Reflections on Language and Philosophy in Regard to Cognitive Psychology, Artificial Intelligence and Educational Studies of Chess and Go

by Peter Shotwell

The first version of this essay appeared in three installments about 15 years ago in the American Go Journal*. Admittedly speculative, it surveyed what I found interesting in these fields.*

First, it explored the differences between traditional Eastern and Western ways of thinking about language and their traditional games of chess and go. It then examined how these differences may affect our understanding of historical and modern developments in cognitive psychology and assist in its future development. It focused particularly on the flaws of the then-popular idea that chess expertise is almost solely the result of learning and storing in long-term memory a great many 'patterns' which can be retrieved and applied to a board position, and which can be best studied by memory-recall experiments. Looking further, there was an attempt to catalogue the potential value of go as a better microworld for the study of perception and artificial intelligence.

Since then, while a few researchers have used go and have even called for it to replace chess as the new 'fruit fly' of artificial intelligence and psychological studies of the acquisition of expertise, chess is still the chief basis for forming theoretical models of how we think when presented with perceptual tasks. What is new in this update is a survey of the very interesting models of thinking that have recently appeared in the field of board game playing. These include two competing Turing Test-like pattern-based computer simulations of how we learn to play chess, some long-term memory- and information processing-based approaches, and some of the preliminary work that is going on about the roles of the brain's hemispheres in board game playing.

Despite this work, however, I feel that the reasons for the original background and conclusions have not changed, although they have been augmented and re-organized and the recent work of Delauze and Guattari has been included to further illustrate them. As before, it is left to the reader to decide if those thoughts are interesting, applicable or useful.

Many thanks to Roy Laird and Richard Bozulich who helped review this edition.

Contents

I. The Background of Language: Eastern and Western Thinking

Thinking is our most characteristically human trait, and people have thought about thinking for thousands of years. As we grow up, we encounter objects and concepts and find out that they have names. Then we talk about them in whatever language we have acquired. Yet if we think about this process, a question arises. Let's say we have already seen a number of chairs and now encounter another – how do we know that it is a 'chair'? By its four legs? Its function? Its shape? By the name others give it?

This is indeed a puzzle and, in fact, this question has been a chief concern of Western philosophy. Greek, Latin and English all utilize the verb *to be.* Thus, something always *is* something. When we say 'This is a chair,' what do we mean? One answer in Western thought has been the perception that an 'ideal' chair forms in the mind as a result of abstracting all the chairs we've experienced. This idea of *chairness* seems to have a life – a 'being' – all of its own. For us in the West, every object seems to have two existences: the 'real,' the 'essential' being, which we tend to think only the mind can apprehend, and the object as perceived by the senses, which can be deceived.

Chinese philosophy, which was unacquainted with Western (or Indian) philosophy until the 3rd or 4th century AD, developed an entirely different approach. As Chad Hansen wrote in his controversial book, *Language and Logic in Ancient China*:

> *The mind is not regarded as an internal picturing mechanism which represents the individual objects in the world, but as a faculty that discriminates the boundaries of the substances or stuffs referred to by name . . . What is hard for us Westerners to acknowledge given our common sense commitment to mental abstract ideas is that the detour through ideas doesn't explain the ability at all. It merely pushes the puzzle to a different level.* (1)

In Chinese thought, he suggested that there is no theory of either abstract or mental Platonic entities – one acquires the ability to distinguish 'chair-stuff' from 'not-chair stuff' through experience, but when one encounters a new chair, one is not seeing a different object but a different part of the same 'stuff.' In other words, the Chinese would not postulate a separate world that exists only in the mind. Encountering a chair, they would simply say, 'I "chair" this object. Tomorrow I might call it something else.' As a result, in China, there was no fervid search for what 'really was.'

In the West, on the other hand, we tended to trust what we believed was inside our individual heads more than we trusted what our senses told us, It was that search for 'ultimate truth' and 'rational' systems of philosophy and religion that contributed, for example, to the idea that there could only be one 'God.'

In China, the result of not needing that search was that their philosophers occupied themselves more with the question of 'how to live.' The Chinese mind starts with the world and works inward because the Chinese language, with two important exceptions, does not permit objects to exist that cannot be perceived by the senses.

One exception is the Buddhist 'Void.' The other is the 'Dao' (actually the 'daos' is more correct – there being many 'ways' instead of just one as is usually thought in the West. However, for the sake of familiarity, a single 'Dao' will be used in this essay.) (2)

In Daoist thinking about the Dao, what we think of as 'opposites' are not really 'opposite.' They cannot be defined separately. For example, if there is 'Something,' then there must be 'Nothing.'

Something and Nothing give birth to each other, Long and Short offset each other, High and Low determine each other, Front and Back give sequence to each other . . . We turn clay to make a vessel; just where it is absent is the use of the vessel. We chisel out doors and windows to make a house; just where it is absent is the use of the house. (3)

Similarly, in the game of go, stones are used to make *eyes;* just where they are absent is in the use. This 'nothing' is the Dao. This is because, in Chinese, *yu* (there is) is not negated by *bu* (not), but rather by *wu* (there is not). 'Real' and 'Unreal' are dealt with similarly. We cannot deal naturally in English with this type of concept – to us, what is 'is' and what is not 'is not.' We might think of vacuums or outer space – 'There is nothing here – it is *nothing,*' we would say. But to the Chinese mind, what 'is' is *yu*; what 'is not' also 'is' – it is *wu*. We cannot perceive it, it is formless; yet, in a sense, everything emanates from it. It has being but does not exist for the senses.

Chess and Go

Buddhism and Daoism as philosophies of mind developed about the same time, ca. 500-300 BC, the Daoist form in China and the Buddhist form in India. Later, after c. 300 AD, as Buddhism was imported into China, the concept of the Void was amended to conform with the Chinese language and pre-existing thoughts about the Dao. These two concepts can point us toward some interesting conclusions about the nature of thinking, especially when they are applied in a symbolic fashion to go and chess, two of the popular games that developed within their sway.

The imported game of chess has been and is played even more than go in China, but it was go that attached itself to Chinese culture in a way that chess never did, drawing on symbolism that stretched all the way from the nature of the universe to the conduct of life, as one after another cultural entity seized on the benefits of playing the game. First it was the Daoists, then the Confucians and Buddhists, then, since the 1600s, the political and economic regimes who nominated it as one of the 'Four Accomplishments' of the trained Chinese mind.

As mentioned, one reason is that ideas about go seem to be more compatible with the Eastern philosophical approach as expressed in their language, while chess seems to be more compatible with the Western style of thinking, as it is expressed in Western languages. The 'reality' on a chessboard would seem to have less to do with perceived patterns that are being discriminated in the manner that Chad Hansen proposed, and more do with the interaction of the ideas each of the pieces represents. For example, the king is a symbol of a position held in a feudal hierarchy which determined his abstract qualities – he can only move in a certain, limited ways; when he can't move there is stalemate; when he is captured, the game is over.

An illustration of this feature of chess is the use the Austrian-born Cambridge-based philosopher Ludwig Wittgenstein (1889-1951) made of the game to develop ideas about learning and language after stumbling over the problem of 'ideas,' the split between them and language, and the world they described. Unable to define exactly what language was, he decided that it was composed of many 'language-games,' and chess was one of his prime examples.

Wittgenstein proposed that chess players, like bricklayers and other groups, had their own metalanguage which used common words that had special denotations. Language itself, he argued, was the sum total of many language games. In their interactions, new words and meanings were created. Thus, language constantly moved forward and shifted its shape. We could only describe it, we could never obtain an enduringly fixed concept of what it was.

However, no one can learn chess on their own – it has to be taught by someone fluent in its rules and concepts, just as one learned a language from other native speakers. Thus Wittgenstein's idea of language games always followed the processes of learning a second, rather than a primary, language.

He began to realize there were other severe problems with his approach and he finally abandoned his theory, leaving us no closer to what went on in the learning process than before.

The Phenomenologists Bridge a Gap

In fact, all Western philosophy had reached an impasse because of problems dealing with the double world of mind/body, and of subject/object. The Phenomenologists then tried a different approach, which resembled, in many ways, a Chinese view of how the mind worked. Karl Husserl (1859-1938) and Martin Heidegger (1889-1976) were more or less the first to explore the possibility that:

. . . words and language are not wrappings for the commerce of those who write and speak. It is in words and language that things just come into being and are. (4)

Husserl meant that we could not 'know' anything without using language. We could not tell that we have discriminated anything from its surroundings unless it had a name. But 'true' reality was not an abstract world in our minds – our 'true' reality was formed by language. Language thus had a being all its own.

In other words, Husserl's 'phenomenological reduction' led to perceiving consciousness as an intentional *consciousness of* something, which therefore had to take account of presuppositions. This idea was very important in legitimizing 20th century scientific observation, particularly in the social sciences and most particularly in the development of gestalt psychology, with its emphases on the mutual dependency of ground and field, the absence of a split between subject and object, and the interaction between observer and observed.

Consider in the context of a game, the following quotation from the French psychologist and Phenomenologist Merleau-Ponty (1908-1961):

Seen from the social angle [which was by no means the only significant one for Merleau-Ponty] *language occurs primarily in the form of a dialogue. Here my thought and that of the other insert each other into a common ground . . . in a common operation of which neither of us is the creator. There is a being-at-two, and the other is no longer for me a mere behavior in my transcendental field, nor am I in his; we are both mutually collaborators in a perfect reciprocity, our perspectives slide* [glisser] *into each other, we coexist across a same world. In the present immediate dialogue I am liberated from myself; the thoughts of the other are not really his own, it is not I who form them, although I grasp them as soon as they are born or I anticipate them, and even the objection which my partner makes to me elicits from me thoughts which I did not know I had, so that if it is true that I lend him thoughts, he makes me think in turn. It is only afterwards, when I return from the dialogue and recall it, that I can reintegrate it into my life, make of it an episode of my history, and that the other returns to his absence or, inasmuch as he remains present to me is felt as a menace.* (5)

The game of go, with its minimal amount of rules (which are often said to resemble those of 'life') would seem to interfere less with this back and forth flow of thought than chess, with its interfering symbolic hierarchies restricting the free movement of the pieces.

Recently, the radical French psychoanalytic philosophers Giles Deleuze and Felíx Guattari have augmented these observations. While discussing the idea of the modern police force being an internal occupying armed 'war machine' with the idea of nomadic armies being one external to the State, they compared the 'discourse' of go as one of *nomos* vs. chess as one of *physis*:

*(*In chess,) . . . *space is striated into lines of tension and the closing off of regions by pieces endowed with intrinsic powers and qualities. Chess is a game of interiority. On the other hand, go pieces are empowered not*

by intrinsic rules but by situational properties. There are no front lines or battles in go, which operates in 'smooth' space. (6)

In terms redolent of cyberspace:

[Go is a matter of] *arraying oneself in an open space, of holding space, of maintaining the possibility of springing up at any point: the movement is not from one point to another, but becomes perpetual, without aim or destination, without departure or arrival. (7)*

And, as a reviewer commented:

The element in chess is its 'innermost core' (both the relationships of the chessmen with each other and with the chessmen of the opponent follow from their immanent characteristics, i.e. they operate structurally), while stones in the game Go recognize only the 'outer' relationships with the real constellations (that which 'plays' is therefore movements of besiege, of delimitation, of distraction, etc.).

[Deleuze and Guattari say] '*The difference is that chess codes and decodes the space, while Go territorializes or deterritorializes it (it changes the external into a territory in space, makes this territory safe by creating others, adjoining it, deterritorializes the opponent by fragmenting his territory from inside, and deterritorializes itself by abandoning everything and leaving for elsewhere). Other justice, other movement, other time and space.' (8)*

To return to Deleuze and Guattari's intellectual predecessors, consider some of the 'proto-go' words and concepts that resounded through the writings of the early Phenomenologists, even though probably none of them were thinking of the game when they wrote.

To Heidegger, language was 'The House of Being,' and to Koreans, 'house' is a simile for the eyes of a living group in a game of go. He agreed with Japanese scholars in the way that language, as a symbol of consciousness, opened up like a flower on a vast Space-Time continuum. It comes into being, in other words, much like the beginning of a go game (but not a chess game), as the stones are placed and the newly-born groups begin to become more than the sum of their parts. (9)

The go board and the rules at work on it could also be regarded as almost a 'microworld' of Husserl's and Heidegger's views about the (macro)

‘World.’ In both, for example, there is a perceptual field (i.e. what we think we see as to the situation on the board and the possibilities for moves in the future). These are bounded by a ‘time-horizon’ (the edges of the board) ‘revolving’ around a ‘Primordial Praxis’ (the natural laws at work within our perceived world cf. the rules of go: principally, ‘When you are surrounded you die’ and, ‘No position can be repeated’). Without these constraints, no learning is possible in Phenomenology, and no game is possible in go.

Just as classical Western philosophy and Phenomenology differ in their understanding of Time, the sense of Time in go and chess is also very different. Whereas chess pieces mark the moves of abstract powers through space, go pieces record the pure movement of Time. A black stone is put down, then a white one – one is meaningless without the other. As in the martial arts, Time is always ‘now’ and there is no ‘objective’ point of view.

In the Phenomenologists’ view, Time consists of ‘Action’ and ‘Reaction’ – without both, Time does not move. We cannot be aware of it. This is why my stone, having no liberties, can capture your surrounded group with one liberty by playing inside. It is also why the suicide rule need not be ‘prohibited’ by an extra rule: it is simply a ‘non-move.’ The opponent must *act* after I ‘say’ my move for my move to have any meaning. A suicide disappears without this action and thus is not part of the on-going ‘conversation’ or game. When the board is completely filled in (meaning, in a theoretical sense, that all of one player’s groups can be reduced to two eyes and no response is possible, while the other player retains unfilled ‘territory’), there is no ‘next move’ possible. Stasis has set in, the game is over, and, in an Eastern sense, the stones return to the Buddhist-like ‘world pool’ of the bowls and a new game, *kalpa* or ‘universe’ begins.

In other words, go is like an oral language that has been visually manifested and recorded by the arrangements of stones on the board.

These observations may have some interesting ramifications in the fields of Anthropology, psychology and Education.

For one thing, because games are always the product of two conciousnesses, they become interesting cultural artifacts. This, of course, is true for chess, also. However, in chess the perceptions involved are not so visual – there is no record of what went on before. Thus, in any testing in the educational field, progress under varying circumstances or the discovery of underlying thought processes would seem to be hindered by the abstract qualities of the visual presentation.

A second consideration is that, because of the profusion of rules and concepts about the nature of the pieces in chess, future possibilities that can be graded in terms of perceptual abilities are not so clear or easy to codify. The possibilities that the use of go presents for following the development of perception past the various plateaus represented in the rating systems are far greater, especially given the visual use of the handicap system which is so different from that of chess. Additionally important for gestalt-type studies of problem solving, full boards rather parts of the board can be presented in the 9x9 and 13x13-lined board versions.

With these thoughts in mind about the greater suitability of go and the inherent difficulties of using chess in perceptual studies, the rest of this essay will examine how chess studies have been applied to the fields of Education and psychology with some glances at how much more might be done if the game of go was substituted.

II. Early Psychology and Chess Studies

As mentioned in the first section, due to peculiarities in their language, the Greeks postulated a split between mental and physical being. The problem with this model was, how did we obtain knowledge from the physical world? If we solve a life-and-death go problem, how do we know that we didn't already know the answer, say from a former life, as Plato suggested in *Menes*?

One answer accepted by Aristotle was further developed by the British Empiricists. Living during the Industrial Revolution, the Empiricists modeled their ideas on early developments in physics, chemistry and mechanics. Their conclusion was that sensations received by the brain were associated together because of their similarity, contiguity or repetition, thus producing 'ideas' in the mind. The main factor in learning was felt to come from the environment in the form of experience.

A corollary of this theory was that these ideas consisted of visual images and were named by one word. Thus, language could remain constant, while intellectual, moral and other types of progress could continue, since ideas were not innate.

By the late 19th century, the science of psychology began to split off from medicine and biology. Using associationist theory in an effort to rid their field of metaphysics and philosophy, these researchers restricted themselves to studying 'objective' behavior. The higher mental processes were ignored, although it was felt that with better observational tools, the workings of the mind could eventually be understood in terms of chemistry and ultimately physics.

The problem with association theory (or behaviorism, as the new school of psychology was called), and its offshoot, Stimulus-Response theory, was that they both ignored consciousness. Was there a direction to consciousness that was more than just a response to the environment? If there was a focus that was more than the aggregate of experience and sensory data input, how could it be studied? (10)

Introspection, even by a trained observer and/or subject, was a faulty tool from the associationist/behaviorist point of view since it did not preserve the subject-object split. Besides, it was also vulnerable to rationalizations and to distortions by what was becoming known as the 'Unconscious.'

Nonetheless, Alfred Binet, best known for his work on the first IQ tests, tried introspective methods on chess masters in 1894 to determine whether their expertise was due to their superior ability to manipulate visual mental images. To his surprise he discovered that they did not seem to use sensory-derived imagery to perform such feats as playing fifty games at once blindfolded. Those that did use it claimed they never saw the whole board at once, and the rest said they used logical-deductive, verbally-based methods to remember and play the games. (11)

Binet and a few others in the early 20th century went on to study the differences between masters and *patzers,* but found the only observable difference was that masters could predict their opponents' moves more accurately. Moreover, since masters did not seem to be more brilliant, or have better memories than ordinary intelligent people, he concluded that it was what he simply called a 'mastery of the game' that distinguished them.

Other Theories Develop

In the meantime, other schools of thought developed. gestalt psychology focused on the structure of the phenomenon, not the parts. Relations were seen, not as sense-based or grasped by trial and error, but as emerging through a structural re-organization of the perceptual field ('insight').

At the same time, Piaget was developing his theory that cognitive development took place in stages during childhood.

Psychoanalytic theory emerged in America in the 1930's, pointing the way to such modern fields as ego psychology and Interpersonal and object relations theory. Ernest Jones, author of a definitive, two-volume biography of Freud, wrote a fascinating psychoanalytic biography of Paul Morphy, the enigmatic chess genius from New Orleans.

Reuben Fine also wrote from a psychoanalytic viewpoint about his fellow chess champions.

The Russians, Luria and Vygotsky, argued that the basis of thinking was in the social world – that thinking was an intrapersonal response to the interpersonal process. Similarly, Heuzinga's *Homo Ludens* looked at much of human activity as play.

Then came Phenomenology. Merleau-Ponty, who was quoted earlier in the first section, argued that associationism committed a 'retrospective fallacy' when it assumed that meaning was the result of, rather than the ground for, any association. Meaning, he felt, was shared and was built up from such things as dialogues. Moreover, there was no place for any preconditions about how we think in the study of thought. We must start with thinking itself when we study it.

Practically the only writer to look at the mind as a dynamic process was Otto Selz, who wrote in Germany in the 1930's. He envisioned cognition as a linear, hierarchical series of steps, with the completion of one step triggering the next. This view of the mind, as a sort of dynamic process of association, became the basis of the modern chess study.

Modern Chess Studies

Adrian de Groot, working in the late 1930's with some of the world's best chess players, attempted to use Selz's cognitive theory to explain the old question of why masters chose better moves than 'woodpushers.'

In his first experiment de Groot asked both types of players to verbally express their protocol, or manner of examining an interesting middle-game position. For his theory, the results were disappointing. Masters seemed to search about as deeply and examined about as many lines of play as weaker players – but the ideas they chose to examine were better ideas. In other words, the processing of both groups was equal – it was the content of thought that was different. Much as Binet had found, it was logical-deductive rather than visual-perceptive powers that seemed to differ. (12)

In the second (and most famous) experiment, a grandmaster, a master, an expert and a novice were presented with middle-game positions for 2-15 seconds, and were then asked to reconstruct them from memory. The results corresponded to their ranks, with the grandmaster recalling almost all the pieces, the expert some and the novice almost none. Thus, de Groot theorized that mastery was not due to differences in native abilities or deeper search, but was based somehow on the ability to recognize significant patterns and utilize them more quickly to choose moves. But these puzzling facts had to wait thirty years for an explanation.

In the meantime it became increasingly evident that behaviorism and Stimulus-Response theory could not fully account for what really happened in thinking. On the other hand, cognitive psychologists found it difficult to specify what cognitive processes (such as Selz's) dealt with, thereby leaving themselves vulnerable to the criticism that such processes dealt with nothing at all.

III. The Computer Age and Chunk Theory

An exciting new paradigm for thought began to develop in the mid- to late-1950s that was based on how computers operated. It suggested that there could be content in theories such as Selz's information processing theory, and that there was an answer to de Groot's puzzling findings about the equality of depth of search between masters and beginners and their different abilities to recall chess positions.

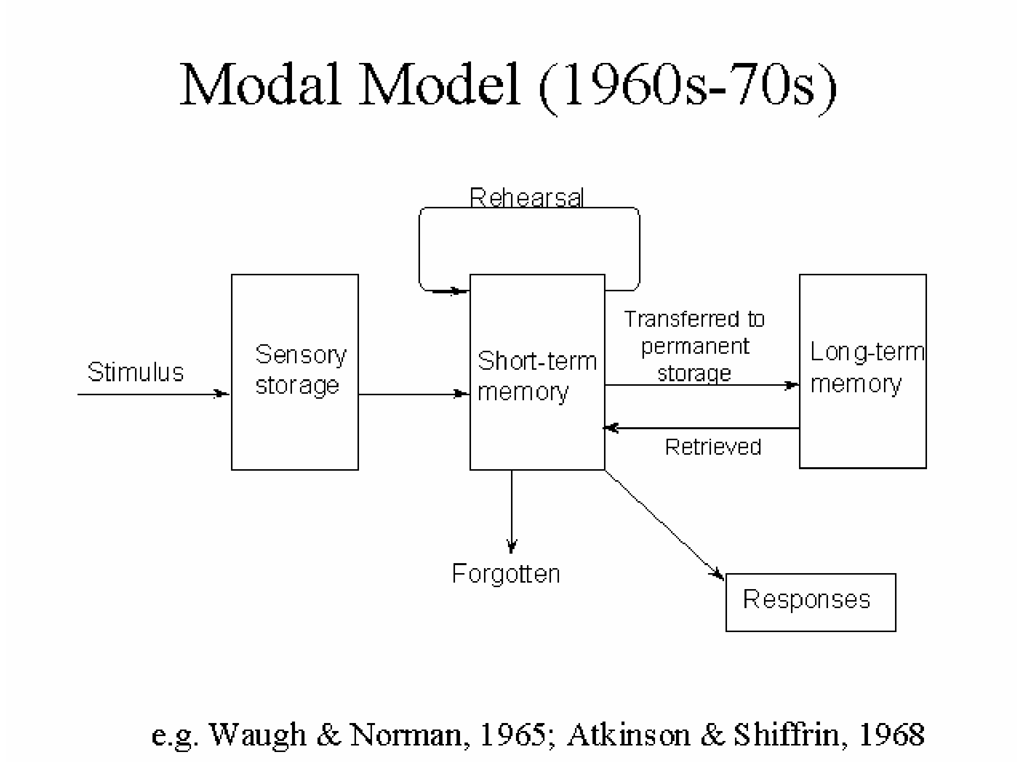
The economist Herbert Simon had proposed that humans do not react according to rational economic models because they have unequal abilities to process the information that is available. Along with K. M. Newell, (and in other fields, Noam Chomsky and Miller, Galanter and Pribenir), he also recognized that computers could do more than just process numbers – they could process symbols.

Meanwhile, experimental evidence was indicating that after the human mind perceived objects, the information was stored in what seemed to be a low-capacity, computer-like 'short-term' memory.

Also, John von Neumann's 'Min-Max' theories of game playing, which started with the desired result and worked backward up the decision tree, stirred interest in the study, first of trivial, then of non-trivial games. Looked at as an ideal 'toy world,' a chess-playing machine that imitated human thought became a major goal of many researchers in the field of artificial intelligence.

The Turing test, formulated by the brilliant inventor of the first chess computer program (although it only worked on paper), suggested that if a computer could interact in a way that was indistinguishable from a human, then the thought processes would have been mechanically reproduced.

Elaborating on the stimulus-response theory that rose from the plans of the factories of the Industrial Age, scientists tried to work out a model of human thinking by postulating that peoples' minds in everyday life were acting as parallel processors dealing with the multitude of information that is coming in from the environment. However, people are also goal-oriented so that when thinking occurs, they are acting as a serial processor which deals with only one thing at a time.



From
http://www.psy.fsu.edu/~charness/courses/expertise/6919f99/intro/sld010.htm

In 1973, in what became one of the most famous experiments in the history of psychology, W. G. Chase and H. A. Simon put de Groot's findings into the context of the new information processing models.

In de Groot's recall task, a chess position was presented for five seconds, and players had to reconstruct as many pieces as possible. The videotapes of the sessions revealed that the masters would put down clusters of approximately 4-5 related pieces and then pause for about two seconds and then put down another cluster, which was called a memory 'chunk.' In this way, masters almost always recreated entire positions, intermediates completed part of the board and beginners were often limited to one cluster.

In the second, copying task, the stimulus board remained in view, and the goal was to reconstruct it onto a second, empty board, which could not be seen at the same time. Here, Chase and Simon used the glances between the boards to detect the memory chunks.

Comparing the pauses between the placement of the successive pieces in the copy and recall tasks, they inferred that pieces re-placed with less than 2 seconds' interval belonged to the same chunk, and that pieces placed with an interval of more than 2 seconds belonged to different chunks.

After this, they showed that the chunk definition based upon the pauses between placements was consistent with a definition based upon the patterns of the chess ‘semantic’ relationships of ‘attack,’ ‘defense,’ ‘proximity,’ ‘color,’ and the type of piece shared by these two pieces.

Then, most importantly, they added a study using an equal number of randomly placed pieces, also observed for a short time. Surprisingly, in the second test, there was little difference in the performances of masters, intermediates and *patzers*.

They tried to explain this phenomena, and the seeming fact that players of all levels searched to about the same depth, by elaborating on the then recently-developed theories about short-term memory. In their version, the mind had a short-term memory capacity of not more than 5-7 chunks consisting of 4-5 pieces associated with various squares.

The explanation for expert skill in the meaningful positions tasks was that during chess masters’ ten or more years apprenticeship, as in the mastery of a language, they had first learned in their short-term memory and then stored in their long-term memory between 10-100,000 of these chunks, which allowed them to see and then quickly recall the board positions. Persons of less skill had fewer (or none) of these chunks so that, after short-term memory had disappeared, they were able to recall fewer of the presented positions. Since none of the subjects had chunked the random patterns, they all performed equally poorly in that part of the test.

To account for performance in an actual game, Chase and Simon introduced an optional feature of the theory, the ‘Mind’s Eye,’ which constructed a concrete image of the recognized pattern which was then manipulated and re-entered into the system to generate new move possibilities. In this scheme, forward search played only a small role and consisted only of confirming the recommendations of the chunk-recognition mechanism, which accounted for the equal depth of search common to all the players.

In 1973, Chase and Simon summarized their view:

The fundamental hypothesis that motivates the information-processing approach to the study of cognition may be stated thus:

The human cognitive system was to be viewed as an information-processing system.

The system consists of a set of memories, receptors and effectors, and processes for acting on them.

The memories contain data (information) and programs of information processes.

The state of the system at any given moment of time was determined by the data and programs contained in these memories, together with the stimuli that were presented to the receptors. (13)

By applying the model of how a computer works to de Groot's puzzling findings, Chase and Simon had assisted in the birth of the modern chess study and their study became one of the most often cited works in the history of psychology. Simon then teamed up with K. J. Gilmartin to develop a computer model of this thinking process.

The basic idea was that long-term memory was accessed through a 'discrimination net,' and that, once elicited, long-term chunks are stored in short-term memory through a 'pointer.' Its relatively low recall performance – slightly better than a good amateur, but inferior to an expert – was attributed to the small number of nodes, about two thousand, stored in its long-term memory. It simulated several human results successfully: increase in performance as a function of the number of chunks in long-term memory; kind of pieces replaced; and contents of chunks. However, in addition to its failure in simulating expert behavior, the program had several limitations. In particular, the chunks were chosen by the programmers and not autonomously learnt, and the program made incorrect predictions for a number of recall experiments that were later carried out.

In any case, by the late 1970's, chess had become the 'fruit fly' of simulation psychology and information processing replaced behaviorism to become the dominant school of psychology.

IV. Criticisms of Computer Models of Human Thinking

Today, in 2002, modeling human thought solely on how a computer works seems even more simplistic and contradictory to common sense than when this article was first written in the mid-1980s. While chunk theory has generally held up as a valid explanation of how short-term memory works, the idea that the manipulation of a repository of stored patterns is the sole source of expertise in the exciting, conscious-directed activity of game playing has generally been abandoned.

The first discussion below is a brief survey of some of the intense criticisms of the chunk theory approach that appeared in the first 15 years after the Chase and Simon experiments. The second part discusses how these problems led to two fascinating redesigned chunk models and the appearance of several rival theories in the 1990s.

In these sections, the most important point may be that the game of go would have been a much better tool to examine what was going on in the 'toy world' of board games. The principal reasons are that the hierarchies and movements of the chess pieces inside their 'fixed' space and their dwindling numbers as the game progresses contrast so poorly with the intertwining perceptual patterns that richly grow and evolve on a go board.

Shortly after publication and continuing until today, the chunking studies began to meet numerous methodological and semantic objections.

What, for example, was a 'chunk?' In order to arrive at the size and meaning of chunk figures, the statistics had to be manipulated around the various strengths of the chess pieces. What did an error in placement mean? If it was a king or a pawn, how was it to be weighted statistically? On redoing the same positions in other studies, sometimes only 65% of the masters' chunks remained the same.

Variations in the timing of the chunks also produced different results. End-game chunks differed in various ways from middle-game chunks. Most chunks centered around pawn structures, not around attack and defense relationships (which usually generate the best next move). Beginners seemed to have one-piece chunks, while those of the masters' varied. Even in the random positions, masters showed better recall when given a longer time to consider the board, while, on the other hand, trained non-players could be bought up to the recall levels of expert players.

Chase and Simon's ideas about the minimal role forward search played in actual games encountered other difficulties. For example, the question of typicality in de Groot's original work came up – how did one know what the 'usual' answer to a problem would be, and how was this a factor? One position he used was a statistically 'average' position of 400 masters' games after twenty moves. What did this mean?

At least a dozen other experiments and papers concluded that strong players differ from weak players in several ways, not just in pattern recognition. Stronger players seemed to focus on squares attacked by pieces while weaker players concentrated more on squares occupied by pieces. Better players were found to make better moves in the meaningless positions.

Error-in-recall indicated also that the configurations were not tied to individual colors or squares. Thus, according to some estimations, '50,000 remembered patterns' could be reduced down to 2500. Not only that, but immediate and delayed recall results were the same, raising doubts as to whether a short-term memory with limited capacity was an essential element at all. Experiments with older players indicated that they searched less but nevertheless made good moves. Also, children's studies indicated that they focused first on attack and then on defense as they grew older.

If skill depended on pattern recognition alone and since studies indicate it remains relatively intact over a lifetime, while working memory and the ability to manipulate sequential thought declines, then why did the ratings of the most skilled players begin to decline in their 30s while the second-highest started their decline in their 40s?

Simon and Chase also encountered problems when they tried to study full-game memory – it seemed that at least parts of the games were simply remembered as they had evolved and the recall involved a simple flow with no pauses. Indeed, some experiments showed that presented positions went directly to the long-term memory, even in the case of moderately skilled players. On the other hand, presentation of two positions at once produced only slightly worse results, though players were remembering more than their chunking positions should permit.

Another series of experiments indicated that there were big differences (for the worse) when positions from games previously played by the subject were presented later as a static problem. de Groot's subjects often complained that they had no 'feel' for the static positions, especially when presented in the middle of an exchange, so he only used positions that did not involve multiple captures. Moreover, a ‘feeling’ of being on offense or defense was found to enhance memory in actual game situations, but not in the static problems.

There were other para-game effects. One was the whole psychological relationship with the opponent (whose strength was overrated, by the way, in static problems). Others included reflections on one’s own thinking, tension as measured by galvanic skin response (the more tension, the better the problem-solving ability), and age. In some very interesting studies, which were not explained by any current theory, older players were found to search fewer lines of play than equally skilled younger players, but with the same success.

This ‘whole perception’ problem also extended to the concept of the game itself. Two researchers used the same patterns but told subjects, half of whom had learned go, the other half go-moku, that exactly similar patterns were from one game or the other. Those who had learned go remembered the pattern better if they were told it was a go pattern, even if it was not, and vice versa. The importance of crucial stones also varied according to the game they were told was being played. In other words, it was the prior perception that affected their abilities to recall – not just the form of the patterns themselves.

Studies of the different ways of planning a game strategy were also found to be relevant to these questions. Masters seemed to use a series of little plans rather than one big plan. The direction of planning – top-down or bottom-up – could also be a factor. Moreover, the differences between masters and novices in whole-game learning seemed to be as large as those de Groot found in problem solving. If these facts had come to light first, then the whole theoretical approach to chess studies might have been much different.

Most important, too, was that a more critical examination of forward search depths revealed that masters, unsurprisingly, actually did search faster and deeper than beginners or intermediates, and they also made better moves from the random positions. When de Groot said that they searched to ‘about’ the same level, he neglected to note that reading one move further could add as many as 240,000 more possibilities and it was found, for example, that a 1300 level player searches 2.3 plies and a grandmaster 5.7 on the average. This represented a difference of several million moves and patterns.

However, no one has suggested that the reason for their superiority was that masters looked at all these possibilities. Instead, correlation studies have indicated that it was chess knowledge, positional judgment, tactical skill that matched up with levels of chess skill, rather than a memory for positions.

In other words, many researchers have found that by making a database the exclusive locus of skill differences, the standard theory starkly omitted any role for higher-level conceptual thinking.

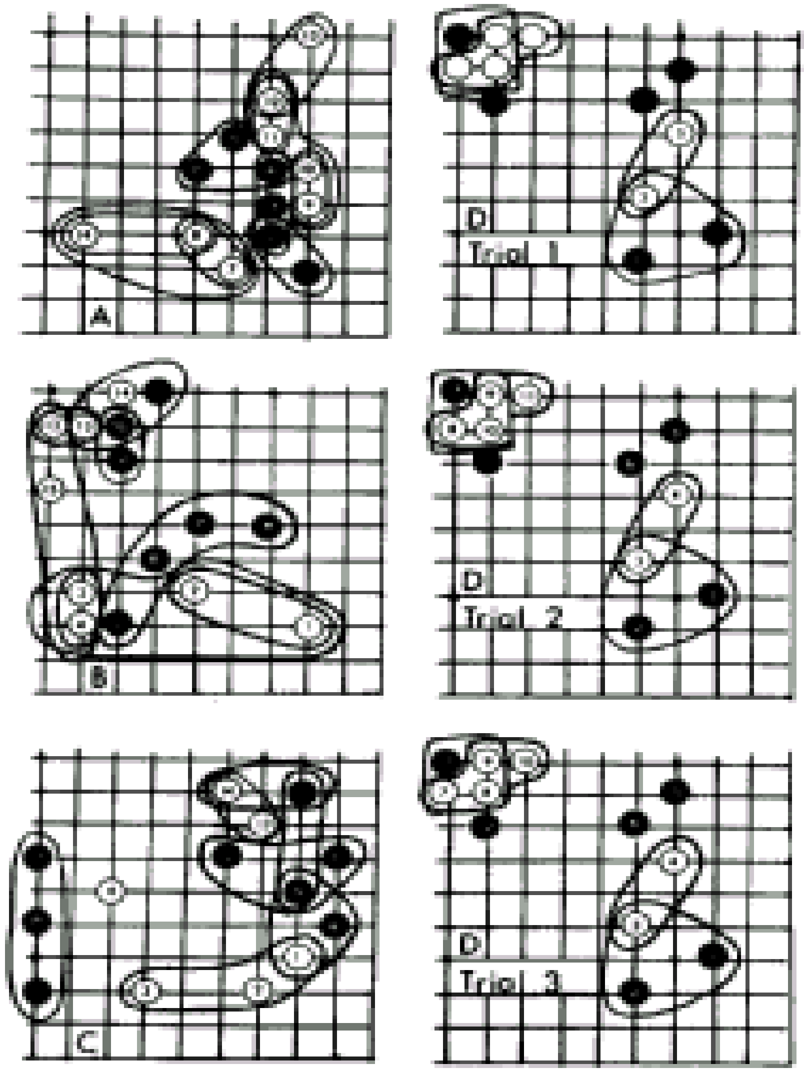
The same lack of regard for the possibility of human higher-level conceptual thinking also appeared when chunk theory was applied to areas such as bridge, computer programming, music and go.

The Reitman Go Study

Unlike chess pieces within the chunk theory rubric, go stones do not move so that the main purpose of a go player's perception would be to divide the board into meaningful chunks. It is not a static feature because each time a stone is added, the chunks will change and there are many possible configurations.

Judy Reitman, in search of a general method of teaching expertise conducted a pioneering go study in the mid-70s using Jim Kerwin (the first Western go professional) as the expert and Bruce Wilcox (who later developed the first commercial AI-based go-playing program) as the beginner. She found that the pause structures of Simon and Chase did not hold up as they seemed to in chess because there seemed to be no clear pauses between chunks. Her solution was to have Kerwin draw circles around what he considered to be the chunks, a method she later applied to computer programmer training, with the result that the chunks seemed to overlap each other.

They also indicated that the chunks had a hierarchical relationship so that memory seemed to be organized around high-level concepts rather than the perceptual characteristics of directly displayed items.



Jim Kerwin's Go chunks (14)

Another way of looking at the situation was that experts at bridge, electrical drawing and computer programming seemed to encode material in terms of its 'sense,' similar to the way, in real life, we remember the gist of sentences rather than the verbatim word order. Unfortunately, Reitman's go study used only corner patterns and positions, unlike the whole-board positions of the chess studies. Thus, it was unclear if the gestalt principles of proximity, color and position were involved in chunk formation – something that was studied, also inconclusively, by substituting pennies for chess pieces by Chase and Simon.

New Theories

Several of chess theorists tried a different approach. One little-known attempt along Phenomenological and Structural lines was done by Chris Aanstoos. He taped the think-aloud protocols of five chess players of various strengths and then attempted to elucidate the structures of thought by following thinking as it thematized the questions in terms of goals ('Interrogation'), watching how it 'Characterized' the situation in terms of the spatial and temporal networks surrounding the objects of thought (both symbolic and real), and then seeing how 'Fulfillment' (the dissolving of ambiguity) took place. (15)

He noted that these three stages could develop in any order. Thus, arrival at a chess maxim, which would ordinarily have signaled the end of thinking for a computer, could signal further 'Interrogation' or 'Characterization' in a person. Moreover, just as thinking could not be separated from the objects it was thinking about, it could not be separated from memory, perception, judgment and verbal knowledge, such as the principles of sound play that it carried on a dialogue with, and which it shaped and was shaped by. This would imply that, for studying how players become better, it was best to start with a clean slate: with beginners or preferably children, as Piaget did in his general learning studies.

A second attempt was Dennis Holding's SEEK (Search, Evaluation, Knowledge) theory which emphatically rejected the chunking proposals. He maintained that the superior performances of masters can be explained by their abilities to grasp the overall situation from a fund of interlocking components such as verbal encodings, traces of former games, storage of lines of play, and a 'metaknowledge' of principles for efficient search (and when to stop that search). This theory postulated a more general working memory instead of rote memory or the distinct components of short- and long-term memories. For Holding, the most crucial factor thus became the masters' long apprenticeship to the game. (16)

Larger Questions

As observed in the original essay, the problems encountered by researchers using the information processing model may have reflected what could happen when theory preceded observation and the structure of the products of the human mind were confounded with the structure of the mind itself.

As Aanstoos and others observed, information was not knowledge. In computer programming, information results when a decision has been made between equally probable alternatives. What was shunted aside in this paradigm was the reason for posing the alternatives in the first place. This, of course, is how humans differ from machines.

In fact, there was a general blurring of what was being called 'perception' and what was being called 'memory,' as was the sorting out of the cause from the effect that was always a challenge in this type of research.

Information processing represented an active mental organism as opposed to the passive one used by the behaviorists, but this switch from Realism to Idealism did not represent a departure from the Stimulus-Response model. Instead, 'Input' still equaled 'Stimulus,' and 'Output' was still equivalent to 'Response,' as in the old Industrial Revolution and the new computer-based models.

Similarly, in pattern recognition theory, the associationist theory was actually retained – only the source of the recalled items were seen as internal (mental), rather than external (environmental). Perhaps this change did not get at what might be the root problem in Western languages – the subject-object split which suggests that there must be ideas in our minds which are copies of reality.

V. Developments Since the mid-1980s

Two Chunk Theorists

By the 1990s, even the most ardent chunk theorists had begun to modify and limit their theories. Today, the two leading disciples of Chase and Simon's Turing Test models are Ferdnand Gobet and Perti Saarilouma, but they have used different models to simulate on computers the chunk acquisition of beginners and experts. (17)

Both Gobet and Saarilouma contend that chunk formation is the major component of chess skill. These chunks consist of discrete patterns which unite a number of pieces and related squares. They are formed as a result of the combination of gestalt and chess-related factors during the learning experience.

Gobet and Saarilouma also agree that chunk theory is the best explanation for why human learning curves slow down with more experience. This is because the chunks learned are getting bigger and more complex. They disagree, however, on how these chunks are organized in the long-term memory and both have built computer models that they say successfully imitates human behavior. These are not meant to be successful chess-playing programs, incidentally, but only meant to model human behavior.

In brief, Gobet's computer version is based on a computational model known as EPAM (Elementary Perceiver and Memoriser) which made improvements on Simon and Gilmartin's earlier program. Its most recent version, CHREST (Chunk Hierarchy and REtrieval STructure), consists of an input device (a simulated eye), a short-term memory for storing intermediate results, and a long-term memory, which contains chunks of information.

Following Chase, Simon and Gilmartin's proposals, CHREST imitates masters' eye movements, which indicate that five relations contribute to the probability of pieces belonging to one chunk. These are 'kind' (as with two bishops), 'color' (the same color is a stronger attraction than opposing colors), 'threat' (one threatens the other), 'defense' (one piece defends another) and 'proximity' (location in near-by squares). In studies of artists, for example, experts' eyes move in definite patterns whereas novices wander all over the canvas. It is the same for beginning chess players who have had no training: the gestalt factors of proximity, color and kind – and not chess specific factors – are what is noticed first in recall studies.

Improving also on Chase and Simon's ideas, which assumed that chunks were too small and singular, Gobet has added a 'discrimination net,' and mechanisms for directing 'eye' movement and managing memory. Most important, the discrimination net structures the chunks in a hierarchical and lateral manner.

Some of the larger chunks (of up to 15 pieces) and certain chess positions are encoded into 'templates,' which are much like Marvin Minski's artificial intelligence-style 'frames.' Like them, the templates have fixed elements called 'slots' that appear when the same squares or types of pieces are learned and then seen in a pre-determined parameter. These templates can be filled up with variable elements like opening sequences, the locations of certain pieces, potential moves and semantic information like strategic plans and tactics during memory encoding of branches of play.

Gobet claims that these features can account for and thus simulate humans' rapid recall of complicated positions within one second of viewing, and the long lengths of study time and game experience that are required to learn them.

In addition, Gobet claims that his version of chunk theory can account for the refutation of the original finding by Chase and Simon that masters and novices seem to do equally poorly with random positions. He proposes that masters can still find chunks in even the most random of positions which accounts for their slight statistical superiority of recall.

Gobet also defends the number of chunks (50-100,000) cited by Simon and Gilmartin as necessary for mastery. In his experiments with distorted chess positions, there was a slight but significant difference in recall, indicating that individual chunks of specific positions are stored in the long-term memory. Other theories, which postulate a fewer number of chunks, or chunks associated with specific squares or direct long-term memory access with no intermediary limited short-term memory, (which are discussed in the next section), cannot account for these findings.

Finally, Gobet accepts Chase and Simon's conjecture that it takes about 8 seconds to create a chunk and about one-second to add information to an existing chunk. Additionally, he accepts their idea that chunks stored in long-term memory are not equally familiar, so that, in the beginning presentation, more familiar chunks are perceived, and then attention shifts to those less familiar. He also incorporates Reitman's proposal that go chunks seem to overlap. Thus, in the first stage of perception, entire chunks are encoded, and in the second, isolated or overlapping portions can be added.

Gobet's chief rival in computer-simulated modeling, Pertti Saarilouma also tries to explain and model the learning curve-problem: why does skill develop so quickly at first and then slows so much if learning is nothing but acquiring more chunks? The problem with earlier studies, he feels, is that only the memories of experienced players were tested. Yet, to build a computer model of human learning, the chunks must be acquired from scratch and, if a valid model is being built, its learning curve must match that of beginners.

Agreeing with Gobet on the basics of chunk theory, he focuses on the roles of working and long-term memory.

> *In the mainstream symbolic simulation model* [e.g. Gobet's] *the idea has been to use a hierarchical structure . . . but it need not be the only plausible model. There are alternative simulation approaches. One may simulate chess results with neural nodes or use heterarchic models. The latter do not presuppose a multilayer unified structure, but it assumes that retrieval structure is formed by a set of parallel and non-integrated patterns. . . . we have constructed a model in which the retrieval structure is not a discrimination net but a set of patterns activated by the presentation of the stimulus. In this kind of model the contents of the patterns themselves cause the integration but no direct links combining patterns are required. (18)*

Assuming the beginner can recognize single pieces everywhere on the board, Saarilouma and his associates began with a computer model of 768 one-piece chunks in its long-term memory i.e. every type of piece (12) on every location on the board (64). The system then started to build new chunks based on study positions – first two-piece and then larger chunks were formed.

The growth of the chunk sizes was interpreted as the construction of more complex retrieval structures which were stored and then retrieved when encountered on the board.

Saarilouma built two versions. One used a 'random neighborhood heuristic,' which builds chunks from a randomly selected piece and its neighbors. The other one uses a 'correlational heuristic,' which learns in a way reminiscent of parallel-processing neural nets. It is based on classic associationism, starting with the most commonly-seen piece and examining its relation to other pieces in terms of gestalt-like, non-chess specific patterns of similarity, color, and type (but not proximity).

So two black knights in neighboring squares are more closely correlated than a black knight and a white knight or two different types of pieces with same color, or two same type of pieces in squares on different sides of the board. The system adds to the chunk the piece with the highest correlation measure with the focal piece, and further expands the chunk to the piece with the highest correlation with this newly added piece. (20)

In his experiment, the models were taught 500 chess positions and the recall was requested with game and random positions with the same intervals as two human subjects – after 30, 60, 175 and etc. studied positions. Test runs with short-term memory chunks of 4, 7 and 10 pieces were tried. The 'neighborhood' method yielded only mixed results, but the correlation version matched the learning curves of novices when chunks were assumed to consist of 4 pieces. When chunks were assumed to consist of more than 4 pieces, the learning curves of experts was simulated.

Summing his efforts up, Saarilouma explained:

The models do not reconstruct positions on empty boards like in Simon and Gilmartin's, but try to cover the pieces on the board with corresponding chunks in the long-term memory if they are found. If the chunk cannot be found, the systems try a chunk which is one piece smaller or a totally new chunk, otherwise they add the chunk to the short-term memory and mark the corresponding pieces on the board as recalled. Finally the recall score is calculated as a percentage of pieces explained by chunks in the short-term memory of all the pieces in the position.

. . . Pieces or chunks that are not seen in the learning phase are never memorized or retrieved, so the models make no commission errors. Once the models have learnt something, they never forget it, nor do they retrieve any incomplete or wrong chunk from the memory. (19)

Saarilouma admits there are many problems that remain to be worked out with this method, but his principal conclusion is that chunks can exist independently of each other in their own locations and act as an integrated whole. Thus, it is not necessary to assume that long-term memory is hierarchically arranged.

While Saarilouma and Gobet's correlation programs both imitate human learning curves, Gobet objects that his CHREST program deals with random positions better because he uses neighborhood proximity as a major part of his program. This accounts for his findings that, in random positions, even beginning test subjects are able to find chunks – something that other, non-learning based programs, cannot account for. In fact, he says, Saarilouma's exclusively proximity-based heuristic gets worse the more chunks it acquires.

The two programs also differ in other ways because Gobet's uses time constraints and a greater number of chunks, which also overlap, to produce his human-like results. However, as Gobet adds, Saarilouma's goal is not really to run cognitive simulations, but to compare two learning methods.

Saarilouoma replies by accepting that chunk theory is a common core of their work. But:

When it is possible to construct several models simulating basically the same data, but having different presuppositions, one must ask what is the argumentative status of computational models.

If we think about the main differences between hierarchy, heuristics and the type of working memory, it is clear that they can hardly be independent. When, for example, the structure of working memory is limited to a tree, it seems necessary to use hierarchical coding. When working memory of a less constrained type is used by making long-term memory assumptions, it is possible to apply a flat chunking structure. Because assumptions are essentially combined, it is often difficult to test assumptions and falsify models empirically. In fact, all time parameters are problematic, as long as the time is not physical time used by people to carry out the presented task or subtask, but rather some numeric parameter depending on the will of the modeler. The classic problems with refuting theories evidently confuse argumentation in modeling. It is always possible to make new assumptions and slightly modify models so that the outcomes of simulations remain in reasonable harmony with new empirical findings. . . .

The difficulties in testing models seem to endanger the whole simulative approach. There are so many ways of making models that one can doubt whether models have real argumentative value. Modeling may look like a game with no deeper purpose. (21)

Knowledge-based Systems

There has been a diversified reaction to the idea that skill is based on the static idea of chunk manipulation by a limited short-term memory in combination with a retrieval center and an unlimited long-term memory. For example, there have been the ‘talent,’ the ‘genetic’ and the ‘environmental’ proposals (or a combination), in which inherent biological or experiential differences among individuals account for the choice of focus and the diversity of skilled performances.

Obviously, different skillful activities call for different talents. One major objection to Chase and Simon’s model is the speed that masters can look at a situation and memorize or act upon it.

As opposed to Gobet and Saarilouma, K. A. Ericsson and W. Knitsch proposed that the major component of skill is a more generic retrieval center, which is able to manipulate the incoming data in such a way that it can be rapidly utilized.

In investigating prodigious memories that are required by different occupations and activities, they found, for example, that waiters learned specific techniques to organize menu orders into categories. In terms of sheer memory feats, they pointed to the difference between trying to recall 21249304924158457769 and reorganizing it as (212) 493-0492 & (415) 845-7769. Thus, in their chess experiments, they trained beginners to replicate master performances in the recall tests.

As a reviewer commented on Ericsson and Kintsch’s work up to 1995:

Problem solving, decision making, and other complex activities require rapid access to information. Within traditional models of memory, short-term memory is the cognitive locus of these activities because long-term memory retrieval and storage processing are thought to be slow and error prone. That is, ‘On the basis of a century of laboratory research on memory [that began in the late 1800s with the study of Morse Code telegraph operators], *many theorists have concluded that long-term memory can meet neither the criteria of speed and reliability for storage nor those for retrieval.’ Ericsson and Kintsch challenge these assumptions given that the severe limitations of short-term memory ‘might seem far too restrictive to allow for human performance levels.’* [i.e. short-term memory does not improve with practice.]

The rejection of long-term memory involvement in working memory is based on two findings. First, storage of information in long-term memory is not reliable. Second, accounting for the retrieval of information in long-term memory, even if it could be reliably selected and stored, is problematic within standard memory models. Ericsson and Kintsch do not challenge these limitations of long-term memory, but disagree 'with the stronger claim that the invariant characteristics of long-term memory rule out an expansion of working memory by storage in long-term memory in all types of performance.'

Moreover,

. . . 'Individual differences in the capacity of working memory are not fundamentally fixed and unchangeable. Instead, they are deliberately acquired.' This view is quite different from the dominant information processing perspective in which constraints on human information processing (e.g., the capacity of short-term memory) are invariant. Ericsson and Kintsch advocate a more situational view of cognition in which the situation dictates processing constraints. To illustrate, a chess master has a greatly expanded working memory capacity when playing chess. Otherwise, he is normal.

From a review of a 1997 paper:

[Ericsson joined up with Neal Charness in 1997 to propose] *. . . that one of the strongest pillars of support for this view is the evolution of domains. For example, 'The knowledge in natural science and calculus that represented the cutting edge of mathematics a few centuries ago, and that only experts of that time were able to master, is today taught in high school and college.' Historical improvements are evident in nearly every field (e.g., music, athletics, etc.).*

How is expertise acquired? Ericsson and Charness argue that deliberate practice is the primary mechanism responsible for the attainment of expert levels of performance. Deliberate practice affords optimal opportunities for improvement through feedback. They distinguish this activity from other types of domain-relevant experience, including work and play. The basic assumption of the deliberate practice framework is that performance improves monotonically with amount of deliberate practice. Individual differences in performance among individuals who engage in *comparable amounts of deliberate practice are explained by differences in the age at which deliberate practice was started.*

[Another classic problem with the Chase and Simon model is how to explain why] *. . . Individuals often maintain high levels of performance throughout adulthood, while less proficient performers show declines in performance earlier. This performance advantage is, however, restricted to domain-specific activities. There is also evidence that older and younger performers can achieve a given level of proficiency in different ways. For example, in chess, Charness found that older chess players rely more on their extensive knowledge base than on planning (an interesting question, however, is whether this strategy shift is age-related). Salthouse has shown that in typing older adults rely on a large eye-hand span.*

. . . It seems likely . . . that there might be a reciprocal relationship between age-related performance and deliberate practice changes such that declines lead to less deliberate practice involvement, which lead to further declines. (22)

An additional knowledge-based sub-theory of these propositions postulated by Ericsson and his colleagues was that masters may have encoded a retrieval structure representing all of the 64 squares – a mental chess board. Thus, if encoding takes place on a lower-level than the long-term memory, pieces are directly related to squares.

Alternatively, Ericsson proposed that there might be a hierarchy of schemas and patterns on various levels that can be utilized at the proper moments.

However, Gobet argues that Ericsson's working memory ideas and Holding's SEEK theories, which have never been tested or modeled, might be limited to explaining activities that require building a memory structure that deals with strategic control, where order is important, and data is serially encoded. Moreover, the chess presentation times of one second cannot allow for the complex, multi-level processing that Ericsson and Holding propose.

Gobet also objects that experiments with interferences presented after the initial position is laid out, and before it is recalled, does not significantly decrease performance. Nor does the presentation of up to as many as five board positions at once hamper performance. These results are difficult to interpret if only one retrieval center is postulated.

Also, Gobet points out that Ericsson's general theories (and the square-based, but not the hierarchy-based theories) cannot account for the statistically valid (although small) superiority of masters over beginners, given short presentation times when dealing with random positions, since there should enormous differences. Similar arguments apply to random move generations in game-simulated tests and to random positions when the players are blindfolded.

In other words, Gobet says that the difference between masters and *patzers* lies in vast memory differences and that the quick encoding and retrieval of the modular character of large knowledge chunks (or of template slots) is the only way to account for superior chess play. (23)

Mental Images, Verbal images

The chunk theorists propose that the main access to chess chunks is visuo-spatial with verbal routes being secondary. They cite evidence from Chase and Simon's letter-substituting experiments, where both letters and pieces were recalled with equal ease, and the fact that chess players seem to recreate positions better when they are verbally described, rather than read, because there is less interference.

They also point out that verbal interference or suppression of the central executive portion of the brain creates less trouble than visual interference. Most striking are the protocols of blindfolded chess masters who continually stress their logical and verbal recall of the games under play – internally, the positions are encoded in key sentences such as 'Panov attack: White builds up an attack on the King's side. Black tries to counterattack on the center.'

In other words, chunk theory maintains that verbal information on the location of single pieces is stored in the 'mind's eye' for a brief period of time and the chunks are connected by visual, verbal or conceptual routes to the long-term memory nodes which are then applied to a visual representation of the board.

Working under the aegis of Stephen Kosslyn's Harvard-based theories of mental imagery, Christopher Chabris has developed a different approach, which he calls a 'mental cartoon' hypothesis. (24)

He notes that the protocols of top chess players have never given any importance to pattern recognition, at least until some became aware of the theories of Chase and Simon in the 1980s. On the other hand, almost all have emphasized the importance of visualization. Thus, he proposes that, 'Expertise in visual-spatial domains such as chess is based on the development of cartoon-like representations of the domain's important properties, as contrasted with photograph-like representations of the domain's constituent elements.' In other words, the mind is controlling what it sees.

In the extreme form of the theory, instead of 'chunking,' the pauses in recall by very skilled players could be reflecting a focusing and shifting of attention to various parts of the board as the image fades in the short-term memory. The pauses could also point to a restart in analysis during the progressively deepening searches that de Groot found. This model would also explain the findings that chess experts do, in fact, search more quickly and deeply in legal positions than non-experts. However, he cautions that proof will require much more research of blindfold chess playing, where there is no continual visual input.

In a less extreme form, the theory would suggest that if chunks were being used by the mind, they would be connected and would overlap spatially and hierarchically in somewhat the same way that Reitman found Jim Kerwin to be doing. In other words, chunks would not exist except in a real (and not random) context in the cartoons, as is the case when letters are easier to identify in words (and not pseudo-words) because of a top-down effect which amplifies and diminishes various aspects of the mental board.

Another aspect of Chabris' theory is that the cartoons are not static. He noted that several grandmasters have commented that the great players do not see squares and pieces but 'force fields,' where certain events have the potential to take place or not take place. As they are considering moves in their search, the pieces jump around so that the image is not only visual but contain motor elements. He also found that experts' abilities to visualize general actions was better than novices, at least partially contradicting Ericsson and Knitsch.

Important for go theorists, also, is how the cartoons would necessarily have to distort spatial properties. In chess, for example, the physical distance between two squares is not as important as the number of intervening squares. For example, the distance between the upper-right and lower-left squares is 1.4 times the distance between the upper- and lower-right, despite the fact that number of squares crossed is equal. In relation to this, Chabris noted that chess champion Emanuel Lasker urged chess players to visualize each of the squares on a completely empty board as a valuable perceptual exercise.

Opining that previous experiments were flawed that tried to prove that masters' play does not improve given more time because pattern-recognition is the basis of their superior play, Chabris created a number of short- and long-term recall and famous-game recognition experiments. He claimed that the results supported his theory better than a hypothetical ‘meaning theory,’ whereby the mind discards all unimportant information and remembers only the concepts behind a chess position.

Noting that the EPAM discrimination network is ‘not the most biologically plausible mechanism for implementing pattern recognition in the brain,’ he claims that his results indicate that Gobet-style theories do not explain any role for conceptual knowledge of strategic goals outside of the templates, but admits that the main weakness of his own theory is that it is not detailed enough at the present time to allow computer emulation.

In conclusion, he says that chunk theory is a useful way to begin research into expert skills, but it is incomplete. It was designed only to account for expert performance in memory tasks and was never designed to account for visual imagery, look ahead or neural mechanisms. But, he notes, the advancement of theory in cognitive psychology often takes place as simple theories are found to be inadequate and are replaced by more complicated ones.

The Role of the Brain’s Hemispheres

Most interestingly, Chabris moved beyond traditional cognitive theory, which leaves open the question of how and where the mental cartoons would be, by including some experiments to test the role of the brain’s hemispheres in chess thinking.

First, he pointed out that previous work suggests that the right-hemisphere is crucial because of EEG studies during blindfold play, that left-hemisphere damage does not curtail chess playing, and that left-handedness is more common among chess players than non-chess players.

Next, he employs computational analyses of human and artificial visual systems that suggest that there is a rule-following ‘default’ system which organizes ordinary perception into meaningful groupings of stimulus elements in everyday life. When a problem arises that cannot be handled in this way, and a rule-violating ‘override’ system kicks in. For example, when two object parts of similar color and texture are juxtaposed in the image, the visual system must overcome its tendency to combine them into a single whole without boundaries.

Within this framework, the right-hemisphere performs better at parsing according to gestalt principles such as proximity, collinearity and similarity (as in the above example), and the left-side comes in when the parse that is needed violates them. In random positions, it should be found that few patterns would obey chess or gestalt rules.

When these findings are applied to the idea of chunks, which, in chess (or go, as in Kerwin's drawings), puts together objects that usually violate gestalt principles, the over-riding left-hemisphere should be the one that remembers them best, and it should be better when it is the first one that the position is presented to.

On the other hand, as a player gets better, in the chunk theory view of the brain, the visual system would be learning new chess-specific groupings. These would become the new defaults, which would mean the right-hemisphere would come into action faster and better when a real chess position appeared.

Neither of these theories might be true, however, since Chabris notes that the right-hemisphere is superior in memory for complex visual data, (such as faces), so that it might remember both types of positions equally well, especially if the random positions are complicated.

Since recognition/recall from memory differences correlate to chess playing skill as measured on the Elo scale and can be determined in 150 milliseconds, and divided brain studies need a time-span of 200 milliseconds, Chabris was able to conduct some experiments to test which ideas of hemisphere function might be correct.

His results, he says, correlate with his predictions that if the right-hemisphere is applying default parsing rules, then it should perform better when the majority of the position contains gestalt-like patterns and vice-versa when it doesn't. In other words, he predicted that the right-hemisphere will do better with single-chunk fragments and the left with pieces of multiple-chunk fragments, although further experimentation is needed because the single-chunk fragments might have accidentally obeyed gestalt rules as well as chunk rules.

On the other hand, his sophisticated statistical renderings show that the left-hemisphere is better at recognizing random but not normal chess positions, contradicting the theory that the left-side overrides the right-side's default, gestalt-oriented parsing rules.

Additionally, the right-side is superior at acquiring the chess-specific chunking rules, which the visual system uses instead of gestalt while playing chess. But, he writes, there is still the question of whether these experiments only show that the right-side is better at 'easy' versions of two perceptual tasks.

He even offers a reason for why such a small number of women reach the top ranks of chess. The right-hemisphere advantage for recognition of faces declines during the menstrual cycles and face-recognition and the pattern-recognition mechanisms of chess players is thought to take place in the right temporal lobe (the FFA or 'fusiform face area). However, further research is needed to find if there is a face-recognition superiority in master chess players as opposed to novices that goes along with their apparent superiority in motion-processing in the middle temporal lobe (which is well-connected to the parietal lobe).

He generalizes from all this evidence that neuropsychological evidence shows that chunking can be understood as the 'imposition of a first-order perceptual organization that arranges its elements into potentially useful groupings.' The left-hemisphere has a role in extracting meaning when the interpretation cannot be supported by chunk representation while the right-hemisphere is critical for chess skill because, 'it is best at using chunking to encode normally-structured positions into memory.'

In summery, Chabris sums up his case by proposing that, 'The overall findings of significant frontal lobe involvement and almost no left-hemisphere involvement in the neuropsychological studies . . . [he] . . . reviewed . . . are consistent . . . with the claim that mental cartoons are a type of semi-depictive, spatial/abstract representation rather than a verbal code or a hybrid spatial/verbal mechanism.'

VI. Some Developments in Go Studies

Verbal Imagery

Meanwhile, in Japan, Yasuki Saito and colleagues confirmed Reitman's findings and have tried to discover what was needed to make chunk theory complete enough to explain human play and become useful for true AI go playing programs – something which was abandoned early on in chess programming in favor of the un-human-like massive search. (25)

In a series of papers, they explained how they tracked eye movements and took extensive protocols of professional and amateur go players, in order to examine in detail the layers of the extensive inner dialogue that takes place before every important move.

They found that before the moves that involved the fundamental factors of life and death and connectivity are considered – which would most directly involve pattern recognition – the possibilities of meta-level concepts must be considered. These include 'influence,' 'territory,' *frukiwari* (in which case, the present battlefield will be abandoned), *meai* (the trading of moves), and most especially, *atsumi*, 'thickness,' for which there are no set patterns.

Moreover, because the go board is six times larger than a chess board, it must be remembered that players will be concentrating on only parts of the board – with attention being paid to particular stones in other regions that might 'break ladders,' and etc. In other words, the board must be considered as a hierarchically-structured field with various levels of importance attached to different segments – which the two players may disagree about and which would change depending on whether one was winning or losing and what stage the game was in.

They also pointed to the extensive vocabulary that go players have built up over thousands of years to deal with these larger-than-pattern concepts of strategy. On the other hand, they found that typical look-ahead is often not deep, which, for Chase and Simon, seemed to point to pattern-based decisions. They concluded that, while patterns are important, they must be *attached to meaning* before they can be utilized. This was an important, if not *the* principle factor in knowledge representation that could shorten the need for extensive look ahead.

Go and the Brain's Hemispheres

Another Japanese team headed by Takeshi Hatta, worked on the hemisphere specialization of Go experts. Using the Salthouse paradigm, numbers were placed at various points on a grid and then quickly replaced with asterisks and the differences in recall of the locations and the numbers by go experts and novices were compared. However, since they were unable to use a full size go board grid, they felt that their findings were inconclusive. (26)

Noting that Chabris' mentor, S. M. Kosslyn, had found that the left-hemisphere is better at processing coordinate spatial relations (above vs. below, in front of vs. behind), and that the right-hemisphere is better at processing coordinate spatial relations, (judging the distance between items), they theorized that because of studying go, experts would perform better than novices at recalling both numbers (which are verbal, left-hemisphere material) and locations (better handled by the right side).

More interesting was their conjecture about hemisphere collaboration: When the visuo-spatial demand increased, the novices' performance sharply decreased, so they asked whether the right-hemisphere was abandoning the responsibility so that the left-hemisphere could be called in for collaboration?

Interestingly, starting with the chunk theory hypothesis, a German team used magnetic imaging of focal bursts of γ-band activity in amateur and professional chess players during a tournament and found that grandmasters seem to rely more on remote than on recent memory:

. . . this activity is most evident in the medial temporal lobe in amateur players, which is consistent with the interpretation that their mental activity is focused on analyzing unusual new moves during the game. In contrast, highly skilled chess grandmasters have more γ-bursts in the frontal and parietal cortices, indicating that they are retrieving chunks from expert memory by recruiting circuits from outside the medial temporal lobe. . . .

. . . Examination of single slices indicates pronounced activity in the region of the perirhinal and entrorhinal cortex, hippocampus and related structures in amateur players, but not in grandmasters. . . .

. . . the activation of expert memory chunks produces focal γ-band activity in the neocortex, whereas amateur players primarily encode and analyze new information tasks that activate the medial temporal lobe and

the hippocampus. It is possible that these structures play only a transitional role during the establishment of expert memory in the neocortex. (27)

VII. Summery: Go, Chess and Future Psychological and Educational Studies

If only philosophies and languages with abstract mental entities are considered, it is not so obvious why go is preferable to chess for studying how the mind transfers visual data into symbolic codes as it learns a task. However, when a point of view which emphasizes discrimination of physical entities from a general background are taken into account, go would seem to be a superior tool.

For one thing, as the Yasuki Saito studies touched on, it is much easier to turn go's 'visual language' into an oral language that can be communicated in protocols and can be interpreted according to levels of skill. In mathematics and languages as well as strategy games, grammars of 'proper play' have been historically assembled and are progressively learned as the players interact with it. Go, for example, has an extensive metalanguage of maxims and principles that have been codified for over two thousand years into a series of proverbs and principles such as a group's 'heaviness' or 'lightness' and 'good' and 'bad' shape. These qualities are much easier to recognize by researchers and players of different levels of skill than are chess's vague general, principally tactical (and not strategical) principles.

In go, this grammar is visually apparent in a most remarkable way because the units are so singular and simple in the way they stand out from the background of the board. With these 'monodies,' positions are progressively built up rather than destroyed as in chess. At the end of a game of go, there remains a visual record on the board that contains many of the objectives of the players as they were formed and modified during the course of action.

In the area of problem-solving as a means to measure improvement, go is also superior to chess. Local problems in go generally concern good methods of play, or the 'life and death' of groups. While chess problems are usually restricted to whole-board endgame positions, in go the problems and proofs can be isolated and concentrated on, aided by the precise ranking and resulting handicap systems, which do not tend to destroy the integrity of the game, as they do in chess.

The look-aheads in go also consist of many more moves than chess and this offers a more fertile and flexible field for investigators because of the multiplicity of variations, and the fact that players of different levels of skill will recognize different matters which are important.

Since this simplicity results in one of the world’s most complicated games, one benefit is that the Turing Test is still valid, *albeit* not in the way the chess programmers have envisioned. Since lowly amateurs can beat all go playing programs, go programmers have been forced to first conceptualize and then try to mimic the ‘short-cuts’ of thinking about probabilities that characterizes good human play. This is opposed to the good computer memory-based play that machines like Big Blue employed, or the more basic chunk-building attempts by the psychologists.

There are also other, ‘phenomenological’ qualities about the game of go that might make it more useful for studies of perception and learning. It’s two simple basic rules – if you are surrounded, you have been ‘eaten,’ and no position can be repeated – seem to be reflected not only in the general principles of Chinese philosophy, but also in the deepest physical and biological principles that Western investigators have been only recently finding out about the ‘game-like’ interactions of Space, Time and Matter.

As Nobel Prize winner Manfred Eigen pointed out, the workings of probabilities within rules or limits – meaning ‘play’ – ’permeates our universe from atomic and molecular reactions to human survival and the movement of stars.’ As the saying goes, ‘Go is like life as life is like go.’ Literally and figuratively, go players could be called both the ‘players’ and ‘the played’ – perhaps an additional reason why go represents a peculiarly ideal symbolic situation for studying how we acquire a perception of that process. (28)

Footnotes

(1) Chad Hansen: *Language and Logic In Ancient China*; Univ. of Michigan Press; 1983, p.30 and p. 179, Footnote 35.

(2) The idea that there was only one 'Dao' was the result of misinterpretations of Christian missionaries in China of already distorted descriptions of Daoism by Confucian scholars. The missionaries also thought that since there was only one 'God,' (which therefore needed to be capitalized), they thought there could be only one 'Dao' in what both the Confucians and missionaries thought of as mystical nature religion, instead of one of the world's first 'philosophies of action.' See Chad Hansen; *A Daoist Theory of Chinese Thought: A Philosophical Interpretation*; Oxford; 1992. See also, Peter Shotwell; *The Game of Go: Speculations on its Origins and Symbolism in Ancient China* elsewhere on this site and, in an earlier version, in *The Go Player's Almanac 2001*; Kiseido; 2001.

(3) J. W. M. Verhaar, D. Reidel (ed.); 'Being in Classical Chinese'; *The Verb Be and Its Synonyms*; Oxford Press; 1967; p. 20. (4) George Steiner; *Martin Heidegger*; Penguin Modern Masters Series; 1980.

(5) Herbert Spiegelberg; *The Phenomenological Movement* (2 vols.); The Hague; 1960; p. 570.

(6) Quoted from Steve Spalding; 'The War Machine and Stateless Organizations or The Nomadology of Anti-States'; p. 1 from *Travels in Theoretical Spaces: Deleuze, Guattari and Foucault* at: http://www.gradnet.de/pomo2.archives/pomo99.papers/Spalding99.htm Many thanks to Omri Glasner for sending me this article.

(7) Deleuze and Guattari; *A Thousand Plateaus: Capitalism and Schizophrenia.* Minneapolis, MN: University of Minnesota Press, 1987; p. 353.

(8) Miroslav Petříček; *Philosophy or Wisdom*; http://www.scca.sk/scca_catal/petriceke.html

(9) See Jacques Derrida, David B. Allison (Trans.); *Speech and*

Phenomena and Other Essays on Husserl's Theory of Signs; Northwestern Univ. Studies; 1973; p 62. Derrida considered Husserl's idea of time to have 'a non-replaceable center, an eye or living core – the punctuality of the real now.'

(10) In Western philosophy this controversy between Empiricism (Realism) and Rationalism (Idealism) begins with the divergent views of Reality offered by Democritus and Pythagoras.

(11) See *Go World* No. 49 for an example of pro-pro blindfold go. There are also stories of elderly, blind players in late 19^{th} century Japan.

(12) For a nearly complete accounting and criticism of the chess studies to 1985, see: Dennis Holding; *The Psychology of Chess Skill*; Erlbaum Associates; 1985. See also the review in *Contemporary Psychology*; 1986; Vol. 31; No. 11.

(13) W. G. Chase and H. A. Simon; *The Mind's Eye: Visual Information Processing*; Academic Press (New York); 1973. See also, Chase and Simon; 'Perception and Chess'; *Cognitive Psychology*; No. 4; 1973; pp. 55-81.

(14) J. S. Reitman; 'Skilled perception in Go: Deducing Memory Structures from Inter-response Times'; *Cognitive Psychology*; No. 8; 1976; pp. 336-356.

(15) Chris Aanstoos; *A Phenomenological Study of Thinking as it is Exemplified During Chess Playing* (Ph.D. Dissertation); Duquesne University 1982. His introduction had a clear exposition of most of the philosophical and historical issues involved.

(16) See footnote (9).

(17) Gobet has an extensive bibliography. See, for example: http://www.psyc.nott.ac.uk/research/credit/projects/chess_expertise/#; http://coglab.wadsworth.com/experiments/Prototypes/index.html

(18) P. Saarilouma and T. Laine; 'Novice Construction of chess memory'; *Scandinavian Journal of Psychology*, Vol. 42; 2001; pp. 140-1.

(19) *Ibid.*

(20) *Ibid.*

(21) P. Saarilouma and T. Laine; 'What do computer models of cognition explain: A reply to Gobet'; *Scandinavian Journal of Psychology*, Vol. 42; 2001; pp. p. 147-8. See also in the same volume: F. Gobet; 'Chunk hierarchies and retrieval structures: Comments on Saarilouma and Laine'; pp. 149-155.

(22) From: http://www.cc.gatech.edu/~jimmyd/summaries

See also: K.A. Ericsson and N. Charness; 'Cognitive and Developmental Factors in Expert Performance'; P. J. Feltovich, K. M. Ford, & R. R. Hoffman (Eds.); *Expertise in context: Human and machine*; MIT Press; pp. 3-41.
K.A. Ericsson and W. Knitsch; 'Long-term Working Memory'; *Psychological Review*; Vol. 102; 1995; pp. 211-245.

(23) See especially: F. Gobet; 'Expert Memory: A Comparison of Four Theories'; *Cognition*; Vol. 66; 1998; pp. 115-152.

(24) C. Chabris; *Cognitive and Neuropsychological Mechanisms of Expertise: Studies with Chess Masters*; PhD thesis; Harvard University; 1999.

(25) Yasuki Saito and Atsushi Yoshikawa; 'A Protocol Study of Problem ' Solving in the Game of Go and other conference papers – see http://www.brl.ntt.co.jp/people/yosikawa/international_conference.html.

(26) Takeshi Hatta, Terumasa Kogure and Ayako Kawakami; 'Hemisphere Specialization of Go Experts in Visuospatial Processing'; *American Journal of Psychology*; Winter 1999.

(27) O. Amidzic, H. Riehle, T. Fehr, C. Wienbruch and T. Elbert; 'Pattern of Focal γ-bursts in Chess Players'; *Nature*; Vol. 112; Aug. 2000; p. 603.

(28) Manfred Eigan and Ruthilde Winkler; *The Laws of the Game: How the Principles of Nature Govern Chance*; Harper and Row; 1983.