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ABSTRACT

Aspects of chess relevant to certain educational issues are explored. Based on findings from a sample of about 50 children from 6 to 18 years of age, discussion focuses on (1) how children play chess and how the process of acquiring expertise differs among children and adults, (2) chess training techniques and why they are effective with children, and (3) some experimental results concerning children's memory for chess positions. In conclusion, implications for educators are specified. (RH)

CHESS AND EDUCATION

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Chess and Education

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We have been studying the development of chess skills as part of a larger research program focussing on the development of expertise. While much of recent research on decision-making and problem solving stresses the limits of rationality and how far we humans deviate from "good" decisions, chess is a situation in which humans can make unusually sound decisions. In fact, young children--not normally known for their rationality--can compete with adults on an even basis and make good decisions that appear rational or analytic. This raises some very interesting questions for educators: How can children, before reaching the stage of formal operations, think so logically? And, more importantly, what are the long term benefits of the experience?

Our own research was not aimed specifically at children. We are interested in the more general question of how expertise develops. The classic expertise literature includes studies of chess. In fact, chess has been called the "fruitfly" of cognitive psychology because of its centrality to our understanding of cognition. Chess has been important in the study of thinking because it pushes human information processors to the limits of their cognitive abilities. It is an extremely complex game requiring intensive concentration, planning, and good memory. As we searched for chess players to serve as subjects, we were startled to find that among those "human information processors" operating at the limits of human abilities were some elementary school children! Studying the best thinking that children are capable of and how they developed those skills may yield some valuable ideas for educators.

First, we will consider how children play chess and how the process of acquiring expertise differs for children versus adults. Next we will examine chess training techniques and why they are so effective with children. Then we will present some experimental results on children's memory for chess positions. Finally, we will outline the implications for educators. Our research sample includes about 50 children from the ages of 6 to 18.

Chess and education

The United States Chess Federation sells buttons that say "chess makes you smart." Among the presumed educational benefits are improved concentration and mental discipline, better skills in planning, and an appreciation of consequences of actions. Chess educators have argued that chess is beneficial, not just for the intellectually gifted, but also for learning disabled and hyperactive children. Among parents and chess teachers, countless case studies attest to the educational benefits of chess. When we started our own research on chess, however, we found very little experimental research with children. In a rare study, Christiaen (1978) studied fifth graders for two years during which time an experimental group studied chess after school, one day a week. After the two years, the experimental group performed better on Piagetian tasks, significantly better on school tests, and better on standardized tests than did the control group.

Chess and cognitive skills

While there is substantial literature on adult cognition and chess, little exists using children as subjects. Chi (1978) demonstrated that child players could remember more pieces from a chess scene that could adult non-players, thus demonstrating that knowledge can be more important than age when asked to recall a complex array. Chi suggests that some of the age differences typically reported in developmental studies may be attributable to differences in knowledge about the stimuli rather than to memory factors alone.

Children who play chess

Our sample came mostly from one chess club at Auburndale School, a small school (700 students, K through 12) outside of Memphis, Tennessee. About 125 students of all ages are members of the club. We studied about 35 of the better players and a few players from other clubs. Most people naively believe that any child who becomes proficient at chess must be an extremely rare prodigy (probably with grandmasters for parents). On the contrary, we found that at Auburndale, as well as at other schools, a particular chess coach consistently produces strong players, year after year--even though the specific children move on. In most cases, the parents know little or nothing about chess. Thus, while the individual's talent is important, the training a child receives appears to be equally important. In fact coaches often say that given a few months of training, any motivated and bright 10 year old can become a proficient player. In other words, the skills we will be discussing are not limited to a very select few extremely gifted children; they are trainable skills.

Our sample includes a wide range of children with a wide range of interests. A few are exceptionally gifted, but others are average, and a few are learning disabled. The chess club members included football players and other athletes, cheerleaders, musicians, computer whizzes, and almost any other group typically found in schools across the country. We've found that among strong players, the majority are boys.

The U.S. Chess Federation ranks tournament players, based on their wins and losses against other rated players. The ratings are derived from probability theory and are a good measure of a player's skill. The mean for all U.S. tournament players of all ages is 1500, and the standard deviation is 200. Above 2200 is a master. Our sample ranges from a low of 1100 (two standard deviations below the mean, or better than 17% of tournament players) to a high of over 2500 (5 standard deviations above the mean and one of the top players in the country). Only fairly serious players tend to play in tournaments, so that an 1100 player can beat most casual, non-tournament playing adults. Our sample, then, consists of children, all of whom can perform a highly complex cognitive task as well as most adults.

The children are coached primarily by the high school math teacher (Mr. Dale Flickinger, rated as an Expert by the U.S. Chess Federation) with help from a science teacher and chess master, Mr. Paul Linxwiler. They play before and after school and during the lunch hour. They participate in tournaments locally, regionally and nationally. Some of them attend a one week summer chess camp.

<u>Stages of Expertise</u>

To put the children's cognitive skills in perspective, it is helpful to consider the stages an adult goes through in becoming an expert. Dreyfus and Dreyfus (1986) studied airline pilots, adult chess players, automobile drivers, and adult learners of a second language to derive the following stages.

1. *Novice.* At this stage, the learner learns to recognize various objective facts and features which are relevant to the skill. The learner begins to acquire "context-free" rules, which are then applied without regard to the situation the learner is in. The novice has little sense of the overall task.
2. *Advanced Beginner.* Here the learner begins to use more sophisticated rules, to take the situation more into account when applying rules, and to set goals.
3. *Competence.* Now the learner's list of rules becomes burdensome and a hierarchical organization of the rules takes place. Learners see complex patterns. By this stage, learners take more responsibility for their performance; at early stages, poor performance is blamed on the rules. Competent performers choose goals and plans and hence feel more in control.
4. *Proficiency.* At this stage, learners begin to develop intuitions about their skill. Proficient people recall whole situations and apply these situations to new situations without breaking them down into component parts. Thinking becomes less sequential and more simultaneous or gestalt-like.
5. *Expertise.* Finally, at this stage, the expert operates automatically and almost instaneously. The expert is deeply involved in the

environment and goals, but the actual problem solving processes occur without conscious deliberation. The best solution feels right.

As one progresses through these stage, he or she (1) obtains increased knowledge which becomes organized in more efficient and abstract ways, (2) uses processes that become more automatic (and intuitive) through experience, and (3) takes a more global (rather than detailed, analytic) perspective. In some superficial ways, children operate like experts: they tend to use intuition rather than careful analytic processes and often ignore many of the details. Because children's limited information processing capacities prevent them from being analytic, they must acquire expertise in ways that differ from adults. Will expertise acquired as a child differ from expertise acquired as an adult? Krogius (1976) offers some startling data showing that grandmasters who learned chess as a child played at their peak for more years and made fewer blunders than grandmasters who learned chess as adults. He compared early acquired chess knowledge to a native language; chess was for those players a first language.

Learning a first language differs fundamentally from learning a second language. The five stages above apply to second language learning by adults. While learning a first language may have some similarities to the five stages above, the process obviously differs substantially (largely because of the learner's age and level of cognitive abilities). Similarly, while the five stages can serve as a general guide, they are not descriptive of how our subjects learned chess. What we will argue is that children achieve competencies in a somewhat different way. If Krogius is right, competencies achieved as a child may be qualitatively different (and superior) from those acquired as an adult.

<u>How a child plays chess</u>

We've observed children and adults of about the same skill level playing together and it is clear that the child plays in a different way. First, and most notably, children play much faster. Consistent with other work, we've found children to be less reflective and more impulsive than adults. Children typically do not ponder the alternatives in as much detail as do adults. In on study (Horgan, in preparation), we found that pre-adolescent children typically did not look ahead more than one move (even those with ratings above 1500). This means that although the adult and child may have similar ratings, the child actually performs as well as the adult in much less time and with much less deliberate analysis. To see where the child's advantage lies, we must consider the four stages of any decision and how a child versus an adult with a rating of 1300 to 1500 would do at each step (Horgan, 1986).

1. Sizing up the problem. When faced with a position, the player makes a preliminary, holistic analysis which guides further analysis. The player asks whether this position is similar to others, and classifies the problem. (This is analogous to the child learning the word "dog." The child must be willing to accept a wide range of dogs as similar and be willing to go ahead and operate while the "dog" category is still very fuzzy. If the child waited until he or she was sure of the meaning of "dog," language development would proceed very slowly. Children are accept fuzzy categories and judgments of similarity based on scanty evidence.)

Focusing on details at this stage will often lead to serious errors and a waste of valuable time. Children may not take a global perspective, but they do tend to focus on sections of the board rather than on specific pieces. Because children tend to overlook details in favor of larger units of analysis, they may have an advantage at this stage over an adult of the same rating who "can't see the forest for the trees". Child players at this level base their strategy on a unit larger than specific pieces, while an adult of the same level may have goals that are too specific and that will require constant revision.

2. Generating alternatives. This is a creative stage; decision trees don't help. One reason children's games are faster is because they do not generate long lists of alternative moves--they satisfice. That is, they search until they find a satisfactory move (not necessarily the best move), then cease generating alternatives. In one study (Horgan, Horgan, & Morgan 1986), we asked children to identify which of several boards were most similar. Younger subjects stopped their search as soon as they found a superficial similarity. They were capable of seeing a deeper, more significant similarity, but few spontaneously spent the necessary time for the search. Satisficing can be a very useful and efficient heuristic, but it may lead to errors.

3. Evaluating alternatives. This is the stage of logical analysis of all the alternatives. If the first two stages were well done, the alternatives will all be good. Children tend to minimize this step. When playing speed chess (where each side has only a minute or two for all moves), children do especially well because they rely little on this time-consuming stage anyway.

Adults of the same level, however, put most of their emphasis on this stage. Adults at ratings of 1300 to 1500, then, are greatly handicapped under conditions of speed. An expert, however, performs well under conditions of speed since the alternatives generated and the preliminary analyses are so strong and the analysis is more automatic.

When we think about decision making, this is the stage we normally emphasize. Yet well-trained children can play chess quite well with very little emphasis on evaluation.

4. Evaluating the outcome. For experience to aid learning, the player must evaluate the outcome of decisions. Children may be less defensive about their errors and able to learn more from experience. Foreign language teachers often report that children are less intimidated and more willing to risk "sounding funny." Children, because they are in a constant learning mode, may learn more from feedback than adults.

At any rate, chess offers unusual opportunities for *process* feedback. In tournaments, players write down all their moves. They then replay their games with coaches or other players, trying rejected alternatives and testing what the outcome might have been. This multi-level feedback and evaluation benefits all learners. But because children's schemas are naturally fluid and open to modification, children may be able to learn faster as a result of this high quality feedback.

Children's tendency to judge positions as similar (or an unknown furry animal as a "dog") without a great deal of evidence and their willingness to overlook details may give them advantages at the first stage. While adults tend to be more conservative in their analyses, children are willing to take risks. Their learning mode helps them to derive maximal benefits from the evaluation of outcome stage. Improvement in evaluation of alternatives comes naturally with cognitive maturation. We believe that players who learn the game during childhood will maintain strength in the first stage while developing deeper or more abstract basis for judgments. Players who learn chess later in life will probably always be somewhat weaker in the sizing up stage. The young chess player may be developing and maintaining superior decision-making skills--especially those intuitive ones not traditionally stressed in educational settings.

In general, children rely more on heuristics and short cuts than do adults. These heuristics are ways of simplifying complex inputs. Children must constantly simplify because their schemas are less well developed. Pushing these schemas to their limits and subjecting them to evaluation may speed up the process of developing more elaborate schemas. In Piagetian terms, assimilation and accommodation occur cyclically as schemas evolve. The rapid testing and retesting of schemas may accelerate development. But more importantly, constant revision may keep schemas flexible and the acquisition and revision processes active. In other words, teaching children to perform a complex task like chess may give them problem-solving advantages later--at least with chess, possibly with other similar situations. Children who learn to use feedback successfully and to take a global perspective may be able to maintain that approach while improving their more analytic skills.

Training

Without training or study, few chess players play well. Just learning to move the pieces and playing with other novices results in very slow progress. We visited other schools where enthusiastic teachers who knew little about chess encouraged daily play. We found players with no sense of strategy and very little skill. What they lacked was (1) teaching of principles, (2) process feedback (they only experienced outcome feedback whether they had won or lost); and (3) specific chess drills. We will consider each of these three topics.

1. Teaching of principles. Coaches do not wait for players to discover the principles. They are taught explicitly. Opening systems are memorized and practiced. Players are urged to study chess theory. Information is presented as a systematic body of knowledge. Interestingly, recorded chess games from the previous century are of lower quality than games played today. The reason usually given is that prior to the existence of a large published body of chess literature, players had to discover principles on their own. Now players have access to a wider, more systematized knowledge base.

When most educators think of gifted and highly motivated students, they assume discovery learning is preferred and memorization is undesirable. What we've found is that young chess players are very adept at and enjoy memorizing openings, learning their names, and classifying them. This pleasure in acquiring a large database is seen, particularly among boys, in collecting information from baseball cards or information about many kinds of dinosaurs. Children, like the novices described by Dreyfus and Dreyfus, acquire a large set of "book moves," moves that are described in text. The child, unlike most adults, is very good at memorizing a large set of moves. The result is children who can learn more book moves in less time than adults, but children who also do not get bogged down in detail. Children's games are usually strongest in the opening, where the moves tend to be more book moves, and principles are rather concrete (e.g., "move both center pawns two squares each"). Starting off well gives these children an advantage (and no doubt teaches them the value of studying!).

2. Process feedback. A major part of learning and improving chess play comes from feedback. Going over games in detail with an expert and replaying games with different strategies offers the opportunity for rapid improvement. Learning to analyze ones' own performance objectively provides an excellent lesson in how to maximize skill. In chess, a player has little opportunity to rationalize losses; children learn to be objective about their own performance. In addition, their improvement is readily measured by increased ratings.

3. Specific chess drills. Chess coaches use a number of interesting training techniques. One is the use of chess problems. Much like case studies constructed for business students, these are problems designed to illustrate a specific principle. Irrelevant details are omitted. Like other kinds of puzzles, they are highly motivating since the learner knows there is a solution.

Paradoxically, players are trained to both play faster and to play slower. Children tend to play fast without much evaluation of alternatives, so coaches have them take more time with moves. In our studies, we found that longer analysis time was correlated with a deeper level of analysis. But coaches also stress speed training. In general, children approach the world in a whirlwind fashion, acquiring schemata rapidly (often inaccurately). If they spend too much time analyzing all the new information available to them, they would not learn as rapidly as they do. Playing chess rapidly forces a global perspective and hence helps develop intuitions. Since children often ignore details anyway, they learn easily to take in the "big picture." Playing fast keeps alive rapid schemata acquisition. It probably keeps the child strong on the preliminary analysis stage.

Another common training technique is to practice playing blindfolded. This forces the player to rely on visualization. Children tend to have good visualization skills, so that early and continued visualization practice will maintain those skills. When evaluating alternatives several moves ahead, the physical board and pieces can get in the way. The player with good visualization skills can "see" the board as it might look under different lines of play. This practice results in more flexible thinking.

<u>Context and memory</u>

An important part of training is the coach's intimate knowledge of each player's skills level and cognitive maturity. We were interested in the role of context in helping young players structure the information contained in a chess scene.

DeGroot (1946) found that chess masters could look at a chess scene briefly, then reconstruct it from memory, whereas less skilled players could place far fewer pieces. When given a board with pieces presented in random places, however, masters did no better than novices. This shows that the master player does not simply have a better memory, but that the master has a memory for *meaningful* configurations. Later Simon and Chase (1973) explained this phenomenon in terms of "chunking." At higher levels of knowledge, a person sees and manipulates information in larger chunks. A literate person, for example, can remembers many letters if they are arranged in meaningful words and sentences, but not nearly as many if they are in a random list.

DeGroot's findings have been crucial in shaping how we think about cognition. In *Search for Excellence*, for example, Peters and Waterman (1982) quote the classic chess studies to show that the manager who thoroughly understands his organization will be better able to process information efficiently and thereby make superior judgments.

We replicated the DeGroot study with children, but with one task modification. On half the trials, before seeing the board, the child was given a brief general comment mentioning the strategic/tactical considerations, but not mentioning any specific chess piece. We reasoned that if, what experts "have" is a global representation around which to organize the board, then children ought to improve their performance if they, too, have some organizing principle. That is, some help with organizing the information could compensate for children's lower memory abilities and level of knowledge.

When boards were presented without the context, performance was correlated with age, r=.377 and with rating, r=.301. When boards were presented with contexts, age and rating were less important. The context "levelled" the performance, resulting in lower correlations, r=.167 for age and r=.230 for rating. This means, that with the context, there were fewer age differences and skill level differences. Table 1 shows scores by grade.

TABLE 1 ABOUT HERE

We see that context greatly helped the youngest children and somewhat helped the junior high subjects. High schoolers did worse with the context. The primary grade children are in a transition from pre-operations to concrete operations and the junior high students are in a transition from concrete operations to formal operations. The overall pattern suggests that providing a global organizing principle may or may not be helpful, depending on the cognitive stage of the child. During transition periods or early in a new stage, children may be most open to different ways to organize information. During stable periods, they may prefer their own organizing principles.

We were intrigued by the correspondence with Piagetian stages, and we looked at U.S. Chess Federation lists of top plays in the country over the last 10 years to see whether there were more patterns suggestive of Piagetian stages. Among the top primary players (age 8 and under), year after year, the top players were in the 1400 to low 1500 range. Within that group of top players, however, six and seven year olds were as likely as 8 year olds to be at the top. Among elementary players (12 and under), the top players were always around 2000 or slightly above. Again, 10 and 11 year olds were among the top players. That is, development did not proceed linearly by age; rather primary children of different ages were similar in their skill, then there was a leap to a new level with elementary children. Again age matters little among the elementary children. This may reflect that by the end of the third grade, children have the tasks of concrete operations mastered and when, in the later elementary years they begin to shift toward early formal operations, there is a corresponding jump in their chess ability. We are investigating this further.

We were also interested in learning under what conditions context was most helpful. We, therefore, looked separately at board positions for different stages of the game. We had chosen boards from middle games and from end games. End games, besides having fewer pieces, are characterized by general rules. For example, there are standard ways to play an end game when certain pieces remain. These "rules of thumb" are more abstract than opening book moves. (Example: "Obtain and maintain the opposition.") In the opening, players play specific pieces on specific squares. In the end game, the "rules" are in terms of general strategies and types of moves. We would expect that players who are ready to go beyond concrete rules in the novice stage to the advanced beginner stage would benefit from some context in which to orient their analysis. Table 2 shows the results for the end games.

TABLE 2 ABOUT HERE

On these stimulus items, context acts as an equalizer: primary children do as well as high school children! Without the context, however, there are large age differences. These results show the importance of matching the material to the level of the learner. They also demonstrate that, with proper foregrounding, young learners can perform complex tasks as well as much older students.

The previous task relies on the subject's memory as well as the way the information was encoded. In an attempt to separate encoding (the perceptual process) from memory, Chase and Simon (1973) used a reconstruction task. We replicated this task, showing subjects a chess position in the bottom of a box. They were asked to reconstruct the board using pieces and a board outside the box. They were free to look into the box as often as necessary. The number of pieces placed at a time, between glances, was scored as a "chunk." Chase and Simon found that masters had larger chunks and could reconstruct a position with fewer lookbacks.

The youngest and the lowest rated subjects in our study averaged about 2 and one half pieces per chunk. The highest rated subject was able to reconstruct the entire board with only a single glance, an average of 23 and a half pieces. We found that the size of the "chunk" increased with rating ($r=.25$) and with grade ($r=.38$). The larger correlation with grade presumably reflects memory constraints that change with age.

Primary and Elementary grade subjects needed about 10 and one half look-backs to complete the board. Junior high and high school needed about 8 (correlation with grade, $r=-.25$). The number of look-backs necessary to complete the tasks was also correlated with rating ($r=-.36$), with more advanced subjects needing to look back fewer times. Here the higher correlation with rating suggests that the better players are able to organize information more efficiently, even if they are young and hence have a shorter memory span.

These results, too, show the complex relationship between learned skill and developmental stage. The younger subjects are handicapped by their cognitive limitations, but are able to compensate, perhaps with heuristics. At any rate, it is clear that we cannot simply say "older subjects do better" or higher rated subjects do better." On different aspects of the same task, age and skill interact.

Implications

While adults progress to expertise from a focus on details to a more global focus, children seem to begin with a more global, intuitive emphasis. This may be a more efficient route to expertise as evidenced by the ability of pre-formal operational children to learn chess well enough to compete successfully with adults. Educators, rather than trying to "stamp out" the intuitive, quick judgments, would do well to encourage these judgments as well as encouraging careful, analytic thought. Many pet phrases of teachers discourage quick judgments: "look before you leap," "neatness counts," "go slow." It may be that practice in making fast judgments forces integration of a child's rapidly expanding knowledge base. The combination of forcing quick judgments and encouraging analytic processes may speed acquisition and revision of schemas. Complex problems should be approached from both the intuitive and the reflective.

One clear lesson from our observations and research is the importance of taking advantage of the cognitive level of the learner. If, for example, the learner is in the data acquisition mode (as evidenced by vast store houses of knowledge about one area, such as baseball), then now is the time for memorization of facts. The chess results show that with a solid base of memorized facts (as in the openings), children have a basis on which to develop higher level skills. The training technique of playing blindfolded takes advantage of the child's natural visualization skills and practice preserves those skills.

Another clear implication is the importance of matching the instruction to the child's current needs. This necessitates knowing exactly the child's current level of functioning--not just the outcome of the thinking, but the processes of the thinking. The memory results show that appropriate foregrounding, introduced at the right time, can greatly enhance performance. The same information at the wrong time, however, can reduce performance. Time and again, we've seen coaches working with players and targetting their explanations in very precise, individualistic ways to fit the player's level of expertise. In the case of our subjects, their coach clearly has each child's "number." (The coach's skill is, of course, expert at Dreyfus and Dreyfus fifth stage.)

Not only must the teacher know thoroughly the learner's state, but these results show the importance of understanding the cognitive demands of different aspects of the task. Within the single task of chess, the demands of the opening, the middle game, and the end game differ, and we found different age players profiting from context statements to different degrees depending on the cognitive demands of the stage of the game.

The reconstruction results show the complexity of measuring performance. When we evaluated performance by the size of chunk, age is more important than rating. This is because size of chunk is closely tied to general memory processes, which increase with age. But when we count the number of look-backs, we find that skill is more closely tied to performance. Reconstructing the board, looking back as few times as possible, requires an understanding of the relationships among the pieces and hence more skill. Teachers may, if they use the wrong measurement tools, mask precocious performance.

Helping learners think logically is not easy. But our observations and research show that young children can be taught to think clearly and with discipline, plan ahead, and make sound decisions. Learning these skills early in life can only benefit later intellectual development. We've seen that the way children acquire these skills differs in fundamental ways from adults. Implications for education are basically twofold: teach children, emphasizing their natural capabilities to take a global perspective and to acquire and organize data quickly, and attend to the processes of their thought rather than the outcomes.

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Table 1. Context effects by age

Number of correctly placed pieces

	CONTEXT	NO CONTEXT	DIFFERENCE
GRADE			
Primary	6.52	2.74	3.78
Elementary	5.97	6.14	-.17
Jr. Hi.	7.53	6.42	1.11
High School	8.38	9.67	-1.29

Table 2. End game context effects

Mean number of correctly placed pieces

	CONTEXT	NO CONTEXT	DIFFERENCE
GRADE			
Primary	5.83	1.67	4.16
Elementary	3.50	3.21	.29
Junior High	5.05	4.11	.94
High School	5.50	6.58	-1.08