate representation system.

Table 13 shows a structural analysis of three such examples of guessing games: Darts, Hangman, and Stars. The first column of the table is a prototypical description of a guessing game with "slots" for elements like the target representation system, the alternate or "hint" representation system, and the form of the guesses. Most of the slots list alternative specifications that can be used to fill them. The other columns of the table specify particular instantiations of the guessing game prototype. For each instantiation, the slots are filled by either selecting one of the listed alternatives or specifying a suitable filler for the slot.

## Table 13

### Structural Analysis of One-person Guessing Games

| *Prototype* | *Darts* | *Hangman* | *Stars* |
|---|---|---|---|
| **State Space** | | | |
| *Target item, guess history, feedback history* | | | |
| Target representation | mixed no. | written word | integer |
| "Hint" representation | position on number line | none | none |
| *Form of guesses* | | | |
| (a) Complete specification in target representation | x | | x |
| (b) Partial specification in target representation | | single letter | |
| *Kind of feedback:* | | | |
| (a) Complete specification of guess in "hint" representation | x | | |
| (b) Relation between guess and target: | | | |
| 1. right/wrong | (x) | x | x |
| 2. high/low | (x) | | |
| 3. close/far | (x) | | x |
| 4. which part is right | | x | |
| **Initial State** | | | |
| (a) Complete specification of target item in "hint" representation | x | | none |
| (b) Partial specification of target item in target representation | | no. of letters | |
| **Transformations** | | | |
| *Add guess to guess history (Side effect: Add feedback to feedback history)* | | | |
| **Goal** | | | |
| *Last guess = target* | | | |

In all the games, the only transformation available to the player is adding a guess to the history of guesses already made. This transformation also has the side effect of adding the feedback from the guess to the feedback history. Thus in addition to the thing being guessed (target item) the state space of these games includes the history of guesses and feedback. Different games generate feedback, accept guesses, and use the histories in different ways, but in all the games the goal is for the last guess to be the same as the target item. Viewing the games in this way, as alternative specifications of a prototype, highlights some of their structural similarities:

> *Darts.* The target item to be guessed in this game is a mixed number. The hint is a complete specification of the number in an alternate representation--position on the number line. Each guess is a complete specification in the target representation system--a mixed number. As feedback for each guess, the game displays a complete specification of the guess in the alternate representation--as a position on the number line. This display implicitly says whether the guess is right or wrong, and if wrong how close it is and whether it is too high or too low.
>
> *Hangman.* In Hangman, players try to guess a secret word, letter by letter. The target item is the written word, the hint is a partial specification of the written word (the number of letters it has) and the guesses are different partial specifications (the letters thought to be in the word).
>
> *Stars.* In the computer game of Stars, players try to guess an integer between 1 and 100. After each guess, they are told how close they are by the number of stars printed (very close gets lots of stars). The target item is the integer and the guesses are complete specifications in this target representation system.

Other guessing games include Snoopy, Hurkle, Mugwump, Bagels, and Don't Fall.

*Board games.* Another large and popular class of games involves the positions and ownership of pieces in some array of cells. As shown in Table 14 with the examples of Tic Tac Toe, Nim, and checkers, games in this group differ on dimensions such as whether the board starts empty, full, or somewhere in between, whether the transformations involve adding, moving, or removing pieces, and whether the goal involves removing pieces or reaching a certain configuration of pieces.[5] The three

[5] The rules of Tic Tac Toe and checkers should be familiar to most readers. In Nim, players take turns removing one, two or three pieces at a time from the original array. The goal is to not be the player to remove the last piece. For the sake of simplicity, the analysis of checkers given here omits the possibility of obtaining "kings". This simplification can be removed by introducing another attribute of pieces (i.e. *rank* which may be "king" or "pawn" and by revising the constraints on moving and jumping to allow backward motion in the case of kings.

Table 14

Structural Analysis of Two-person Board Games

| *Prototype* | *Tic Tac Toe* | *Nim* | *Checkers* |
|---|---|---|---|
| **State Space** | | | |
| *Positions and ownership of pieces on a board* | | | |
| *Board:* Rectangular array of square cells<br>*Size* | 3 x 3 | 1 x 9 | 8 x 8 |
| *Pieces* | | | |
| (a) Separate ownership | x | | x |
| (b) Joint ownership | | x | |
| **Initial State** | | | |
| (a) Empty board | x | | |
| (b) Full board | | x | |
| (c) Other arrangements (Standard checkers arrangement) | | | x |
| **Transformations** | | | |
| *Players alternate moves. Both players can make the same kinds of moves.* | | | |
| (a) Place own piece in an empty cell | x | | |
| (b) Remove own piece from an occupied cell | | x | |
| (c) Move own piece to an adjacent cell (Constraints: Cell moved to is unoccupied, and move is in a forward diagonal direction.) | | | x |
| (d) "Jump" a piece. Move own piece across one occupied by opponent's piece and remove opponent's piece. (Constraints: Same as for transformation (c).) | | | x |
| **Goal** | | | |
| (a) Three of own pieces in a straight line. No three of opponents pieces in a straight line. | x | | |
| (b) Not remove last piece from board | | x | |
| (c) None of opponents pieces on board. Some of own pieces still on board. | | | x |

games shown here are chosen to illustrate a variety of initial states, transformations, and goals possible in the board game state space. A number of other board games, such as Chinese Checkers and Go, use different combinations of similar elements.

*Generating new games*

To generate a new game using these structures, one only has to fill in different values for the slots in the prototype descriptions. This can be done by creating new options for a slot or by recombining options already present. For example, one can easily imagine a Tic Tac Toe-like game with an extra transformation added so that not only can pieces be placed on the board, but pieces already on the board can also be moved to adjacent squares. As another example, there could be a checkers-like game in which not only can pieces be moved, but they can also be added to the board during play. There is no guarantee, however, that the games generated in this way will be interesting. One professional game designer (Solomon, 1977) describes a slightly less general version of this technique and reports that it helped him invent one successful game out of many tries.

My informal experimentation with a number of games generated combinatorially from common features of board games suggests that *the single largest determinant of whether a game like this is interesting is whether its outcome is uncertain.* Most of the games generated by arbitrary combinations of features are uninteresting because their outcome is certain in one of the following ways:

(1) Neither player can ever win (e.g., if the goal is to remove all pieces and no transformations remove pieces).

(2) The first player wins with an obvious strategy.

(3) There is a guaranteed tie if both players use an obvious strategy.

I suspect that any game of this type with an uncertain outcome will be interesting. Notice that the notion of an "obvious" strategy introduces some consideration of the cognitive capacity of the game players. For example, as discussed above, Tic Tac Toe is an interesting game for children until the strategy that guarantees a tie becomes obvious to them.

The second application below shows another use of this technique where, instead of recombining features, new representation systems are substituted in the guessing game prototype to create a game in a new domain that is a structural analog of Darts.

## Applications

In order to illustrate the usefulness of the above principles, I will now apply them to several examples:

### *An arithmetic drill-and-practice program*

In this example, I will suggest several relatively minor changes to an existing arithmetic drill-and-practice program that I think would make it more fun for students. I will stop short of suggesting major changes in the way the curriculum for this program is conceived.

In this program, the difficulty level of arithmetic exercises is automatically adjusted according to how well the student does, and the percent of problems correct is printed at the end of each lesson. At first glance, this automatic difficulty level adjustment appears to be a good way of maintaining the challenge of the program. But according to the principles described above, the first necessary element of a challenging environment is a goal. The only thing like a goal provided by this program is the percent correct printed at the end of each lesson, and some students do try to get "hundred percents". But this goal is not made particularly obvious or compelling, and given the automatic difficulty adjustment, it is actually fairly rare for students to get all their problems correct. In fact, since the difficulty adjustment is hidden from the students, the goal of getting all the problems correct may seem to students to be inexplicably receding as they approach it.

Aside from major curriculum revisions involving intrinsic fantasies and curiosity-driven learning, I think there are still a number of ways that extrinsic fantasies can be combined with goals and performance feedback to make this program more interesting. One of the simplest things to do is to select an extrinsic fantasy like those in Table 1--or better yet let the students themselves pick fantasies from a list. Ideally, this fantasy can be represented graphically and remain on the screen throughout a lesson as correct and incorrect answers affect a student's progress in the fantasy world. It would be nice to use sound effects for right and wrong answers. Reaching the final goal or catastrophe in the fantasy world should be accompanied by more elaborate sound and graphics. In addition to the first two levels of goals within a lesson (getting individual right answers and reaching the fantasy goal), the automatic difficulty adjustment can provide a higher level goal of making progress in the curriculum. If the extrinsic fantasy includes multiple levels of goals, the movement of a student to a higher difficulty level can be accompanied by even more fanfare in the fantasy world. Obviously, the details of these changes still have to be worked out, but perhaps this short description shows how the principles above can be used to suggest changes to existing programs.

*A simple program to teach children how to tell time*

In this example, I will suggest how to increase the interest of a proposed computer game for teaching the relationship between three different notational systems for time: clock face, digital display, and English words.[6] The original proposal for this game was to have the three different representational systems simultaneously displayed on the screen so that when the student changed any one representation, the other two changed accordingly. One insight afforded by the above list of principles is that this game has no apparent goal. A nice way to provide a goal would be to use an analogy of the Darts game. In this new game, a time is represented in one system, and the student tries to guess the time in one of the other systems. After each incorrect guess, either the incorrect guess in displayed in the target system or the student is simply told that the guess is too early or too late. The game might be even more interesting if it included an intrinsic fantasy about setting alarm clocks and being early or late for school.

*Other educational applications*

More generally, a game prototype can suggest analogous games in domains very different from the original ones. For example, the guessing game structure described in Table 13 can be used to invent games to teach many different kinds of knowledge:

(1) *To teach an ordered list, use a guessing game that gives high/low feedback.* For example, to teach the list of U. S. Presidents in order, use a game in which the players try to guess a secret President. After each guess, they are told whether their guess is before or after the secret President and perhaps how close it is. This kind of game can be used to teach either the contents of a list (U. S. Presidents, steps in a procedure, etc.) or the ordering relationship ("less than" and "greater than" in a number-guessing game).

(2) *To teach the correspondence between two representation systems, use a guessing game that gives hints in one system and asks players to guess in the other system.* For example, the Darts game is designed to teach the relationship between numbers represented on a number

[6] The original system on which this game is based was suggested by Laura Gould.

line and in mixed number format. In the previous section, I described a new game to help teach children how to tell time. This game uses one time display format, say a clock face, as the target representation and another, say English words describing the time, as the alternate representation. The rest of the game structure is identical to that of Darts with each incorrect guess being displayed in the alternate representation. This kind of game can be used to teach other correspondences like foreign language vocabulary, Cartesian coordinates for points on a plane (Hurkle), or spelling of words (Hangman).

(3) *To teach the properties of items in a set, use a guessing game in which players guess properties of the target item (like Twenty Questions).* For example, Williams and Hollan (1978) describe a Twenty Questions game to teach Navy crew members about the equipment on enemy ships. In this game the players try to guess the secret ship by asking questions about its equipment. Similar games could be used in almost any domain. For example, they could be used to teach the characteristics of different diseases to medical students or the climates and economies of various countries to geography students.

This technique of using structural analogies with old games seems to be a powerful way of inventing educational games in new domains.

*Computer programming*

The purpose of this example is simply to suggest that, in some senses, computer programming itself is one of the best computer games of all. In the "computer programming game", there are obvious goals and it is easy to generate more. The "player" gets frequent performance feedback (that is, in fact, often tantalizingly misleading about the nearness of the goal). The game can be played at many different difficulty levels, and there are many levels of goals available, both in terms of the finished product (whether it works, how fast it works, how much space it requires, etc.) and in terms of the process of reaching it (how long it takes to program, etc.). Self-esteem is crucially involved in this game, and there are probably occasional emotional or fantasy aspects involved in controlling so completely, yet often so ineffectively, the behavior of this responsive entity. Finally, the process of debugging a program is perhaps unmatched in its ability to raise expectations about how the program will work, only to have the expectations surprisingly disappointed in ways that reveal the true underlying structure of the program.

*"Real life"*

There are even times in "real life" when some of these principles can be applied to make a boring situation more interesting. For example, when someone "makes a game out of" something, I think it means that they select a goal--usually a higher order one ("Let's see how fast we can wash all these dishes")--and perhaps a fantasy ("Let's pretend that all the dandelions are Klingons and we are trying to destroy them.").

## Summary

In this chapter, I described how the theory developed in the last chapter can be used to generate a specific set of heuristics for increasing the appeal of instructional computer games. I also described a way of generating ideas for new games based on structural analogies with old games. These structural analogies suggest a principled basis for a taxonomy of games. Clearly, for the taxonomy to be very useful in inventing new games, it should be expanded to include more game classes.

# Chapter VII
# Conclusions

This dissertation set out to answer two questions:

(1) Why are computer games so captivating? and

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

My answers to both questions are organized in three categories: challenge, fantasy, and curiosity.

To answer the first question, I started by assuming that the answer might be different for different kinds of games and different kinds of people. After surveying a number of people about a number of games, I examined two specific games in detail. These two games, Breakout and Darts, seemed to be good representatives of highly motivating recreational and instructional computer games, respectively. In a sense, the experiment with Breakout demonstrated the importance of challenge (goals and scoring), and the experiment with Darts demonstrated the importance of fantasy (arrows and balloons) and curiosity (music and high/low feedback). The experiment with Darts also showed that there were important differences in preferences between kinds of people (in this case between boys and girls) and that some of the presumably motivational features of the game actually made it less interesting for many people. It is not yet clear, without further empirical study, how generally these results will hold for different kinds of games and different kinds of people. But the technique developed here of varying specific features in a set of nearly isomorphic games seems to be a powerful way of studying this question.

To a certain extent, the answer to the second question is the same as the answer to the first one. The same features that make any computer game fun should make instructional computer games fun, too. And in Chapter 5, I showed how most of these features could be used in many other kinds of instructional environments, not just in computer games.

But if computer games--or other kinds of intrinsically motivating environments--are to be used for instruction, then there are a number of other important issues to be addressed that are only touched on here. In spite of a great deal of enthusiasm in recent years for educational games, there have been only a few empirical tests of their instructional effectiveness (see Boocock & Schild, 1968). While it seems very hard to believe that, say, students would not learn to spell the words they use in playing Hangman, it will be important to demonstrate this.

It will also be important to examine the interaction between learning and fun. Clearly there are features that could be added to instructional environments that would make them more fun, but less instructional. For example, if time-consuming audio-visual effects that are unrelated to the material being taught are added to instructional computer games, the games might be more entertaining but less educational. As I suggested in Chapter 5, however, there seems to be an important correspondence rather than a contradiction between most of the features that make an environment fun and those that make it educational. For example, environments that vary in difficulty level increase both challenge and the potential for learning. Intrinsic fantasies not only stimulate interest, they can also provide instructionally useful analogies. Finally, environments that evoke cognitive curiosity and then satisfy it can be both captivating and educational. The technique of comparing both interest and learning in nearly isomorphic game versions seems like one useful way of studying these interactions.

The new technology of computers--with its uniquely rich possibilities for responsive fantasy, captivating sensory effects, and individual adaptability--has an unprecedented potential for creating fascinating educational environments. But as our cultural experience with television indicates, great potential does not guarantee wise use. I have tried to point the way, in this report, toward a humane and productive use of this new educational technology that avoids the dangers of soulless drudgery on the one hand and mind-numbing entertainment on the other.

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# Appendix

### Descriptions of games mentioned in text
### (See also Table 3)

| *Game* | *Description* |
|---|---|
| Adventure | The player explores a vast underground systems of caves with dragons, etc., trying to find treasures. The cave is populated with knife-throwing dwarfs and other dangers. |
| Bagels | The player tries to guess a three digit number. After each guess, the player is told how many digits were correct. |
| Breakout | The player controls a paddle to hit a ball that breaks bricks out of a wall |
| Chase | Two players chase each other across an obstacle course. |
| Darts | A game designed to teach elementary students about fractions. Three balloons appear at random places on a number line and students try to guess where the balloons are. They guess by typing in mixed numbers, and each time they guess an arrow shoots across the screen to the position specified. If the guess is right, the arrow pops the balloon. If wrong, the arrow remains on the screen and the player gets to keep shooting until all the balloons are popped. Circus music is played at the beginning of the game and if all three balloons in a round are popped in four tries or fewer, a short song is played. |
| Hangman | The player tries to guess a word, letter by letter. After each incorrect letter guessed, one more body part of a man being hung is drawn. The player loses if the whole body is drawn. |
| Hammurabi | Player acts as king of ancient Babylonia and decides each year how much wheat to plant, how much to store, and how much to save. There are occasional plagues, rat infestations, etc. The number of people who are born, starve, etc., each year is reported. |
| Hurkle | The player tries to guess where an animal called a "Hurkle" is hiding in a Cartesian coordinate grid. After each guess, the player is told in which direction the Hurkle is from the guess. |
| Lemonade | The player runs a lemonade stand buying supplies, advertising, etc., and tries to make a profit |
| Logo | A sophisticated programming environment where, among other things, children control the motion of a "turtle" on the screen or on the floor. |
| Mugwump | Like Hurkle except that after each guess player is told how far the guess is from the correct answer, but not in what direction. |
| Snoopy | Snoopy and the Red Baron appear at different positions on a signed number line. Player says how far Snoopy should shoot to hit the Red Baron (as a signed integer). |
| Star Wars | Player tries to shoot down enemy space ships as they appear in a graphic display. |