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ABSTRACT

The use of hand-held electronic devices and microcomputers in places of public access and in the home are discussed. First, the different activities supported by this technology are described, with emphasis on the commonality of game playing to both hand-held devices and microcomputers. The need for research to investigate the motivational qualities of these games and their influence on learning is stressed. Motivational aspects of microelectronic games are discussed, particularly the attributes of popular computer games and the effects of external constraints on intrinsically motivated activities. The types of learning which can be influenced by electronic game playing are considered. To illustrate how cognitive learning strategies might be affected, a general description of developmental and population differences in learning and memory is provided, and factors which may cause changes in strategy use are discussed. Specific examples for research, involving both observational and experimental methods, are presented. A 9-page reference list is included. (Author/LMM)

Implications of Hand Held Electronic Games and Microcomputers for Informal Learning

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Abstract

This paper is concerned with the use of hand held electronic games and microcomputers in places of public access and in the home. The paper consists of four sections. The first section provides a description of the different activities supported by this technology. Game playing is an activity common to both hand held devices and microcomputers. Indeed, game playing is a major introductory use of microcomputers. Thus, an important entry point for research concerning the impact of this technology on informal learning will involve an analysis of the factors which affect the child's interest in electronic game playing and evaluation of the kinds of learning opportunities provided by these games. Specifically, what makes these games so captivating and how do they influence children's learning?

The second section of the paper is concerned with the motivational aspects of microelectronic game playing. An exemplary study by Malone (1980) concerning attributes of popular computer games is discussed. Also, the effects of external constraints on intrinsically motivated activities, like electronic game playing are examined. A consideration of the types of learning which can be influenced by electronic game playing is presented in the third section. In order to illustrate how "cognitive learning strategies" might be affected, a general description of developmental and population (e.g., socioeconomic status) differences in learning and memory is provided. A discussion of factors which may be responsible for changes in strategy use is also included.

The final part of the paper is devoted to suggestions for research. Drawing on the background information provided in the previous sections of the paper, specific examples for research, involving both observational and experimental methods, are presented.

Introduction

Advances in microelectronic technology have made a wide range of new products available to the American family. This paper is concerned with how two of these products, hand held electronic games and microcomputers, are used outside of school and the types of learning opportunities they provide children.

A variety of hand held electronic games are available. With these gadgets we can play electronic versions of athletic games, engage in the fantasy of shooting at UFOs, test our memory or sensory motor coordination, and even have an opportunity for old fashion drill and practice. If you wanted to purchase one of these new electronic gadgets, consulting Consumer Reports (November 1980) would provide information on the objective of the game, price, target age group, types of batteries required, and comments on enjoyment value. Articles in popular magazines suggest that these new electronic devices may represent the "learning machines" of the eighties (see Gardner, 1979). However, it is difficult to uncover either evaluative or experimental evidence concerning their instructional value. In this regard, the traditional marketing research conducted for many of the items does not include large scale assessment of instructional effectiveness.[1]

A microcomputer is a computer system which is usually small enough to fit on a desk top and can cost as little as $500. The major components of a microcomputer include an Input, such as a typewriter keyboard; a Central Processing Unit, located on a silicon-based microprocessor chip, which interprets instructions and controls the flow of information in the system; a Memory for the storage of data and programs; and an Output, such as a television.[2] Similar to hand held electronic devices, microcomputers provide a medium for playing games. Because of the "power" of microcomputers, such as the Apple II or the Atari 800, more sophisticated versions of these games can be supported and complicated simulation games can also be played. Furthermore, software is available to the consumer for a variety of activities such as business, finance, education, entertainment, or word processing. The promise of computers in formal education is substantial, particularly in terms of advanced forms of Computer Assisted Instruction (e.g., Ragosta, 1980) and "creative computing" activities (see Kay & Goldberg, 1977; Papert, 1980). Furthermore, the invasion of schools by microcomputers has been anticipated (see Spuck, 1979) and some research concerning the instructional implications of microcomputers in classrooms and other school related activities, such as computer clubs, is beginning to appear in the literature (e.g., Levin & Kareev, 1980a).

Many children, however, will have their first exposure to microcomputers outside of school settings. For example, they may encounter them in their own homes or in places of public access, such as museums, shopping centers, and amusement parks (see Kahn, 1981, for a detailed description of public access to microcomputers and projections of purchase patterns for home use). Generally speaking, these environments are distinguished in two ways from the classroom or computer clubs which have been traditionally associated with children's use of computers. First, the child will not have a teacher or other expert to guide their use of the microcomputer or to encourage their discovery of "creative computing activities." Second, these settings allow for more direct parental involvement in the child's activity. For example, Sesame Place, a play park for children 3-13 (see Kahn, 1981, for a complete description), includes a Computer Gallery. In the gallery, 57 modified Apple II microcomputers are available to the children. A menu of one to three games is available on each microcomputer and the children have a total pool of forty different games. Each game was designed with a specific educational concept in mind. For example, one available game, "Reflect," is concerned with the concept that angle of incident equals angle of reflection. Children make menu selections for the games and move between microcomputers without direction from Sesame Place personnel. Parents also get involved, typically using their children as "foils" so they can play with the microcomputer game too (Hakansson, 1981 a and b).

When parents introduce microcomputers into the home, the same type of extensive game playing with entertainment or educational software by both children and adults can probably be expected (e.g., Levin & Kareev, 1980). The discovery of innovative uses for the microcomputer beyond game activities, however, may require the guidance by a family member with some expertise concerning the range of activities possible as well as financial resources necessary to support these additional activities through the purchase of additional software and/or hardware for the microcomputer. In this connection, middle and upper income families will probably be in a better position to take advantage of this new technology for the home (see Wallings, Jr., Thomas, & Larson, 1979). Thus, if large numbers of children from upper income families use microcomputers for educationally relevant activities in the home, existing social class differences in school achievement could be exacerbated.

In summary, game playing is a feature shared by hand held electronic gadgets and more powerful microcomputers. This type of game playing, including entertainment games and the wide range of so called educational games which are becoming available, probably constitutes the first sustained interactive activity most children and adults will have with this technology outside of the schools. Thus, gaining an understanding of the types of games children actually spend time playing constitutes the first step in determining what children may learn from such experiences. Thus, in the next section of this paper we will consider why these games are fun and how such information can lead us to a better understanding of what children might learn from these games.

Motivation and Learning

Children and adults spend endless hours playing with hand held electronic games and the various interactive games which can be purchased for use with microcomputers. Although these games may have been designed with a specific educational objective in mind (e.g., learning how to spell new words) most children and adults are probably playing for the "fun" of it. For example, a device like Speak and Spell offers the individual a rich interactive experience in the three different senses of touch, vision, and hearing. Indeed, it is not uncommon to find competition between children and "grown-ups" for the opportunity to play with these games (see Gardner, 1979).

Because these electronic games are so captivating, a rich opportunity is provided for informal learning. However, are all hand held electronic and microcomputer games equally captivating? If not, what dimensions distinguish the games children enjoy playing from those they do not enjoy playing? Answers to questions like these will bring us one step closer to determining whether and how children learn from such interactive experiences. That is, once we have an idea of what types of activities children spend time with, we can analyze the activity to determine what can be learned and how it is learned.

Sources of Motivation

An important distinction can be made between activity which is intrinsically motivated versus extrinsically motivated. That is, activity can be viewed as extrinsically motivated if the activity leads to external rewards or social reinforcement. Alternately, activity can be viewed as intrinsically motivated if the activity is conducted in the absence of obvious external rewards. This distinction is made in a different way by de Charmes (1968) who focuses on the locus of perceived causation.

> ...we propose that whenever a person experiences himself to be the locus of causality for his own behavior (to be an origin), he will consider himself to be intrinsically motivated. Conversely, when a person perceives the locus of causation for his behavior to be external to himself (that he is a pawn), he will consider himself to be extrinsically motivated (page 328).

This conceptual distinction between intrinsic and extrinsic motivation for activity is useful in understanding the sustained electronic game playing activities of both children and adults. For the most part, people do not play electronic games because of the expectation of some external reward or because they are "directed" to play by an external agent. To the contrary, they play because the games are "fun." Accordingly, this game playing behavior is intrinsically motivated.

Malone's Study on "What Makes Things Fun to Learn?"

A recent study by Malone (1980) provides some preliminary evidence concerning what makes computer games fun. His study will be described in some detail because it provides unique evidence and suggests methodology for future work in this area.

Three experiments were reported by Malone. The first was designed to evaluate the computer game preferences of 65 children ranging between the kindergarten and eighth grades. These children from "relatively affluent families" attended a private elementary school near Palo Alto, California. The children had been exposed to 25 different games in computer classes. The children's experience with computers ranged between 2 months to 2 years. The children were asked to rate their preference for each game on a 4 point scale (0 = never played, 1 = didn't like, 2 = like, 3 = like a lot) and they were also interviewed about their preferences. Definite game preferences were reported by the children. For example, one of the most popular games was Breakout where a player controls a paddle to direct a bouncing ball that breaks through a wall piece by piece, while the lowest rated game was "Gold" in which an individual fills in blanks in a story about Goldilocks. A number of game features were positively correlated with subjects' game preferences. For example, games which had a clear goal (e.g., breaking all the bricks out of a wall) were more popular than those that did not (e.g. speaking with a psychiatrist - Eliza). Also, games which included graphic effects were liked, while word games were generally disliked. Some large individual differences in game preferences were also found. For example, when the children were asked to rank order their top 10 games, no single game received more than 17% of the first place rankings. Amount of prior computer experience and the sex of the child were both found to influence game preference. For example, children with more computer experience tended to rate the games lower in preference and give higher ratings to the outerspace games of Star Wars and Star Trek in which players shoot down enemy space craft. Boys also preferred Star Trek more than girls.

Malone's second and third experiments were designed to assess the effects of the presence or absence of certain game features on children's game preference. The second experiment, conducted with 10 Stanford undergraduate students, evaluated the motor skills game of Breakout. Malone created versions of the game which manipulated whether the game included the presence or absence of 1) bricks breaking out, 2) mechanical scoring (i.e., numerical feedback on the screen indicating the number of bricks broken, balls left, etc.), and 3) the motor skill activity of bouncing the ball off the paddle. The results from this study clearly indicated the secret to the game's popularity "...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" (page 30). Malone has also stated that "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 the goal", thus suggesting that the breaking out of bricks actually includes an aggregate of important features.

The third experiment examined a cognitive game called "Darts." In this game, balloons appear at random places on a vertical numbered line which is on the left side of the TV screen. The player attempts to guess each balloon's position by typing in whole numbers and/or fractions. After each guess is made an arrow shoots across the screen from right to left to the specified position. If the guess is correct, the arrow pops the balloon.

Malone suggests that "Darts," which was designed to teach children about fractions, "...typifies...the best kind of highly motivating instructional computer games..." (page 31). The game provides the player with both performance feedback, by indicating if the player's guess was correct, and constructive feedback concerning the accuracy of the player's guess (too high or too low). Another equally important feature of this game is fantasy. Malone distinguishes between two types of fantasy, extrinsic versus intrinsic. In an extrinsic fantasy, the fantasy depends on the correct use of the skill, while for an intrinsic fantasy "not only does the fantasy depend on the skill, but the skill also depends on the fantasy." In "Darts," for example, the fantasy of arrows popping balloons is considered intrinsic because the relative sizes of the numbers selected are directly related to the positions of the arrows and balloons in the fantasy. This can be contrasted to a version of the game in which the child is asked to guess the position of a marker on a line (as opposed to a balloon) on the left side of the screen. If the guess is correct an arrow shoots across the screen from left to right and pops a balloon. In this version of the game the relative sizes of the numbers selected bear no direct relationship to the "positions" of the balloons popped on the right side of the screen when the guesses are correct. Thus, the fantasy is considered extrinsic.

Subjects for this third experiment were 80 fifth grade children attending public schools in Palo Alto, California. These children were drawn in equal numbers from schools serving a middle to upper-middle class community and a predominantly low-income minority community. The children were tested using one of eight versions of the Darts game on an Apple II microcomputer. Three preference measures were evaluated: 1) How long they played with Darts in preference to another game, Hangman; 2) ratings of the game on a 5 point scale; and 3) subjects rated their preference for playing Darts versus Hangman. A major finding from this experiment is that the "fantasy" element played a large role in determining the popularity of the game. In particular, boys preferred the version of the game with intrinsic fantasy more than extrinsic fantasy, while the opposite was observed for girls. The importance of this finding is best summarized by Malone:

> 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 audience, they may actually make the environment less interesting rather than more. (page 47)

Malone's research provides an excellent example of how descriptive/observational research can and should lead to systematic manipulative research. Specifically, game preferences were revealed in the descriptive phase, while in the experimental phase the specific attributes of game preferences were systematically manipulated to assess their contribution to the child's preference. Furthermore, the research provides an indication of the types of games that children will spend their time playing.[3] Some important questions unanswered by the Malone study include the following: 1) What is the stability of game preferences over time? 2) Are there systematic age or socioeconomic status group differences reflected in game preferences or in those attributes that make certain games captivating? 3) What do children learn from these games?

Turning Play into Work

Playing with hand held electronic and microcomputer games appears to be an intrinsically motivated activity. Although we do not know, as yet, what children actually learn while playing these games, the sheer amount of time they spend with these games provides an excellent opportunity for learning. However, to what extent can an intrinsically motivated activity be undermined by external factors? Furthermore, what are the learning or performance consequences of such interference? Studies by Lepper (see Lepper, Greene, & Nisbett, 1973; Lepper & Greene, 1975; Amabile, DeJong, & Lepper, 1976) indicate that extrinsic intervention can undermine the intrinsic motivation for the task and perhaps degrade the quality of task performance (see Kahn, 1978, and Bates, 1979, for reviews of this issue in informal learning and classroom learning contexts).

For example, in a study by Lepper, et al, 1973, nursery school children were given an opportunity to play with felt-tip markers and paper. Children showing an interest in drawing with the markers were subsequently assigned to one of three drawing conditions: 1) reward condition, 2) an unexpected reward condition, and 3) a no reward condition. After subjects participated in one of the three drawing conditions, they were given another opportunity to play with the markers in a free play situation.

The results indicated that children in the expected reward conditions played with the materials less than subjects in the other groups, suggesting a decrease in intrinsic motivation. Furthermore, the pictures drawn by subjects in the expected reward condition were judged to be of poorer quality than those drawn by subjects in the other groups. A subsequent study by Lepper (Lepper & Greene, 1975) replicated this reduction in intrinsic motivation under different task conditions. Of particular interest was the finding that "surveillance" of the children's activity could decrease intrinsic motivation for the activities.

An important implication of this research is that the intrinsically motivated activity of playing with microelectronic games, which provides the opportunity for informal learning, could be undermined by "contextual" factors. For example, if a parent believes that a child should "learn" something from an an electronic game, they may direct the child's learning or promise the child a reward for the activity. Based on the research reviewed, this type of parental intervention may result in a reduction in the amount of time the child will play with the game and the quality of the learning which might take place. Whether or not parents will intervene and the nature of their intervention with the child's activity will depend on a number of factors including the socioeconomic status of the family (e.g., Hess & Shipman, 1965), parent's achievement attitudes (e.g., Katkovsky, Preston, & Crandall, 1964 a & b), and the extent of parental computer literacy (see Anderson, Klassen, Johnson; Harris, 1977 and Johnson, Anderson, Harris, & Klassen, 1980).

The Development of Cognitive Learning Strategies

Playing with hand held electronic games or microcomputer games establishes excellent opportunities for informal learning. When reliable and general information is available concerning the kinds of games children find intrinsically motivating, research then can be conducted to determine what is learned from playing these games.[4]

Gagne (1974) has identified the following five categories of learning outcomes:

1. Information. Learning that previously encoded entities, properties, states, actions, concepts, or rules are related to each other in particular ways.
2. Intellectual Skills. Acquisition of mental procedures for classification and rule application.
3. Cognitive Strategies. Internally organized capabilities which govern cognitive processes. When these strategies are acquired, the individual knows how, for example, to learn, to remember, to understand, etc.
4. Attitudes. Learned internal states that affect an individual's preference or choice towards activities, entities, persons, or events.
5. Motor Skills. The acquisition of individual motor actions and the control of a sequence of such actions that make up a complete performance.

Playing with hand held electronic and microcomputer games can potentially implicate all of these types of learning. A feature common to most of the games is the creation of a rich environment for children to invent, discover, practice, and to modify their use of cognitive strategies. These are the strategies that children use to facilitate their learning, memory, problem solving, and understanding. Thus, they are the instruments of independent thinkers and self-learners. An important problem, therefore, is to determine how hand held electronic and microcomputer game playing influences children's acquisition and use of cognitive strategies.

Thus, it is important to identify and understand the development of strategic abilities in children. Accordingly, research concerning children's learning and memory development will be reviewed because such a review will facilitate our understanding of:

1. The development of cognitive strategies in children;
2. Socioeconomic status and ethnic population differences in strategy use;
3. Identification of prompts which facilitate efficient strategy implementation; and
4. Factors which are responsible for strategy application.

In addition, this review will provide important theoretical and empirical frameworks essential for a synthesis of evidence which will be derived from experiments regarding strategy development in children's playing with hand held electronic and microcomputer games.

<u>Strategy Development in Children's Learning and Memory</u>

Research in learning and memory development has traditionally used experimental procedures such as paired-associate learning or free recall learning of categorical items. The research strategy has consisted of isolating a reliable developmental increase in performance on a specific memory task. In many memory tasks, the age difference in performance is due to the older subjects' spontaneous use of a strategy which facilitates their performance, while younger children are either "production deficient," since they fail to generate the strategy, or "production inefficient" because they generate an inappropriate strategy or do not consistently use the appropriate strategy. In order to identify the use of a strategy as the source of a developmental difference in performance, an experiment can be conducted to determine if "prompting" the use of the same strategy in younger children will affect their performance (see Rohwer, 1976, for a discussion of this approach). If such strategy prompting attenuates the developmental differences in performance typically observed under the standard condition when prompting is absent, the strategy manipulated can be implicated as a source of the developmental effect. However, if the prompt fails to improve the performance of the young children, a structural limitation in the young children might be suggested.

An example of developmental differences in strategy use is found in associative memory studies. The paired-associate procedure is used in this kind of research and consists of presenting subjects with unrelated nouns for learning on a study trial. Subjects are tested for their memory on a test trial in which one member of each pair is presented and the subject is asked to recall the associate. College age subjects can typically recall more paired associates than can younger children between the ages of five and ten. Adults typically report using a relational encoding strategy. Elaboration is an example of such a strategy and consists of creating a semantic episode for the otherwise unrelated pair.[5] For example, when presented with the pair "fish--pipe" on the learning trial, the subject might encode the semantic episode of a "fish smoking a pipe." Young children, five and six years of age, on the other hand, either report using very ineffective memory strategies, such as rote rehearsal, or no strategy at all. Young children's performance improves when they are prompted to use a relational encoding strategy (see Levin, 1972; Pressley, 1977; Reese 1977; Rohwer, 1973). Indeed, task conditions can be arranged so that this strategy is automatically prompted in the children (Kee & White, 1977; Kee & Nakayama, 1980). Furthermore, research indicates that children from a variety of different ethnic populations (see Kee & Rohwer, 1973) and socioeconomic status groups (see Rohwer & Bean, 1973; Kee & Beuhring, 1978) can benefit from such strategic prompting. Research indicates, however, that the spontaneous use of the elaboration strategy in older children may be limited to middle and upper income populations (e.g., Rohwer & Bean, 1973; Kennedy & Suzuki, 1977).

Another illustration of strategy development is provided by research concerning organizational processes in memory. A free recall list learning procedure has been used in which children are presented with a list of items drawn in equal numbers from different conceptual categories such as clothing, vehicles, table ware, and animals. Subjects are allowed to memorize the items and then they are tested for their recall of those items. A strategy which has been implicated as a source of developmental differences in free recall performance is taxonomic organization (see Moley, 1977; Lange, 1978). That is, older children and adults tend to notice the categorical structure of the list and exploit this by organizing the items within their respective categories to facilitate their recall, while younger children do not. Although the research in this area has emphasized taxonomic organization as a source of developmental differences in free recall, a recent study by Kee & Bell (in press) reveals that older subjects actually use a variety of sophisticated strategies to facilitate task performance. The additional strategies used by older subjects include:

1. Counting--in which the subject counts or estimates the number of items to-be-remembered;
2. Intercategorical elaboration--involving the creation of an association between items from different taxonomic categories using either sentences or interactive images;
3. Intracategorical organization--in which the subject creates associations within a taxonomic category based on function, acoustic similarity, alphabetical sequence, etc.; and
4. Self-testing--in which the subject looks away from the presentation of stimulus pictures and attempts to think of the items just viewed.

With regard to ethnic/socioeconomic status differences in free recall performance, an early study by Jensen and Frederiksen (1973) indicated that fourth grade middle socioeconomic status white children perform at a higher level than low socioeconomic status black children. Jensen and Frederiksen attributed this difference to corresponding differences in conceptual encoding capacity (i.e., Level II intelligence) of middle socioeconomic status white children relative to low socioeconomic status black children. However, Jensen's interpretation has been criticized (e.g., Mandler, 1979) and more recent research indicates that these two groups do not differ in their ability to conceptually encode taxonomic information in memory (see Kee & Helfend, 1977; Nakayama & Kee, 1980; Orasanu, Lee, & Scribner, 1979). Furthermore, the free recall performance of low socioeconomic status black children can be substantially improved by prompting them to use an appropriate taxonomic strategy (e.g., Kee, Nakayama, Cervantes, & Osaze, 1981), thereby suggesting that the population differences observed in free recall can be attributed primarily to differential use of appropriate taxonomic strategies.

In summary, research in memory development suggests that the proficient performance displayed by older children and adults can be attributed, in part, to their spontaneous use of task appropriate strategies, while the poor performance of the young children can be the result of either a production deficiency or inefficiency. The research also indicates that young children can be prompted to use appropriate memory strategies, thereby improving their performance. While ethnic and socioeconomic status differences have been detected in the development of strategic behavior, strategic prompting which facilitates the performance of middle socioeconomic status white children is also found to be effective with children from other socioeconomic status and ethnic groups.

Factors Which Can Influence Strategy Utilization

What prompts some older children and adults to spontaneously employ appropriate strategies to facilitate their task performance? One possibility, which has been suggested by Flavell & Wellman (1977), is the extent of our knowledge concerning our memory skills, which is referred to as metamemory. Metamemory includes our abilities to:

1) predict our capacity limitations;
2) accurately appraise the task demands;
3) be aware of strategies and their appropriate use;
4) execute the strategy in the appropriate task;
5) monitor the use of the strategy; and
6) make use of the feedback from this monitoring.

These aspects of metamemory can also be viewed in more general terms. That is, they comprise many of the features of an "executive process" in cognition (Brown & Deloache, 1978). Thus, the development of these "metacognitive" skills, increasing conscious control and regulation of goal-oriented strategies, are important not only in memory development but in other domains such as problem solving (e.g., Klahr, 1974) and understanding (e.g., Brown & Collins, 1978).

Direct training of metacognitive skills is an important issue (e.g., Brown, Campione, & Day, 1981; Resnick, 1976). However, a recent study by Beuhring (1979) suggests that, at least in associative memory, relevant metamemory knowledge is neither a necessary or sufficient condition for the spontaneous use of elaboration. For example, some adolescent children who used elaborative strategies in the paired-associative task, displayed little metamemory knowledge. Conversely, some subjects who displayed substantial metamemory knowledge failed to use elaboration to facilitate their task performance. An interesting view expressed by Beuhring is that the developmental relationship between metamemory and strategy use is bi-directional or interactive. That is, metamemory development during adolescence may both determine, and be determined by a developing (or accidental) tendency to elaborate paired items.

A problem related to metamemory development is the notion of strategy transfer. For example, in free recall learning, transfer can be estimated by comparing the performance of "production deficient" children previously required to use an appropriate organizational strategy in free recall with a comparable group of children who have simply been given practice in free recall. Generally speaking, children previously exposed to the strategy do not show reliable gains in performance, relative to the control subjects, when on subsequent lists they are asked to learn the material without a reminder to use the memory strategy (see Moely, 1977). A more promising direction for the promotion of strategy acquisition and transfer will probably consist of training aimed at fostering general metacognitive skills and/or providing children with structured opportunities in which they are encouraged to discover and manipulate various task relevant strategies.

Working Memory Capacity

Another factor which may limit the child's spontaneous use of appropriate strategies is that they are incapable of coping with the information demands of the learning situation. In this regard, experimental evidence documents the limited nature of working memory (see Dempster, 1981) and developmental research suggests links between the growth of working memory and the child's abilities to utilize increasingly complex strategies (see Case, 1977).

The recent works of Pascual-Leone (1970) and Case (1975; 1978b) are particularly relevant. They have been concerned with evaluating the relationship between M-space (a neo-Piagetian construct which describes the unit-by-unit increase in children's attentional capacity with age) and the types of executive strategies required to solve Piagetian tests of concrete and formal operations (e.g., Case, 1978 a & b). Recent research indicates that a person's functional M-space can also serve to modify the execution of more basic strategies. For example, a recent study by Bell & Kee (1981) required first grade children to learn logographs for objects and actions. Subjects were then asked to read and then act out simple logograph sentences [e.g., (sit) (on) (the pillow)]. Two types of response strategies were displayed by the children. Some of the children would act out the individual components of the sentence by sitting down, making a gesture for "on," and pointing to the pillow, while others would spontaneously act out the "meaning" of the sentence by sitting on the pillow. A number of "predictors" of response strategy were evaluated (M-space, IQ, reading level) and only M-space significantly discriminated between children using the nonintegrative style versus the integrative style in the logograph task.

The foregoing discussion concerns only some of the general patterns of strategy development in children's memory; dynamic changes in strategy use are typically detected in other areas as well (see Brown & Deloache, 1978, for a detailed discussion of relationships between memory and problem solving research and Case, 1978b, for a consideration of the relationships between memory and executive strategy development). To the extent that hand held electronic and microcomputer games of high intrinsic motivation include strategic components for successful performance, wide variation in strategy production and utilization can be expected. Furthermore, the captivating nature of these games will also provide children with the requisite opportunities to develop their strategic abilities.

Research Suggestions

With the literature background provided in the previous sections, research suggestions can now be considered concerning motivational and learning aspects of games available on both hand held electronic devices and microcomputers. The long term use of microcomputers in the home will include many more activities than game playing. However, game playing dominates the introductory use of microcomputers in the home and is a major activity with microcomputers in places of public access. Thus, analysis of the motivational and learning aspects of these electronic games is a prime area for the initiation of research which will provide important evidence relevant to understanding the child's early interest and success in using this technology and its potential for facilitating informal learning.

Hand held electronic games are usually priced below seventy-five dollars, whereas microcomputers can range in price from a few hundred dollars to a few thousands dollars (see Kahn, 1981). Because of these price differences, in part, it can be expected that microcomputers and even some types of hand held devices will be found more often in homes of higher income families. To the extent that children in the upper income levels enjoy an advantage because of this in-home availability of technology, corresponding differences in academic achievement between socioeconomic status groups will be increased. Thus, population group comparisons are required in this research in order to provide a data base that can be used for projections about the differential effect the home use of this technology by some families might produce. Furthermore, an emphasis has also been placed on evaluating what children learn from playing with microcomputers in places of public access. This interest is prompted, in part, by the possibility that the provision of microcomputers in places of public access can provide children from lower income families with one type of compensatory opportunity to benefit from this new technology.

Hand held Electronic Games

Important questions concerning the informal use of hand held electronic games include the following:

1. What are the effects of game use on the acquisition of

information, skills, and cognitive strategies?[6]

2. How will external constraints affect the use of these games?

3. Will the patterns of learning and/or motivational effects differ as a function of age level or population membership (e.g., ethnic minority or socioeconomic status)?

Game Selection

The research should emphasize the evaluation of educational games, that is, games which can facilitate the child's acquisition of information, intellectual skills, and/or cognitive strategies.[7] Because of the variety of games currently available and those planned for the market (see Kahn, 1981) it will not be feasible to include a large sample of these games in the research. Furthermore, some of the games can be excluded from consideration because they are simply electronic versions of familiar paper and pencil or board games (e.g., Master Mind). In this connection, a review of the existing research literature may be sufficient to uncover evidence concerning the games instructional effectiveness (e.g., see Lawrence, 1977, for a detailed discussion of the problem solving strategies used in the game Master Mind).

Selection of the games for study can be guided by sales figures provided by the manufacturers. For example, games which are "market leaders" should be evaluated because their popularity suggests, although indirectly, wide exposure and use of the game by children. Also, games which have exploited microelectronic technology in a new and creative way should be evaluated because they may represent examples of future applications of the technology in hand held games.

A game which meets all of the forenamed requirements is "Speak and Spell." The educational objective of the game is to provide children with practice in both spelling and word pronunciation. Different game modes are available (e.g., "Hangman," "Mystery word," etc.). Also, the game presents questions and provides feedback with a synthesized voice, a unique application of microelectronic technology in hand held games (see Kahn, 1981, for a complete description). Thus, Speak and Spell will be used as an example of the type of game to be studied. However, the general research problems previously identified and the design suggestions to follow are not limited to this one game.

Research Design

Standard evaluation and laboratory procedures could be used to determine if Speak and Spell influences the rate of word acquisition relative to appropriate control conditions. The evaluation should include provisions for assessing the effectiveness of Speak and Spell in contrast to a low cost alternative, such as flash cards. Direct observation of the child's use of Speak and Spell will also be desirable for providing a complete description of the various stages associated with the use of the game (e.g., changes in the strategies used to play the "Mystery word game," etc.). In this connection, those "strategy prompts" which may facilitate the child's success with the game should be identified. The effectiveness of these prompts could be empirically verified in subsequent research.

An evaluation of potential negative side effects should also be conducted. As an example, the keyboard on Speak and Spell is arranged from A to Z as opposed to the QWERTY arrangement found on most typewriters. Thus, one possible side effect may be that children will learn keyboard strategies with Speak and Spell that may interfere with the acquisition of normal typing skills.

To examine how children's enjoyable and informal use of Speak and Spell might be undermined by extrinsic controls such as rewards, an experiment using procedures similar to those used in the study by Lepper, et al (1973), could be conducted. Children would be stratified into groups based on their initial levels of interest in Speak and Spell (i.e., high vs. low).[8] This factor of intrinsic motivation is crossed in the experimental design with the manipulated factor of exposure to an extrinsic motivational prompt (i.e., present vs. absent) and the child's subsequent interest in playing with Speak and Spell would be one dependent variable of interest. Indeed, a cleverly designed experiment would include provisions for estimating learning gains (e.g., number of new words acquired) as a function of the two experimental factors of intrinsic motivational level and exposure to external motivational prompts.

Although the research is concerned with the implication of the informal in-home use of Speak and Spell on learning and motivation, it would not be feasible to conduct the foregoing experiment in children's homes. Thus, the research could be conducted in an informal or a semi-structured classroom setting which would also allow for the study of a reasonably large and representative sample of children.

Other Considerations

Estimates of age and population differences in the use of Speak and Spell should be considered. Speak and Spell was designed for children ages seven and above. Thus, reasonable ages for the study might include ages six versus nine versus twelve. These ages generally correspond to different developmental levels (e.g., M-space). Comparisons with children from different socioeconomic levels will indicate whether differential benefits can be expected with the use of Speak and Spell in the home. The important issue is not whether different "baseline" levels of performance are observed for the groups, but the degree of improvement they show. Research will be required to identify those conditions (e.g., prompts, extended practice, etc.) which influence these performance gains. In this connection, research should also be sensitive to whether Speak and Spell can be used to facilitate language learning in non-English or limited English speaking populations. Perhaps what is required is a special bilingual version of Speak and Spell for these groups.

Another consideration will be the examination of how parents and children participate in the use of Speak and Spell (see Hansen, 1981, for a detailed discussion of this issue). This evaluation could be conducted using observational procedures either in the home or under informal laboratory conditions. Specific emphasis should be placed on understanding how parent-child interaction patterns in different socioeconomic status groups encourage or discourage playing and learning from Speak and Spell (see Hess & Shipman, 1965).

The evidence provided by the kinds of studies suggested above will provide direct estimates of the "rate of learning" associated with Speak and Spell and how external constraints might interfere with such learning. This information will be useful to both parents and teachers (e.g., Marshall, 1978) in making optimal use of Speak and Spell. The findings will also hold implications for current research and theory concerning intrinsic motivation and learning in different populations.

Microcomputers

Important questions concerning the early informal use of microcomputers include the following:

1. What are some of the features of popular "educational" computer games?
2. Does game preference vary with either age level or socioeconomic status?
3. What are the relationships between different measures of game preference?
4. What is the long term stability of game preferences?
5. What kinds of knowledge, intellectual skills, or strategies are acquired in playing with the popular games?[6]
6. Is there a relationship between a game's popularity and the degree of children's learning from the game?
7. If children acquire new knowledge, skills or strategies

by playing a specific game, can they transfer this information to other situations?

8. Can prompts be identified to facilitate, for example, strategy acquisition in game playing? Can these prompts be effectively designed into the game?

Game Selection

Games which are based on clear educational objectives should be identified for study.[7] The games should range from activities aimed at the acquisition of specific knowledge or skills, like the games of "Reflect" or "Darts" previously discussed, to simulation games designed to foster a complex of learning activities, such as the acquisition of knowledge, intellectual skills, and cognitive strategies. Sets of the different types of games should be constructed for the study of subjects' preferences. The specific games selected should be guided by a consideration of software sales patterns. For example, inclusion of popular, best selling games presumably would be important because they are representative of the kinds of games generally available for use in the home. Also, inclusion of games found on microcomputer menus in places of public access (e.g., Sesame Place) will also be important. As previously discussed, these games may represent the first introductory activities many children will have with microcomputers.

Research Design

Descriptive, observational, and experimental phases to the research can be identified. In a descriptive phase of the research, procedures similar to those used by Malone (1980) can be used to establish game preferences and the "attributes" of popular games. A special emphasis, however, should be placed on examining differential game preferences and the relative importance of various game attributes, such as fantasy, in different populations. This evidence will be important for determining if children from different groups are intrinsically motivated to play the same kinds of games, thereby establishing similar opportunities for learning. In this connection it will be important to directly observe how children play the games in order to provide an analysis of the different stages of knowledge, skill, and strategy acquisition prompted by playing the games. Also, children from different groups may play the same game differently because they are captured by different components of the game which may result in corresponding differences in what is learned from the games.

Places of public access provide ideal locations from an external validity perspective for the collection of some of the descriptive data concerning game preferences. Questions, however, concerning the long term stability of preferences and the relationship between various preference measures would be more appropriately collected in the informal context of a "computer club." The large samples required for this research would make the collection of this data in home settings prohibitively costly. However, the longitudinal study of microcomputers in the homes of a limited number of families, representing different income levels, would be desirable. For example, the studies in the home will provide an opportunity to assess the generality of the findings concerning children's preferences for games. Furthermore, the observations in the home can lead to a description of 1) the transitional stages in microcomputer use by children, 2) how these stages are influenced by parental support, and 3) how the microcomputer becomes "integrated" into the home (see Cole, Hutchins, Levin, & Miyake, 1979). A sociolinguistic ethrography framework would be particularly useful in capturing the structure of these transitions (see Green & Wallat, in press). Specifically, this approach provides a reliable method for identifying naturally occurring events, specifying the antecedent conditions for these events, and systematically mapping transitions between events.

An experimental phase of the research should be included in order to determine the direct consequences of game playing on learning. Some of this evidence could also be collected in the descriptive research by monitoring the child's progress towards successful game performance. A limited number of games would be used in this research phase. Each game would consist of two versions, one version designed to be high in intrinsic motivation, while the other version would be designed to be low in intrinsic motivation. For example, drawing on Malone's (1980) ideas about the importance of challenge, fantasy, and curiosity as elements of intrinsically motivating instruction, the versions of the games could vary according to the degree to which these forenamed elements were present. That is, a game designed to be high in intrinsic motivation would incorporate these elements, while the alternate version designed to be low in intrinsic motivation would limit the use of these elements. A validity check on this manipulation will be important. This factor of intrinsic motivation would be crossed with the factor of learning sets (e.g., learn instructions vs. free play instructions). Measures of game playing enjoyment and information/skill/strategy acquisition would serve as the dependent variables of interest. Also, tests of transfer to other games, tasks, or more traditional modes of instructional assessment like paper and pencil tests could be included in this phase of the research. This experimental research could also be conducted in places of public access, informal settings (e.g., computer clubs), and/or in the laboratory.

Furthermore, if systematic differences in learning or transfer are observed between children of different ages or socioeconomic groups, experiments should be conducted to assess the effects of "instructional prompts" designed to eliminate such differences.

Other Considerations

As previously discussed, both age and socioeconomic status group comparisons should be included in this research. The specific age levels to be sampled will be determined, in part, by the sophistication of the games selected for study. However, the age range sampled should allow for the assessment of both novice and expert levels of performance. This will be particularly important in the identification of "instructional prompts" designed to facilitate the performance of children who are not proficient in the games.

The findings from the suggested studies will identify popular microcomputer games and the attributes which are associated with game popularity in different groups . This evidence will be immediately useful to instructional designers and teachers interested in tailoring games to interest children in different populations. Furthermore, the results will provide direct evidence concerning the effect of external constraints on the use of the games and the kinds of learning these games support. This information is vital for our understanding of hospitable conditions for effective informal learning.

Hand held electronic games and microcomputers offer exciting new opportunities for informal learning. The research outlined in this paper indicates how some of the basic evidence concerning motivational and learning aspects of the informal use of this microelectronic technology can be effectively developed. The emphasis has been placed on research which combines observational and experimental analysis. The use of experimental procedures in the research will be particularly important for the immediate identification of factors which reliably influence the effectiveness of this technology in informal learning. Building on this evidence, other creative and educationally relevant uses of this new technology can be explored.

Footnotes

1. Representatives at a number of leading companies (e.g., Coleco, Mattell, Milton Braddley, and Texas Instruments) producing hand held electronic games/toys were contacted in connection with this issue.
2. Excellent introductory articles which provide descriptions of microcomputers, also known as personal computers, and microcomputer systems for education available in the current literature include: Bork & Franklin, (1979), Kahn, (1981), McIsaac, (1979), Miller, (1980), Milner, (1979), and Perry, (1980).
3. Based on the results of his three studies, Malone (1980) has developed a theory of intrinsically motivating instruction. This theory emphasizes the role of three critical game features: Challenge, fantasy, and curiosity. A detailed discussion of the role of these features in the design of instructional games is provided in Chapter 6 of Malone's paper.
4. Only a limited selection of "educational" games are currently available for evaluation. During next few years, however, a substantial variety of games designed for hand held devices and microcomputers will be produced. These games will teach children a range of content and skills which have usually been acquired by more traditional instructional modes. For example, mathematics learning is an area which has exploited the use of games for instructional purposes (see Bright, Harvey, & Wheeler, 1977) and these types of games are currently being developed and implemented on microcomputers (e.g., Kraus,

1981).

5. Processes (e.g., elaboration) used in successful associative memory have also been implicated in more complex task (see Labouive-Vief, Levin, & Urberg, 1975) and school relevant tasks (e.g., Lambert, 1970; Rohwer, 1971).

6. A Comment on Basic Information Processing Skills. The studies outlined will involve the evaluation of complex learning, such as the acquisition of intellectual skills and the development of cognitive strategies. In contrast to these complex abilities, more basic skills can be identified which might be affected by playing with electronic games. Although a consideration of game playing effects on these basic processes is beyond the purview of this paper, it is important to recognize that such effects can hold important consequences for the child's execution of more complex skills. For example, many of the games which require the tracking of visual information may serve to influence early stages in children's visual information processing. For example, research suggests that children may not process visual information as quickly as older children because of their failure to consistently fixate on relevant target information (see Lawrence, Kee, & Hellige, 1980). The substantial practice, however, provided in some of the games at rapidly identifying and tracking visual stimuli (e.g., enemy space ships) may influence this basic ability. The development of visual information processing skills is particularly important to children's reading ability (e.g., Massaro, 1975).

7. "Educational games" will refer to both games designated as "educational" by the developer and games which can lead to the learning of important information, skills, and/or strategies. These latter games might be classified as "entertainment software." For example, an "entertainment" game like Atari's Star Raiders requires the coordination of sensory-motor skills, strategic planning and systematic coordination of game information, (i.e., metacognitive skills), effective strategy implementation, and knowledge acquisition.
8. Lepper, et al (1973) research design did not include children showing <u>both</u> low and high intrinsic interest in the target task.

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