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Toward a Theory of Intrinsically Motivating Instruction*

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First, a number of previous theories of intrinsic motivation are reviewed. Then, several studies of highly motivating computer games are described. These studies focus on what makes the games fun, not on what makes them educational. Finally, with this background, a rudimentary theory of intrinsically motivating instruction is developed, based on 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.

"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)

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What makes things fun to learn? How can instruction be designed in a way that captivates and intrigues learners as well as educates them? As the above quotation from Plato illustrates, these are not new questions. But there will be two new aspects in my treatment of them. 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?

To help answer these questions, I will first review a number of previous theories of intrinsic motivation and learning. Then, I will describe a series of empirical studies of what people like about computer games. Since these studies are a first step in addressing the complex question of what makes things fun to learn, they only focus on what makes the games fun, and not on what makes them educational. Finally, using these empirical studies as a base, I will outline a rudimentary theory of how to design environments that are both interesting and educational.

Much recent research on instructional design has involved detailed hypotheses about the changes in cognitive structures and processes that occur in learning academic skills like arithmetic and geometry (e.g., Resnick, 1976; Greeno, 1976; Brown & VanLehn, 1980). 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. In a similar vein, the most impressive recent work in intelligent computer-assisted instruction has involved programming elaborate cognitive models of the learners so the program can make real-time instructional decisions based on inferred knowledge states of the learners (Brown & Burton, 1978; Burton & Brown, 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. 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 modeling (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, and 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 children in a control group who 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. If students are intrinsically motivated to learn something, they may spend more time and effort learning, feel better about what they learn, and use it more 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).

1. CHARACTERISTICS OF INTRINSICALLY MOTIVATING INSTRUCTIONAL ENVIRONMENTS

An activity is said to be intrinsically motivated if people engage in it "for its own sake," if they do not engage in the activity in order to receive some external reward such as money or status. I will use the words "fun," "interesting," "captivating," "appealing," and "intrinsically motivating," all more or less interchangeably, to describe such activities. In this section, I will review a number of theories about what makes environments intrinsically motivating. The theories are loosely organized under the three major categories to be used in section 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 most 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," or 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." (1979, p. 213)

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 as to why these features are important, or how they relate to each other. In section 5 below, 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 throughout 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 jump rope and marbles) if, after the hierarchy of players is established, the outcome of each round becomes predictable. A game is sporadic of there is little variation in the degree of challenge and little challenge to begin with. And finally, a one-shot game (like Hula-Hoop) 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 (1951) explains fantasy in children's play primarily as an attempt to "assimilate" experience into existing structures in the child's mind with minimal needs to "accommodate" to the demands of external reality. In a somewhat similar vein, Freud's (1950) explanation of symbolic games that children invent for themselves emphasizes an attempt by the ego to actively repeat traumatic events that have been experienced passively. This repetition allows a kind of belated emotional mastery over the event. In addition to this symbolic conflict resolution, Freud sees much of fantasy, especially dreams, as the fulfillment of (often unconscious) wishes. For example, Sears (1950) describes a study of the aggressive doll play of preschool children that is consistent with both these aspects of Freudian theory. The children who received the most punishment for aggressive behavior at home showed less interpersonal aggression than moderately punished children, but they were more aggressive in their fantasy play with dolls. The presumption is that the highly punished children had acquired strong aggressive motivation through frustration at their parent's punishment, and that this frustrated aggression was expressed primarily in fantasy. Even though these theories of fantasy deal primarily with the fantasies people *produce* (as in dreams or imaginary play), their proponents would presumably argue that similar processes are involved in determining the fantasies people find *appealing* in external environments.

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 has 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), 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 last 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 section 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, autotelic, productive, and personalization principles.

The perspectives principle suggests that learning is more rapid and deeper if the learner can approach the subject matter from as many of the following perspectives as possible: 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.

The autotelic principle requires that, in general, the initial learning of complex skills be protected from serious consequences (such as prizes or physical dangers), so that it can be enjoyed for its own sake. Once the learning of a skill is well underway, however, 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 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.

The personalization principle includes the ideas that an environment should be both responsive to the learners' activities and helpful in letting them take a reflexive view of themselves. A responsive environment permits the learners to explore freely and make full use of their capacities for discovering relations of various kinds. It is self-pacing and informs the learners immediately about the consequences of their actions. 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 learners can learn not only about the subject matter, but also about themselves as learners. For example, the use of motion pictures of athletic contests to help players spot their weaknesses and strengths encourages a reflexive view of learning.

Other Structural Features. In a brief but very useful article specifically devoted to computer games, Banet (1979) lists 13 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) "The game incorporates fantasy elements (piloting a space ship, finding treasure, etc.)." (4) "The computer can time the players' responses and calculate scores based in part on quickness of response."

Choice. 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. 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 give some insight into which factors are most important in making computer games fun and to see how the importance of these factors varies for different people and different games.

It is certainly not the case that all intrinsically motivating instructional 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 chose to study game-like activities on computers as a source of insight for designing intrinsically motivating instructional environments.

2. 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. As a preliminary approach to understanding this phenomenon, I interviewed 65 elementary students about their computer game preferences..

Method

Subjects. The subjects for this study were all students in the computer classes at a private elementary school near Palo Alto, California. There were 42 boys and 23 girls, ranging from kindergarten through eighth grade with a concentration in the early elementary grades.

All the children had been playing with computer games in a weekly class for at least two months, and some for over two years. 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.

The children to be interviewed were selected randomly from those present. The 65 children surveyed constituted about 75% of the children enrolled in computer classes, and about 25% of the children enrolled in the school. Since it was very easy for all children in the school to participate in the computer classes if they wanted to, this sample is in some ways less biased than groups of children who have to make a special effort to go to a science museum, or other public access computer center.

Procedure. The teachers of the computer classes provided a list of the 25 games they thought were the most popular among the students. Then, each child was asked to rate each game on a four-point scale: 0-never played, 1-didn't like, 2-liked, and 3-liked a lot. 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, while 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 four 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% of the games identically both times. Their ratings for 18% of the games changed by one point; and on 11% of the games, they changed their mind about whether they remembered playing the game.

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 the order of presentation, sex of the child, and the 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 1 lists all the games in the 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 children who saw the games in on 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% 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 children interviewed. Table 2 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.)

TABLE 1
Computer Games in Order of Preference

Game	Average Rating	Description
Petball	2.8	Simulated pinball with sound
Snake 2	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 Snake 2 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.

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 2 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 2
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:	
(+)	Older or more experienced like the game more
(−)	Older or more experienced like the game less
(M)	Boys liked the game better than girls
(F)	Girls liked the game better than boys

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

Table 3 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 three games all had obvious goals (getting a high score in Petball, trapping the other person's snake in Snake 2, and destroying all the bricks in the Breakout game), while the bottom two 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.

Discussion

This study begins to answer 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.

TABLE 3
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*

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

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 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 two studies I will describe next each focus on a single game and systematically vary the features of the game by having different versions of the same game.

3. BREAKOUT: A SENSORIMOTOR SKILL GAME

Figure 1 shows a typical screen display in the Breakout[1] computer 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.

The survey above and other casual observations indicate that this is one of the most popular contemporary computer games. Why is it so popular? What is the "secret" of the success of the Breakout game?

[1]Breakout is a trademark of Atari, Inc.

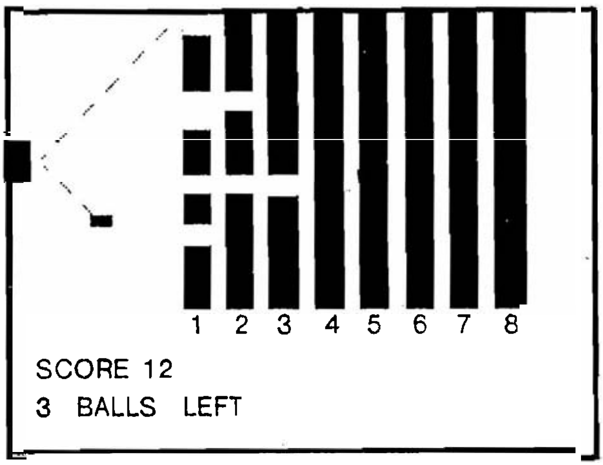

Figure 1. Display format for the Breakout game.

Many devotees of the Breakout game and similar games mention their score—usually their highest one—when talking about the game. Is the challenge of getting a higher score than your own or someone else's record the principal attraction of the Breakout game? Is it something about 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 ball? There are, of course, many other features of the Breakout game, but these three—the score, the breaking out of the bricks, and the ball bouncing off the paddle—seem to capture the essence of the game.

Method

To see which of these three features was most important in the appeal of the game, I constructed six different versions of the game varying the three features in all sensible combinations (see Figure 2). 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 Version 2, the ball bounces back and forth between the paddle and the wall without ever breaking out any bricks. One point is scored for each bounce. In Version 3, the ball does not bounce off the paddle; it is simply "caught" when the paddle is placed in front of it. One point is scored for each "catch". Versions 4, 5, and 6 are just like Versions 1, 2, and 3 respectively except that the scores are omitted. In all versions, if the ball is hit (or "caught") correctly five times in a row, it automatically speeds up.

To make all the versions seem equally difficult, the distance from the paddle to the wall in the "catch" versions (3 and 6) was increased. This adjustment was apparently successful, since five of the 10 subjects thought the versions were equally difficult, and the other five had no consensus about which versions were more difficult.

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 the Breakout game before.

Procedure. Each subject played with each of the six versions of the game for about three minutes. 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 from 1 to 5, with their least liked version(s) being 1 and their most liked version(s) being 5.

The subjects who had never played the Breakout game 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 the Breakout game, had difficulty learning to play the game. These three subjects were discarded from the analysis and were not included in the total of 10 subjects in the experiment.

Results

Table 4 shows the average rating for each version. A four-way analysis of variance predicting the rating from the order of presentation, sex, amount of computer game experience, and version found a significant effect of only versions ($F(5,24) = 25.84$, $p < .001$). Not surprisingly, the original version of the game was shown by *a priori* contrasts of the ratings to be significantly more fun than all the other versions. Using Tukey's HSD *a posteriori* contrasts at the .05 level, the questionnaire 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 5 shows the results of a multiple regression predicting 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 in importance, and both are much less important than breaking out the bricks.

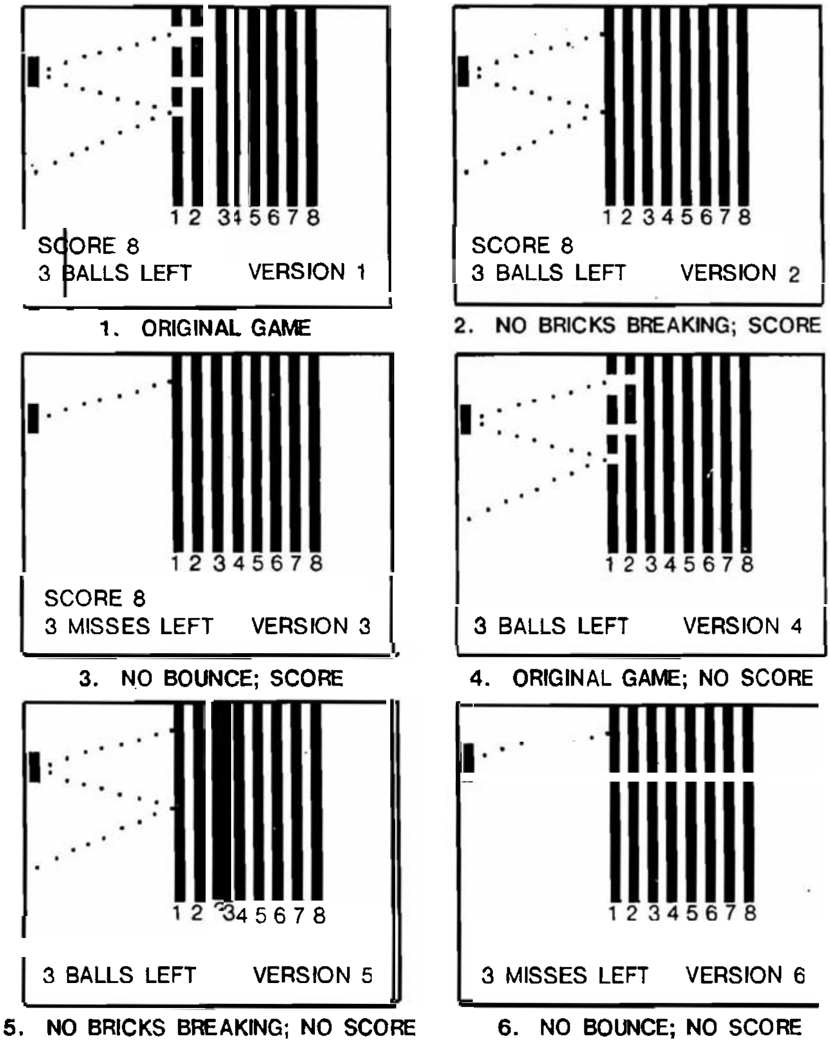

Figure 2. Different versions of the Breakout game.

TABLE 4
Appeal of Different Versions of the Breakout Game

Version	Features: Break Bricks	Features: Bounce from Paddle	Features: Score	Average Rating	A Posteriori Contrasts*
1	x	x	x	4.8	
4	x	x		4.1	
2		x	x	3.3	
3			x	2.1	
5		x		2.0	
6				1.4	

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

TABLE 5
Importance of Game Features in Preference for the Breakout Game

Feature	Beta in Multiple Regression
Breaking out bricks	.77
Score	.32
Bounce from paddle	.30
Multiple R	.87

Discussion

It is not clear from this study what aspects of the bricks breaking out are most important, but the list of features in Table 3 above suggests a number of important possibilities. A partially destroyed wall of bricks presents a visually compelling fantasy 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, fantasy, 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 showed that the versions that had neither a score nor bricks breaking out were significantly less appealing (using *a posteriori* contrasts) than the other versions. In other words, the versions in which there was no clear goal, other than a vague "keep the ball going as long as you can," were significantly less fun than the others. Without a clear goal, the game was not really a game at all.

The results of this short experiment with a relatively small number of subjects do not definitively reveal the "secret" of the Breakout game. These results do, however, illuminate the importance of a clever combination of challenge and visual effects in the design of the Breakout game. I believe a similar combination is important in the success of other popular games like Space Invaders.[2]

4. DARTS: A COGNITIVE SKILL GAME

The second game I studied in detail was a game called Darts that was designed to teach elementary students about fractions (Dugdale & Kibbey, 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.

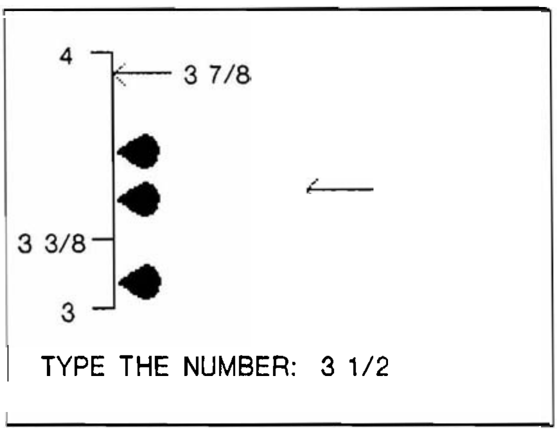

Figure 3. Display format for the Darts game.

[2]Space Invaders is roughly analogous to the Breakout game. Instead of a stationary wall of bricks, there is an advancing squadron of alien invaders, and instead of knocking bricks out with a ball, one destroys invaders by shooting them.

Darts is a good example of what may be called an *intrinsic fantasy* where the fantasy (the positions of arrows and balloons on the number line) is intimately related to the skill being used (estimating fractions). By contrast, an *extrinsic fantasy* (like Hangman) is only weakly related to the skill being used (spelling and vocabulary). In extrinsic fantasies, the fantasy usually depends only on whether the answers are right or wrong, so the same fantasy may be used for many different subject matters. For example, the Hangman fantasy could be used just as well for arithmetic problems as for spelling problems. This distinction is discussed in greater detail in section 5 below. Besides the intrinsic fantasy, Darts has a number of other potentially motivational features such as feedback, music, and graphics.

To find out which of these features contribute most to the appeal of the game, I constructed a sequence of eight different versions of the game, each of which had one more presumably motivational feature than the last. As illustrated in Figure 4, the following versions were used:

1. *Non-interactive drill.* The student guesses the location of rectangles on a number line, but there is no feedback about whether the guesses are right or wrong. This version is a rough analog of paper-and-pencil worksheets.
2. *Add performance feedback.* After each guess, the student is told whether the guess was right or wrong. This version is a rough analog of traditional drill-and-practice computer programs.
3. *Add scoring.* A scoreboard at the bottom of the screen tells the number of tries and the number of correct answers in each 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.).
5. *Add extrinsic fantasy.* Each time the student guesses the position of a rectangle correctly, an arrow pops a balloon in another part of the screen.
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 correct and incorrect answers are marked by short lines on the number line.
8. *Add intrinsic fantasy.* The original Darts game is used with arrows popping balloons on the number line.

The sizes of the rectangles in each version were adjusted to try to make the probability of success (number of correct answers/number of tries) approximately the same for all versions. Also, when the introduction of a new feature in a version made the information of an old feature redundant, the old feature was dropped.

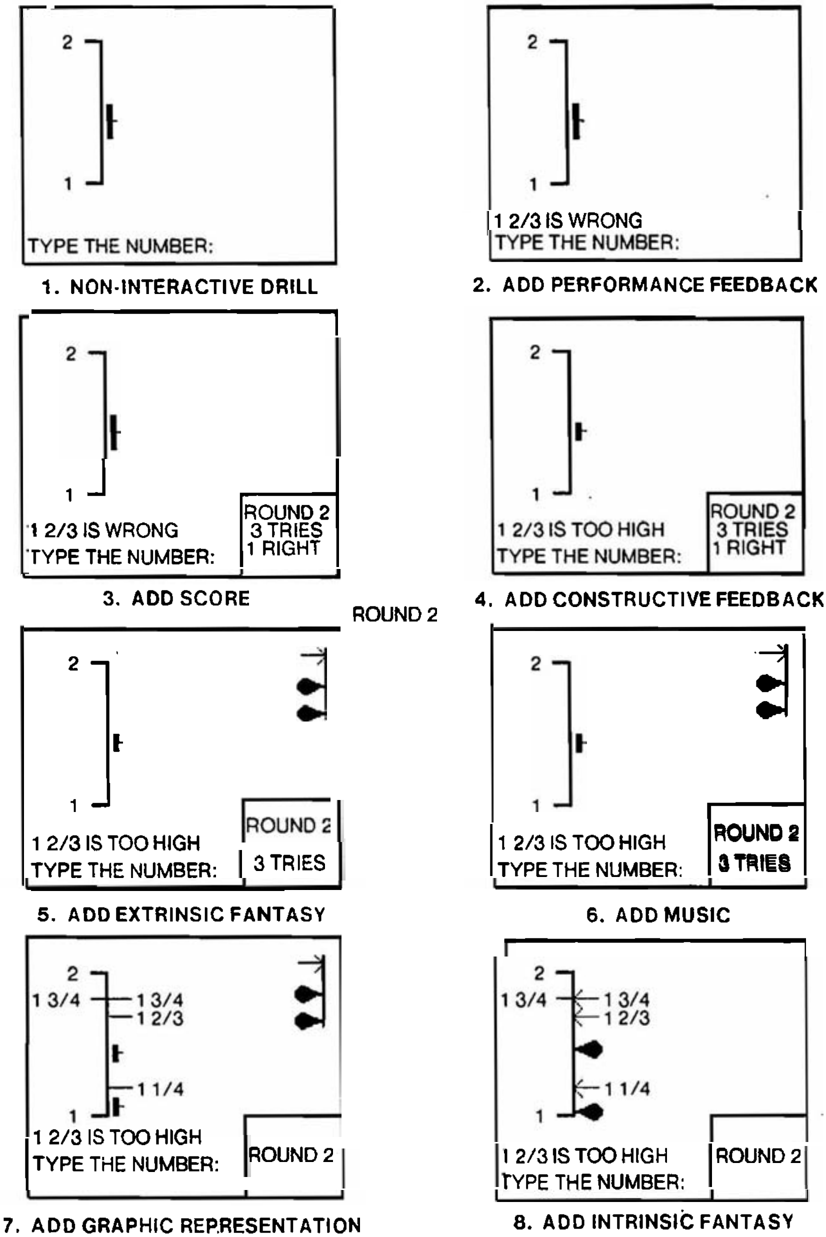

Figure 4. Different versions of the Darts game.

To eliminate the possibility of "contamination" between versions, each subject saw only one version of the game. If each subject were to see several versions of the game, then subjects who saw balloons popping in one version might imagine balloons popping in later versions that did not actually show 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. 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.

Method

Subjects. There were 80 subjects in this experiment, 10 assigned randomly to each of the eight 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.

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. Students were able to change back and forth between the two games as often as they wanted during two 20 minute sessions. At the end of the second session, they were asked to say which game they liked best and to rate how well they liked the two games.

Results

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 ($F(7,48) = 4.84$, $p < .001$). No other main effects or interactions were significant. Since there were no significant effects of school, students from the two schools were pooled for the remainder of the analyses, giving cell sizes of 4 to 6.

Because each pair of adjacent conditions differs by only one feature, *a priori* comparisons were planned between each adjacent pair of conditions. Table 6 shows the average values and the significant differences between conditions for the three interest measures. Because of the significant interaction between sex and condition, these comparisons are shown separately for boys and girls. Though it is not shown in the table, the only significant difference when boys and girls were analyzed together was a significant increase ($p < .05$) in "liking Darts" when the extrinsic fantasy of arrows and balloons was introduced (Condition 4 vs. 5).

The most surprising result in Table 6 is that the original 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). Finally, and somewhat surprisingly, the version with no performance feedback (Condition 1) was not significantly less interesting than the version with simple performance feedback (Condition 2) for either boys or girls.

TABLE 6
Interest in Different Versions of the Darts Game

Condition	Interest Measures					
	Time Playing Darts (0–40 mins.)		"Like Darts" (Scale from 1–5)		"Prefer Darts to Hangman" (Percent of Subjects)	
	Boys	Girls	Boys	Girls	Boys	Girls
1. Non-interactive drill	20.5	15.5	3.3	3.2	0	20
2. Add performance feedback	18.8	20.2	3.8	3.2	50	0
3. Add scoring	24.2	19.8	3.0	3.4	0	40
4. Add constructive feedback	16.2*	22.2	3.6	2.6	40	20
5. Add extrinsic fantasy	25.8*	20.8	5.0*	4.2	80	30
6. Add music	21.8	30.0*	4.0	4.0	30	80
7. Add graphic representation	28.3	29.8	4.3	3.8	80	50
8. Add intrinsic fantasy	34.5	19.8**	4.5	3.5	100	50
Average	23.4	22.0	3.9	3.5	48	36

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

As described in more detail elsewhere (Malone, 1980a, 1981), the boys' apparent dislike of verbal constructive feedback is not significant when a multiple regression model is used to analyze the contribution of each feature in all versions where it is present. Furthermore, when the times spent playing the game are transformed to utilities according to a plausible model of choice behavior, neither the boys' dislike of verbal constructive feedback nor the girls' liking of music are significant (see Malone, 1981). Therefore, these latter two results seem less reliable than the sex differences in fantasy preference.

Discussion

Why should the original game (Condition 8) be significantly less appealing for girls than the version with an extrinsic fantasy (Condition 7)? 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 if 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 at least two possible explanations for the girls' preference of Condition 7. The girls might have 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 to find out if their guesses were right or wrong. Or the girls might have 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.

I prefer the latter explanation 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, one 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. Also, Maccoby and Jacklin (1974) found convincing evidence that boys are more aggressive than girls. Thus to the extent that the fantasy of destroying balloons with weapon-like objects is aggressive, this may explain the sex difference in preference. Finally, there is anecdotal evidence that the girls did not like the Darts fantasy. One 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 (Condition 8) because the arrows and balloons fantasy—which they disliked in the first place—was more salient in that version.

Conclusions

The primary result of this experiment was that the boys seemed to like the fantasy of arrows popping balloons and the girls seemed to dislike the fantasy. I do not think the implication of this result is that boys should be given one kind of fantasy and girls should be given another. Instead, I think it would be better to let each person choose whichever fantasy seems most appealing at the time. These choices will presumably depend on many factors besides gender. But even if gender is only one of many determinants of what children find interesting, an understanding of these differences may help prevent unintentionally designing instructional environments in a way that appeals more, say, to boys than to girls.

I think the most important implication of this experiment is that fantasies can be very important in creating motivating instructional environments. But, unless the fantasies are carefully chosen to appeal to the target audience, they may actually make the environment less, rather than more interesting (as indeed the arrows and balloons fantasy did for the girls here).

The technique developed here of varying specific features in a set of nearly isomorphic games seems to be a useful way of empirically studying intrinsic motivation. In both of the experiments described here, I removed features from already popular games, but clearly the same techinque could be used to study the enhancement of games by adding new features. In the next section, I will outline a set of features that can often be added to games or other educational activities to make them more interesting.

5. FRAMEWORK FOR A THEORY OF INTRINSICALLY MOTIVATING INSTRUCTION

Several of the theorists discussed in section 1 (e.g., Piaget, 1951; Bruner, 1966; Berlyne, 1965; Moore & Anderson, 1969) deal with intrinsically motivated learning, and several others (e.g., Csikszentmihalyi, 1975, 1979; 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, 1978).

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 section how a more comprehensive theory of instructional design might be developed, based on three categories: *challenge, fantasy,* and *curiosity.* The framework for this theory is outlined in Table 7.

Challange

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 number of important consequences follow from this simple principle.

Goals. There are several reasons for believing that goals are important to intrinsically motivating environments. In the survey described above, 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 order for a goal to be motivating it should have several characteristics.

First, a good goal is *personally meaningful.* A study by Morozova (1955) has some tantalizing implications for making goals personally meaningful. 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. This is related to what Papert (1980) calls the "power principle", that the knowledge being learned should "...empower the learner to perform personally meaningful projects that could not be done without it" (p. 54).

TABLE 7
Framework for a Theory of Intrinsically Motivating Instruction

- **I. Challenge**
  - A. Goal
    1. Personally meaningful goals
    2. Obvious or easily generated goals
    3. Performance feedback
  - B. Uncertain outcome
    1. Variable difficulty level
       - a. determined automatically
       - b. chosen by learner
       - c. determined by opponent's skill
    2. Multiple level goals
       - a. score-keeping
       - b. speeded responses
    3. Hidden information
    4. Randomness
  - C. Toys vs. tools
  - D. Self-esteem
- **II. Fantasy**
  - A. Intrinsic and extrinsic fantasies
  - B. Cognitive aspects of fantasies
  - C. Emotional aspects of fantasies
- **III. Curiosity**
  - Optimal level of informational complexity
  - A. Sensory curiosity
    - audio and visual effects
  - B. Cognitive curiosity
    1. "Good form" in knowledge structures
       - a. complete
       - b. consistent
       - c. parsimonious
    2. Informative feedback
       - a. surprising
       - b. constructive

Most games have what Csikszentmihalyi (1975) calls a *fixed goal,* that is a goal that is predetermined by cultural convention. Fixed goals can be made obvious and compelling by the use of visual effects (Breakout) or fantasy (Hangman). In contrast to games, other kinds of activities, like drawing pictures or writing stories, may have what Csikszentmihalyi (1975) calls *emergent goals;* that is goals that arise out of the interaction between a person and the environment. In order to be motivating, environments like this should be structured so that users can easily generate goals of appropriate difficulty. For example, Papert (1980) describes a computer-based environment in which a moving "Turtle" draws designs on a computer screen or on the floor in response to the learner's commands. One of the strengths of this environment is that it is easy for children to think of things they would like a moving "Turtle" to do. But, unless beginners have some help evaluating the difficulty of possible projects, they might easily pick tasks that are discouragingly difficult. Finally, in order to be motivated by a goal, learners usually need some kind of *performance feedback* to tell whether they are achieving their goal.

Uncertain Outcome. An environment is not challenging if the person is either certain to reach the goal or certain not to reach the goal. 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: *variable difficulty level, multiple level goals, hidden information,* and *randomness.*

Variable Difficulty Level. Most good computer games are playable at different difficulty levels. In computer games, as well as in other educational activities, the choice of difficulty level can be either: (a) determined automatically according to how well the player does (e.g., Breakout, drill-and-practice), (b) chosen by the learner (perhaps the 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 why competition is motivating is simply because it provides a challenge at an appropriate difficulty level.

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. There are at least two kinds of multiple level goals.

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.

In the second kind of multiple level goal, the higher level goals involve accomplishing the lower level goals "better". 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 a problem-solving model (Newell & Simon, 1972; Newell, 1979), 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; Shiffrin & Schneider, (1977).

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. Environments that include *scorekeeping* or *speeded responses* often emphasize this sort of high level goal, and therefore these features seem especially appropriate for instructional situations (like drill-and-practice) where the purpose is to optimize previously learned procedures.

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, as well as contributing to the challenge of an activity.

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 or activities (e.g., Hammurabi, Adventure).

Toys vs. Tools. This analysis of challenge illuminates an important distinction between toys and tools. Toys can be defined as systems used for their own sake with no external goal (e.g., computer games, puzzles, etc.). Tools can be defined as systems used as a means to achieve an external goal (e.g., text editors, programming languages, etc.). The requirements for good toys and tools with respect to challenge are mostly opposite. Since a good tool is designed to achieve goals that are already present in the external task, it need not provide a goal. Furthermore, since the outcome of the external goal (e.g., writing a good letter, getting a program to work) is already uncertain, the tool itself should be reliable, efficient, and usually "invisible". In a sense, a good game is intentionally made difficult to play to increase its challenge, but a tool should be made as easy as possible to use. This distinction helps explain why some users of complex computer systems may take a perverse pleasure in mastering tools that are extremely difficult to use. To the extent that these users are treating the systems as toys rather than tools, the difficulty increases the challenge, and therefore the pleasure of using the systems.

Self-esteem. Challenge is captivating because it engages 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, however, 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. 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), and they may or may not be likely to occur in the learner's environment (e.g., balloons vs. dragons).

Intrinsic and Extrinsic Fantasies. 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 (Baseball), or avoids some fantasy catastrophe (Hangman), depending only on whether the player's answers are right or wrong. These are examples of *extrinsic fantasies,* where the fantasy depends on the use of the skill but not vice versa. Other factors such as speed of answering can also affect extrinsic fantasies. For example, the Speedway game in which students' race cars move along a race track depending on how fast they answer arithmetic problems is an extrinsic fantasy. Since the exercise of the skill does not depend in any way on the fantasy, the same fantasy could be used with completely different kinds of problems. For example, Baseball and Hangman fantasties 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.[3]

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, and players receive a natural kind of constructive feedback. For example, in Darts, the skill of estimating distances is applied to the fantasy world of balloons on a number line, and players can see graphically whether their answers are too high or too low, and if so by how much. Other intrinsic fantasies in math games include the search for a hidden animal on a Cartesian grid in the Hurkle game and Snoopy shooting at the Red Baron on a number line 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).

I would like to claim that: *In general, intrinsic fantasies are both (a) more interesting and (b) more instructional than extrinsic fantasies.* The Darts experiment described above 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. Metaphors or 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.

Another 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, 1972; Paivio, 1971).

[3]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 but not described elsewhere in the text.

Emotional Aspects of Fantasy. 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 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.

One obvious consequence of the importance of emotional aspects of fantasies is that different people will find different fantasies appealing. If instructional designers can create many different kinds of fantasies for different kinds of people, their activities are likely to have much broader appeal. For example, one can easily envision a math game where different students see the same problems, but can choose which fantasy they want to see. Instructional designers might also create environments 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 (which seem to be very popular in computer games), will players become more 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 section 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. Since both require an optimal level (of difficulty in one case and complexity in the other), both often depend on adjusting the environment to the learner's ability or understanding. Both also depend on feedback to reduce uncertainty (about one's own ability in the case of challenge and about the state of the world in the case of curiosity). In fact, challenge could be explained as curiosity about one's own ability, or 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 have little to contribute to an understanding of challenge. 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. There is no reason why educational environments have to be impoverished sensory environments. Colorfully illustrated textbooks, television programs like *Sesame Street,* and tactile teaching devices (e.g., Montessori, 1912) demonstrate this point. Computers provide even more possibilities for graphics, animation, music, and other captivating *audio and visual effects.* These effects can be used: (1) *as decoration* (e.g., circus music at the beginning of Darts), (2) *to enhance fantasy,* (3) *as a reward,* and perhaps most importantly, (4) *as a representation system* that may be more effective than words or numbers (e.g., graphic representation of fractions in Darts, and different tones in Breakout to signal bounces and misses of the ball).

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. Cognitive 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, 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 (i.e., filling in the murderer "slot" in the murder "frame"; see Minsky, 1975). Or, as Morozova (1975) suggests, curiosity can be stimulated by pointing out inconsistencies or paradoxes 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. Finally, one might evoke curiosity by giving a number of examples of a general rule before showing how (or letting students discover that) all the examples can be explained more parsimoniously by the single new rule.

The "Socratic method" and the tutorial strategies of master teachers (Collins & Stevens, 1981) can be seen as ways of systematically exposing incompletenesses, inconsistencies, and unparsimoniousness in the learner's knowledge structures. One extremely powerful tool for tailoring feedback in this way for specific learners in computer-based learning environments is to maintain on-line cognitive models of the learners (e.g., Burton & Brown, 1979).

Informative Feedback. Several more specific principles for designing instructional environments follow from these general ideas. One way of making environments interestingly complex is to make them responsive (see Moore & Anderson, 1976). 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, players of the Hammurabi simulation may be surprised at how many people starve at first. But the underlying relationships between amount of grain and number of people are consistent and can be discovered by the players.
(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.

6. CONCLUSION

In this article, I have suggested a coherent framework for a theory of intrinsically motivating instruction. As described in more detail elsewhere (Malone, 1980a, 1980b), one use of this framework is as a checklist of heuristics to be used in designing instructional environments. Few instructional environments include all the features mentioned above, and it is usually possible to think of ways that any given activity could incorporate more of these features. For example, at least one fifth of the computer games in the survey described above do not have any way of varying their difficulty level, and could probably be improved by adding this.

I have focused in this article on features that can be present in all intrinsically motivating learning environments. In so doing, I have neglected two important kinds of features. First, I have assumed, as part of the definition of intrinsic motivation, that learners are free to choose their activities without external pressures. As mentioned briefly above, this freedom of choice can be an important motivator by itself.

Second, I have neglected 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.

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APPENDIX
DESCRIPTIONS OF GAMES MENTIONED IN TEXT
(See also Table 1)

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.
Chase	Two players chase each other across an obstacle course.
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.
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.