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Chess and content-oriented psychology of thinking

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In this paper a number of principles for content-oriented cognitive psychology will be presented in the context of research into chess players' information processing. It will be argued that modern theoretical concepts of attention, imagery and memory are based on underlying concepts of capacity and format and that these concepts are not sufficiently powerful to express all phenomena associated with mental contents. Instead, one must develop a genuinely content-oriented theoretical language to discuss, for example, contents and their integration into thinking. The main problem is how to explain the contents of representations. Why do representations have precisely the contents that they have. Here the main attention will be focussed on the question how can one explain the selection of content elements in representations. To formulate the basic concepts of content-oriented thought research several issues must be discussed. Firstly, it will be shown that traditional attention and memory research is capacity-oriented and therefore unable to express mental contents. Secondly, it will be argued that there are content phenomena which must be explained by properties of other content phenomena. Thirdly, it will be shown that in chess, people integrate information into representations by using functional rules or reasons, i.e. concepts and rules, which tell why some information contents must be included in a representation. It will then be shown that people integrate information around learned 'thought models' whose contents, together with functional rules or reasons, explain and clarify the content-structure of a mental representation. It will also be argued that the analysis of contents is metascientifically closer to linguistics with its basic method of explication and content analysis than natural sciences, which form the most common underlying model in current experimental psychology. Finally, content-oriented cognitive psychology and its presuppositions will be compared with neural and computational approaches to show that it gives an additional and alternative theoretical resource, but not a contradictory conceptual platform, to the previous theoretical ways of working with human thinking.

Key words: content oriented psychology, chess, information processing.

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Chess provides a compact and easily controllable task environment and therefore it has over the last few decades called attention of many psychologists interested in problems of skills and thinking (Anderson, 1978; de Groot, 1965, 1966; Charness, 1976, 1981, 1992; de Groot and Gobet, 1996; Elo, 1978; Newell and Simon, 1963, 1972; Saariluoma, 1995). The main goal has mostly not been in understanding chess per se, but in investigating a number of theoretical issues related to human information processing, expertise and thinking.

Over the years, psychologists have worked to analyse individual differences, cognitive skills and thought processes by means of chess. In individual psychological research, the questions of talent, (Baumgarten, 1930; Doll and Mayr, 1987), age and life span have been regularly studied (Baumgarten, 1930; Charness, 1981a, b, c, 1985; Chi, 1978; Elo, 1965, 1978; Lehman, 1953; Weinert, Schneider and Knopf, 1987). In addition, the motivational structures and professional backgrounds of chess players have stimulated interest among individual psychologists (Fine, 1956; de Groot, 1965; Jones, 1987). Questions of skills entered chess psychology with Cleveland's (1907) work on chess players' thinking and its development, but the most important work has been on memory and thinking (Djakov, Petrovsky and Rudik, 1926; de Groot, 1965, 1966). Finally, Newell and Simon (1963, 1972) created the theoretical concepts of information processing which made it possible to integrate the diversified theories under one relatively systematic framework (Chase and Simon, 1973; Shannon, 1950; Turing, 1948, 1950).

The ideas of Newell and Simon (1972, 1976) the took human mind to be a computing machine or a physical symbols system, and this aroused enormous enthusiasm among many other researchers (e.g., Anderson, 1976, 1983, 1993, 1998; Newell, 1990, 1992; Kieras and Bovair, 1997). However, the positive reception was not animous and many cognitive psychologists and scientists strongly opposed the idea that human mentality is essentially computing. The systematic critique of the conceptual power of computational concepts centred on the issues of contents (e.g., Dreyfus, 1972, 1992; Searle 1980).

This computational dispute has always relied on arguments based on chess players' psychology (Dreyfus, 1972, 1992; Newell and Simon, 1972). This is not surprising because the chess tradition as a whole provides a psychological micro world, which can be used to investigate very fundamental issues such as the theoretical concepts one should use in investigating human thinking. The main claim of the opponents of computational psychology have been that computational concepts lose something essential about human mentality, and consequently, the power of computational concepts is too low to express all the essential aspects of human mentality. Be this as it may, the problems are unresolved and we do not have a clear idea about the possibilities and limitations of computational models.

Because arguments in this discussion have been so strongly associated with chess, it is possible to investigate the basis of the computational psychology of thinking, the validity of the argumentation, and the type of language one should have when discussing human thought processes in the context of chess research. The core of all the problems is mental contents. Computational researchers believe that mental contents can eventually be explained in computational terms, but opponents claim that this is impossible (Dreyfus, 1972, 1992; Searle, 1980; Simon, 1996). In this paper, on the ground of chess research, it shall be proposed that computational concepts indeed have their limits, but it will also been argued that it is possible to create content-oriented cognitive language to investigate problems of mental contents in thinking.

Attention in chess

Attention is an important notion in chess because chess players must be able to detect various kinds of possibilities and threats. The logic of chess is clear: Carelessness over one move may destroy hours of good work. This means that understanding chess players' information processing attention is a central topic. As it seems conceptually illogical to think that we could attend to targets which are not present in stimulus information, I review here only experiments in which one can have a direct perceptual contact with a physically present target.

The main systematic outcome of attention experiments has been clear: experts are superior to novices in picking up information from a board position. They clearly perceive faster all kinds of chess-specific perceptual cues. If chess players' are, for example, asked to detect as fast as possible, whether one of the kings is checked or not, masters are clearly superior in speed as well as in accuracy (Saariluoma, 1984, 1985). The same superiority can be also be found when chess players assess if a mate in one possible (Saariluoma, 1984).

The results of perceptual classification experiments, such as counting the number of bishops and knights show that experts notice individual pieces, threats and even mates more rapidly (Saariluoma, 1984, 1985, 1990a). Experts' superiority even survives the randomisation of positions (Saariluoma, 1984, 1985). The only conditions in which experts' superiority is not evident, are met when subjects have to calculate the number of pieces on the board (Saariluoma, 1993).

The experimental evidence provides us with knowledge about the possible attentional mechanisms involved in chess. The basic mechanism must be automatization, though it is not achieved by constant mapping but by decades of varied training (cf. Shiffrin, 1988). However, the core mechanism cannot be faster activation of piece and threat information in the memory, because skill differences disappear in the total piece counting task, in which players need to discriminate the pieces from each other. This means that the discrimination of pieces has an important role to play in chess players' attention.

Undoubtedly, attentional superiority of experts may be an element in explaining some thought errors, because experts do not make errors in discriminating important information as novices do. When investigating real games experts very seldom made errors by leaving pieces en prise, whereas this kind of errors were very common in novices (Saariluoma, 1995). However, attention cannot really offer exhaustive explanations, because there is no information about the selection of relevant targets nor about search in imagined problem spaces.

Mental images

Attention is a stimulus bound process. This means that the information that we attend to must be present in a peceivable stimulus. We cannot attend to atoms, for example. However, the explanatory limitations of attentional concepts can be surpassed by investigating higher cognitive processes. Here, the main problem is the function of mental imagery in chess players' thinking. When our visual attention pick's up information from spatial locations, imagery, if it is involved, should for its part release processing from the immediate stimulus control.

A major problem for chess psychology has been to show that imagery processes are involved in chess players' thinking. Chess players' intuition has favoured this explanation, but experimental evidence is slow in coming (Abrahams, 1951; Blumenfeld, 1948; Krogius, 1976). Of course, this is an issue which is closely related to the classic imagery debate (Anderson, 1978; Kosslyn, 1980; Pylyshyn, 1973). If images are involved in chess players' information processing, then one cannot say that people do not actively use mental images in thinking. However, if no imagery involvement exists, then propositional coding is the essence of human thinking in chess.

In a series of experiments, it has been shown that mental transformation of pieces is an analogical process in which distance plays a role. However, this role is related to the level of skill. When novices have to perceive threats between close and distant pieces, there is a correlation between spatial distance and reaction time, but it is much more difficult to find such correlation with experts (Bachman and Oit, 1992; Church and Church, 1977; Milojkovic, 1982).

A paradigm which has also provided clear evidence for the active imagery involvement is visual suppression in the working memory (for the main features of this paradigm see Baddeley, 1986; Baddeley and Hitch, 1974; Logie, 1995). When working memory experiments have been carried out, a systematic effect has been that articulatory suppression has very little if any effect, but visual suppression and central executive secondary tasks cause substantial impairment in the level of performance (Bradley, Hudson, Baddeley and Robbins, 1996; Saariluoma, 1989, 1992a,1998).

In addition, experiments in blindfold chess also suggest that people actively use images in solving chess problems. In blindfold chess, a player does not see pieces or the board, instead the moves or their opponents are given verbally to them. Often, a chess player turns his chair 180 degrees so that the player's back is towards the board and the opponent says from which square he or she moves the piece and gives its destination square. One psychologically interesting form of this memory-based game is simultaneous blindfold chess in which players play several games at the same time.

Blindfold chess has been investigated by Binet (1893/1966), Cleveland (1907) and Reuben Fine (1965). This early research has made many observations concerning meaningful associations and representations. Modern research has also been interested in the role of imagery in chess players' information processing. Skill differences are very large in this task. Whereas novices can only follow a few moves in a reading of ten simultaneous games, experts are able to continue it practically without error up to at least 35 moves (Ericsson and Stazsewski, 1989; Saariluoma, 1989; Saariluoma and Kalakoski, 1997, 1998).

Thus, in the light of empirical evidence, imagery involvement seems to be a fact. It is not feasible to say that imagery is not involved. This raises a very interesting issue, which was first, discussed in the context of chess by Anderson (1978). Namely, the relation of propositional and imagery information in human thinking. What are the roles of these two information formats in chess thought, when the idea that images are epiphenomenal cannot be empirically supported?

The problem with the notion of image is that it does not bear on contents. Mental transformation experiments may show that transformation depends on analogies with the physical world. However, imagery concepts do not provide us with information about whether a subject should transform on the right or on the left. Notions like right and left, bishop or knight do not thematize in terms of mental images, because they presuppose propositional knowledge. Contents are outside format (Saariluoma, 1997). This means that in chess, people cannot really say that either images or propositional information would be of no use. Rather, the case is that propositional information provides images with their contents. In the thinking, imagery debate it seems that the two sides are speaking about different things. While image theoreticians discuss format, propositional theoreticians pay attention to the contents. Both are equally necessary and the whole debate is caused by differences in presuppositions and their limits.

Chess players' memory

Memory has been very important in chess psychology for numerous reasons. Memory is the basis of skills and learning, but memory is also the very platform for thinking. Consequently, memory concepts can be widely used in explaining thought-related phenomena and this is a reason why memory has had such an important position in research into the chess mind.

In memory tasks, expert chess players normally perform much better than novices. They are superior in recognizing chess positions as well as random positions (Goldin, 1979; Saariluoma, 1984). Recent research has also shown that recognition is selective. When chess players are presented with a position they have seen before and are asked to say which they have seen before, they can much more easily recognise the new positions where there are transformations in important areas for game situation than in the positions where transformation is in less important areas (Saariluoma and Kalakoski, 1996, 1998). This means that recognition is based on 'meaningfully' selective encoding. Obviously, experts' superiority in recognizing random positions is also founded on the same principles.

Recognition is important here, because recognition has a role to play in chess players' thinking. Recognition activates hypothetical solutions in the minds of chess players, and experts differ from novices with respect to the ability to recognize better base moves (Calderwood, Klein and Randall, 1988; Chase and Simon, 1973a,b; de Groot, 1965, 1966; Gobet, 1997, Klein, 1989; Klein and Peio, 1989; Saariluoma, 1984, 1990, 1995).

Another important property of chess memory has been found in recall experiments. This is the basic paradigm for studying chess players' working memory, and the best-known working memory phenomena is the expert superiority effect in recall. It was originally discovered by Djakov, Petrovski and Rudik (1926), but it became famous with de Groot's (1965, 1966) work. In these experiments, it was shown that chess experts recall chess positions better than novices. Later in an unpublished investigation by Lemmens and

Joongman it was additionally demonstrated that skill differences practically disappear when positions are randomised (Chase and Simon, 1973; Vicente and de Groot, 1990). This means that experts' superiority is based on familiar piece configurations, which can be used in chunking the presented positions (Chase and Simon, 1973; Gobet and Simon, 1996, 1998; Miller, 1956).

Subsequent analyses have shown several additional properties of chess memory. Charness (1976) found that secondary tasks do not impair recall (Frey and Adesman, 1976; Lande and Robertson, 1979). Only during the encoding stage, might secondary tasks infer chess memory (Robbins, Anderson, Barker, Bradley, Fearnyhough, Henson, Hudson and Baddeley, 1996; Saariluoma, 1989). It has also been found that the locations of the pieces rather than the form of chunks are important in swift storage of the positions (Gobet and Simon, 1996; Saariluoma, 1984, 1994, Saariluoma and Kalakoski, 1997, 1998). Moreover, the number of chess positions is very large, which can be shown by blindfold chess or position memory experiments (Gobet and Simon, 1996; Saariluoma, 1989). Finally, it has also been shown that when chess players have sufficient time they can also remember randomised positions better (Lories, 1987; Saariluoma, 1989).

The results imply firstly that there is no difference per se between the memories of masters and novices; the difference with masters is the number and size of the patterns learned during a ten-year-long period of training (Chase and Simon, 1973; Ericsson and Lehman, 1996; Hayes, 1981). They also imply that chess players do not store chess positions into the short-term working memory but into the long-term memory or rather into the long-term working memory (Ericsson and Kintsch, 1995). Finally, the encoding is based on a perfect match between chunks in the long-term memory representation and board position.

Apperception and content integration

The next questions in investigating chess players' thinking are what are the content-elements in representations and how they are selected and integrated. Attention and memory psychologies do not provide much information to answer this kind of strongly content-oriented problems. The basic notions of capacity and format are not sufficiently powerful in expression to allow one to discuss problems of contents integration in representations (Saariluoma, 1997). This also means that they provide only partial answers to the problems of selectivity in thinking (Saariluoma, 1995). To understand the problems of content integration, one must find new theoretical concepts.

To begin, this work we need revisiting the standard intuitions which have for a long time dominated chess psychology (de Groot, 1965). Expert chess players ‘see’ chess positions differently from novices. Whereas novices only see a set of pieces experts concentrate on intellectually and emotionally satisfactory ideas. Naturally, it is cognitively very interesting to discover how one can explain what experts and novices see in chess positions, because it gives us information about the nature of information selection and integration into human mental representations.

Chess players’ "seeing" cannot be object perception or attending. Their "seeing" is not modality specific but they can imagine visually or auditorily presented chess positions as well as they can normal positions (Saariluoma, 1989, Saariluoma and Kalakoski, 1998). The contents of "seeing" are thus quite independent of the perceived stimulus content and the arguments against taking "seeing" as object perception are clear and self-evident.

Consequently, the ambiguous term "see" is best to be replaced by the classic term apperception (Kant, 1781; Leibniz, 1704; Stout, 1896; Wundt, 1880). Apperception refers to the conceptual perception or construction of representational contents (Saariluoma, 1990, 1992, 1995; Saariluoma and Hohlfeld, 1994; Saariluoma and Kalakoski, 1998). It assimilates the perceptual stimulus and conceptual memory information into a semantically self-consistent representation that is characteristic of the human mind.

Apperception is thus a content-integrating process. Apperception determines which semantic elements of conceptual memory and of the stimulus information can be and should be integrated into the prevailing representation. The contents of apperceived representations need not be directly related to the stimulus environment. To introduce empirical contents into the notion of apperception in chess one must investigate, how chess players select the relevant contents in a stimulus among all the possible alternative paths in a problem space (Saariluoma, 1990, 1992, 1995, 1998; Saariluoma and Holhfeld, 1994; Saariluoma and Kalakoski, 1996, 1998).

Chess, like most games, has a tree structure, in which all the possible move series in a position form a basic problem space (Newell and Simon, 1972). However, this tree is normally far too wide to be searched by the human mind and therefore apperception abstracts a few, small problem subspaces around which chess players’ problem solving is organised (Saariluoma, 1990, 1992, 1995). These problem subspaces have been called mental spaces (Saariluoma, 1995). To understand apperception thus means to have a clear idea about the content-specific selective and integrative mechanisms involved the mental space abstraction. It means an answer to the question why are precisely these moves relevant in this mental space.

The content structure of mental spaces

To open the content-structure of mental spaces it is good to begin with the defender who attempts to parry the attacker's actions. This action necessarily runs through a set of squares and this set can be called the path. Obviously only those moves make sense which can bring a piece into the path and thus prevent the intentions of the attacker. The role of these two mechanisms in organising the defender's moves is explicit in following example in Figure 1.

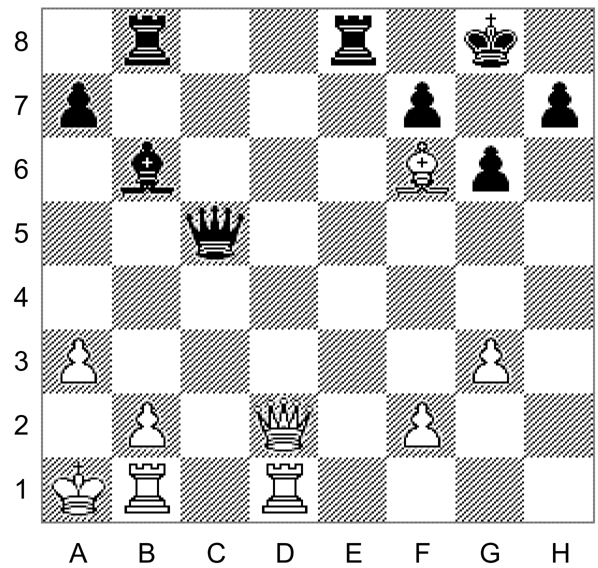

Figure 1. An episode by subject NN in the position and the move types.

Qh6 (transfer to threat g7), Qf8 (exchange in g7),
Qxh7 (check and transfer to threat Qh8 mate), Kxh7 (exchange)
Rh1 (threat), Qh6 (blockade)
Rxh6 (exchange), Kg8 (escape)
Rh8 checkmate
(Other possible moves would also lead to a checkmate)

The defender's moves in the example can thus be divided into four main types: exchange, blockade, escape and counter-action. Exchange means a move by which the defender can take one of the attacker's active pieces, blockade refers to a move that brings a piece between the attacker's initial and destination square, escape means that the target escapes. Finally, counter-action refers to any action which has more important goal that the one of the attacker, so that the attacker must abandon his current plan.

These move types define content-specific constraints for the generation of all defenders' moves. Only moves of these types may make sense in trying to parry the attack, and all the subjects in all protocols generate moves drawn from these four types for their defence. It means that the functions of the four types of moves bringing pieces into the path explain the senseful structure of mental spaces in protocols. Moreover, the moves of the four types also explain the size of mental spaces. In practice, only a few moves in a position may fulfil one of these criteria, and this is why the mental spaces are so small and compact compared to computer-generated search spaces (Saariluoma, 1990, 1995, Saariluoma and Hohlfeld, 1994).

Interestingly, it is possible to show that the attacker's moves in protocols also have a very similar content-specific logic as defender's moves. They also fill their functional criteria. The attacker always attacks something, either a specific square or a small set of specific squares. These squares and the pieces in these squares can be called target squares and targets respectively. The square(s) in which the target is located can be called a target square. Concerning the functional structure of a mental space, the target-square is the most vital square on the board. The attacker must get some piece into that square in order to reach the goal, and therefore the target's square spans the attacker's path and the selection of moves in a mental space.

Let us assume that this target is the king. In a real game position, the king can normally be threatened only by a few pieces, if it can be threatened at all. These pieces cannot threaten the king from any square, but they can only attack the king from a few free squares. Let us term these squares "key squares". To threaten the king, a piece must be able to move into a key square. In practice, the attacker's pieces do not have unlimited opportunities to do so. The key squares must be free for the attacker's pieces so that it is not exchanged or blockaded before it can reach the destination, and typically, the number of such squares is small. The target and key squares help us now to derive a classification scheme for the attacker's relevant moves.

A move whose current end-square is not the final goal for the moving piece in the move network can be called a transfer move. A move to a key square which has the aim of occupying another square can be called a threat. Further, a transfer move which is intended as a threat, e.g. to take a piece, can be called a transfer for threat. To occupy a key square and make a threat, one must be able to transfer piece(s) into key square(s). The piece cannot, however, be transferred via squares which an opponent is able to defend. An opponent must not be able to exchange the key piece or blockade it, nor can the opponent exchange or blockade some of the supporting pieces. This means that senseful transfer moves do not have much freedom on a board, because the key piece(s) must be transferred to the key squares along a safe path. Let us take another example, in Figure 2.

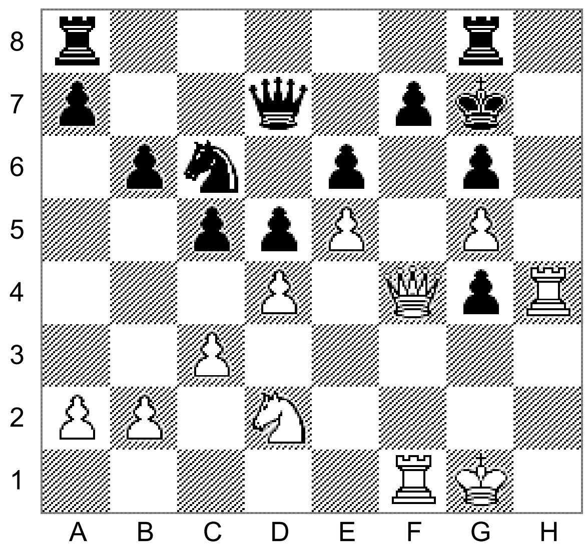

Figure 2. Position, protocol, key squares and path.

Protocol: Well, this is so that.. Yes...Rh7+ (threat) Kf8 (escape) is impossible because white has three pieces, which can take (f7 exchange.), so the only move is Kxh7 (threat; Kxh7 omitted in original protocol). Qh2 (threat) and black must play Kg7 (escape), Qh6 mate.

The key squares for white h7, f7, h2, h6. The crucial key square is h6. The rest of the squares such as a2 are of secondary value here.

Path squares: h2,h3,h4,h5,h6,g7,f7,f4,g3.

If it is black's move, knight d8 (exchange) could support f7 and the whole combination would collapse.

The location of the target thus spans the attacker's path. It determines both the possible squares for transfer and the key squares. The key square must be free or it must be freed by some preliminary operations. This means that the defender must be unable either to exchange an attacker's key piece, or to blockade the attack, and the path to the key and target squares must be free. The number of such squares and corresponding operations, i.e. moves reaching the key squares, is always very small. The pawn chain, the fields of threat of the pieces, and the location of the target greatly constrain the attacker's senseful moves. He cannot reach the target squares as he wishes, but must instead find or create a system of weaknesses in the opponent's camp.

The same simple principles are also valid when the target is some other piece than the king. The target may equally well be the opponent's piece, pawn, or just an empty square. Even in restriction type cases in which one tries to control the whole system of the opponent's squares, the control of the restricting piece must be located in a key square, and the occupation of this square spans the move network in a mental space. From here onwards the presented content-specific criteria will be called functional constraints, because they select the relevant moves to mental spaces on the functional grounds.

A set of found functional constraints directing move generation is presented in Table 1. The explanatory efficiency of these constraints can even be tested by computer simulation, which produces practically identical mental spaces as the ones generated by human beings (Saariluoma, 1995).

Table 1. Functional constraints for mental space spanning (Saariluoma, 1995).

Transfer (tr)	a piece is moved to get it to the path by some subsequent move
Exchange(ex)	an active piece is taken
Blockade (blo)	an active piece is prevented from achieving a key square by placing a piece between its original and destination square
Escape (es)	the target piece is moved to another square
Pin (p)	an active piece is prevented from moving, by placing a piece so that its movement is illegal (absolute pin) or would be too costly (relative pin).
Unblockade (ubl)	a piece is moved to allow some other piece to make an active move
Clearance (cl)	an enemy piece supporting some key square is exchanged or forced to lose the control over a key square
Decoy (dc)	A target piece is forced to move into an undesirable square
Threat (thr)	a piece is moved to achieve a goal in the next move
Counter-action (ca)	any move which is made to achieve some independent goal

The surprising thing in these constraints is their explanatory power. They can explain the calculation process in any protocol we have met so far, and they can explain precisely the size of human problem subspaces in any chess protocol. Since the number of constraints found so far is small, it is evident that they tell something essential about how apperception works in constructing meaningful representations in chess. It may be possible to find some additional rules, but it does not change the principles of content integration in chess players' apperception.

Thought models

In order to use the apperception research in chess as a prototype for content-oriented cognitive psychology we must introduce one further theoretical concept. This is called a thought model. It has been argued that in a chess position a chess player recognises a familiar piece configuration and an associated set of moves (Saariluoma, 1984, 1990, 1995). This kind of a piece configuration or pattern and several associated moves can be called a thought model. Recently, Gobet (1997) has also made similar theoretical conclusions with somewhat more computer-oriented terminology.

On the grounds of protocols one can claim that chess players' apperception is organised around thought-models (Saariluoma, 1984, 1990, 1995). Chess players recognise familiar models in a position and integrate the relevant moves following functional constraints. Thus, functional constraints explain the selection of moves in a particular problem position. Only, in very rare cases and with absolute novices is the process independent of thought patterns and but these cases are relatively rare (Saariluoma, 1990).

A thought model consists of a characteristic piece configuration and a set of associated moves. Chess players' often call them themes of combination and often have specialised names for them. Smothered mate, Damiano's mate Epaulette's mate etc. are typical names for thought models in chess (Saariluoma, 1984, 1990, 1995). Attempts have been attempted made to simulate them by means of templates (Gobet, 1997).

Thought models control human information processing in several ways. They are learned and form an essential part of chess experts' knowledge storage. The better the player the more he or she has such models. They are activated by recognition (Gobet, 1997; Saariluoma, 1984, 1990), but apperception can combine and embed these models into more complex structures (Saariluoma, 1984). Nevertheless, their main function is that they define the paths organising information integration. Models are not completely similar from one position to other, but it is primarily necessary to check whether the problem subspace activated by a thought model can be realised. However, the moves which may refute the problem space are selected by given functional rules (see Table 1).

Thought models can be seen as a specific type of mental models (Johnson-Laird, 1983). They are content and task-specific models, which are used by apperception to organise human thinking. As a whole, the presented system of functional constraints and thought models explains why human problem subspaces have the kind of structure they do. These concepts also explain the compactness of human search spaces.

Explaining contents by contents

The final topic of this discussion will be more general by nature. Instead of going into further details of chess players' information selection by means of presented principles, attention is called to the metapsychological consequences of empirical findings in chess. In fact, the way problem spaces and apperception are analysed has some characteristic features, which can be used to discuss the bases of content-oriented thought research, namely research, which works to explain content-based selectivity and information integration in human thinking.

The presented explanatory model for information integration in chess players' thinking is based on the idea that mental contents in psychology are explained by other contents. It is the representational contents which justify the selected content elements. There are constraints which explain why the moves make sense or why they are senseful or 'meaningful'. The functional constraints, nevertheless, are not merely causal, they are reasons or to be more accurate functional reasons by nature. In a chess move making sense in a mental space means for a chess move that there is a reason or a set of reasons which justifies that move. It is the contents of the explicated functional constraints and thought models, which explain the generated moves, and thus investigating contents of representations presupposes explicating the underlying thought models and the systems of functional constraints, which explain the selection of the moves into representations.

One may now wonder whether this kind of highly chess bound model can be used to form the basis of content-oriented psychology of thinking. Contents, after all, can be so different. As Hunt (1991) put it, chess cannot be relevant for any theory of contents, because contents are so domain specific. However, we can use chess to build conceptual tools for investigating contents and this is what has been done in this paper (Saariluoma, 1995). Indeed, when we take a closer look it is very easy to see that the two basic theoretical concepts, thought models and functional constraints are very commonly met in human thinking.

Thought models are by nature complex sets of associated elementary actions, which people have learned. Large parts of our knowledge used in thinking is organised around such wholes. An architect planning a house, for example, knows that he must have walls, windows, parking lots etc. He or she has a scheme of the required elements. However, to adapt his original model to the reality, he must follow principles that make sense and these rules are functional in nature (Saariluoma and Maarttola, in prep). He or she must resolve, for example, how light and the noise of traffic must be taken into account as well as the demands for elasticity of structures (cf. e.g., Russell, 1981 e.g., p. 263).

When thinking of the history and position of the notion of reason in investigation into human thinking since the classical times, it is clear that this concept is essential in research into human thinking. Reasons explain why medical doctors use lancets to open tissues and why they use narcotics. Their actions have goals, and reasons explain why the subparts make sense in the structure of representations. Consequently, cognitive psychology should have a much deeper understanding of how to investigate these knowledge structures and it is one goal for content-oriented cognitive psychology to reveal these systems of mental contents to improve our understanding of mental representations.

The levels of explaining mental contents

To close our argument about explaining by contents, it is necessary to find a place for content-oriented thought research. Of course, it is important to understand the contents of thoughts, because thoughts always have some contents. Explaining is undoubtedly the key, because various issues of mental contents can be explained by very different types of approaches, which fortunately seem to be effective with somewhat different phenomena. Indeed, the simple expression "explaining by" is one of the conceptual tools in comparing the traditions.

A natural way of explaining contents could be provided by neuroscience. It is clear that neurochemistry or physiology have a very important role among psychological explanations. However, they seem to be relatively ineffectual when problems like the integration of mental spaces are discussed. Indeed, there are fundamental reasons which greatly limit the use of neural explanations when mental contents are analysed (Saariluoma, 1999). Brains are a relatively open modifiable system, and this is why only their interaction with various environments can provide them with their information contents. We have a brain-based ability to learn languages, but this does not mean that the languages we speak can be explained in terms of this ability. Brains simply cannot predict their environment, and hence there is no way one could exhaustively explain mental contents of thought in biological concepts.

Similarly inadequate are common capacity and format-based cognitive explanations. Even though it is true that our working memory has the capacity of only a few units, this capacity can be filled with an infinite number of mental contents. Consequently, capacity cannot explain contents, and of course, the same is true with format such as mental images (Saariluoma, 1997). Imagery ability does not either explain mental contents.

The main field of investigating mental contents has been simulation. However, even simulative models entail problems in giving a full account of contents. They are formal structures, which abstract contents and therefore a number of difficult problems arise. The most problematic issue is the relevance of the selected contents elements. As is well known formal systems cannot decide which contents elements belong to each other. The programmer must always decide the relevance of the particular contents of elements (Saariluoma, 1997). Consequently, models have not been able to solve such relevance-related problems as frame problem, match, conflict resolution and exponential growth.

Even explaining by semantics is conceptually too modest an approach for the type of content-specific explaining used concerning the sensefulness and coherence of mental spaces. This may sound odd and controversial, but contents and semantics are two different things. By knowing all the semantic rules of a language one cannot generate a single representational content. Semantic explaining typical of semantic networks, for example, cannot give a precise account of mental contents. The semantics of any language is not sufficiently powerful to explain the contents of thoughts. In fact, mental contents can never be described exhaustively in terms of language.

This means that the main explanatory model used in chess is explaining by contents. The contents of the rules and thought models are used to explain some psychological phenomenon. In this case a set of implicit content rules are used to explain the structure of representation. Of course, this means that in any chess representation one can use these rules to predict the structure of the search process. Naturally, this is a special case, but it may give information about the nature of psychological explanations.

The key point in the discussion of explaining is to point out that our theoretical concepts have limited powers of expression (Saariluoma, 1997). Of course, the problems in the scope of scientific concepts have been known since the time it was shown that the sides and diameter of a square cannot be expressed by means of natural numbers. Similarly, there are reasons why neural language cannot provide us with an exhaustive explanation of mental contents. On the other hand, there are problems which are not resolvable without a good understanding of contents. Therefore, it is important to work with the small pieces of understanding that we have about explaining by contents.

CONCLUSIONS

Human chess players' apperception works with previously learned thought models and follows, when generating mental spaces, very simple functional constraints defining relevant moves. The recognised thought models set the goals for search, and functional constraints explain the generated moves. This mechanism tells why subjects do not generate more than ten to a hundred moves for positions in which computers would generate millions of alternatives, but it also explains why some moves are selected and why some other moves are neglected.

The number of moves fulfilling the functional constraints is always very small compared to all possible moves. The whole economy of chess players' apperception is based on these very simple principles. They define what is essential and what is not in a network of moves. Neglecting one move, which does not fulfil the content-specific constraints is not significant, but neglecting a relevant move may jeopardize the problem solving process. Moves are senseful only if they are designed to parry or to aid some operation and hence fulfil the functional constraints for relevant moves. Consequently, the presented principles can be used to explain the nature of search moves.

Interestingly, the functional constraints presented here are not widely known among chess players. Types of defence moves and by and large also the attacker's moves cannot be found in chess books. They are too primitive to have a prominent place in chess theory. Nor can they be found in protocols. Yet chess players use them all the time when calculating variations. This means that human apperception often uses unconscious or implicit primitive principles in separating the essential from the inessential. The use of unconscious content-specific principles is probably the most interesting aspect of the constraints on moves, because it raises the question to what degree human apperception is based on similarly unconscious task-specific principles.

The concepts of content-oriented cognitive psychology have also important theoretical consequences. An almost standard argument against cognitive psychology is that it is internal. It does not take into account cultural connections. The explanation for the ahistorical character of modern cognitive psychology is the very clear biological origin of capacity-based explanations. Cognitive structures determining the limits of capacity in attention and memory are independent of culture and history, because they are biological structures. However, mental contents are different, because they depend on culture (Saariluoma, 1995). Therefore, content-oriented thinking provides theoretical concepts for investigating mental and internal processes in cultural and historical contents.

In sum: Chess players' apperception uses content-specific and unconscious principles to provide mental spaces with senseful structure. Only information which fulfils the constraints is accepted. Thus, chess players' apperception is an example of content-specific information selection in thinking. The explanation of information selection is based on the senseful structure of the representations, and not on capacity or some other principles. This means that content-specific psychology is basically the explication of the partly unconscious apperceptive mechanisms, which create the logical structure and contents of human mental representations.

RESUMEN

En este artículo presentamos un conjunto de principios que definen la psicología cognitiva orientada hacia el contenido. Estos principios se presentan en el contexto de la investigación realizada sobre la forma de procesamiento de los jugadores de ajedrez. En el artículo se defiende que los conceptos teóricos de atención, imagen mental y memoria están basados en los conceptos de capacidad y formato, y que éstos no son lo suficientemente poderosos para expresar los fenómenos asociados a los contenidos mentales. Por el contrario, es necesario desarrollar un lenguaje teórico que esté genuinamente orientado hacia el contenido para poder discutir, por ejemplo, los problemas de contenido y su integración en el pensamiento. El principal problema es cómo explicar los contenidos de las representaciones ¿Por qué tienen las representaciones los contenidos que tienen?.Aquí focalizaremos la discusión en la manera en que se puede explicar la selección de elementos contenidos en la representación. Para formular los conceptos básicos de la investigación sobre el pensamiento orientado hacia el contenido se han de discutir primero varios puntos. Primero, se mostrará que la investigación tradicional sobre atención y memoria está orientada hacia la capacidad y, por tanto, no es capaz de expresar los contenidos mentales. En segundo lugar, se defiende que hay fenómenos referidos al contenido que se tienen que explicar mediante otros fenómenos relacionados con el contenido. En tercer lugar, se muestra que en ajedrez, las personas integran la información en representaciones mentales a través de reglas funcionales o razones que especifican por qué algunos contenidos deben incluirse en la representación. Finalmente se muestra que las personas integran la información alrededor de "modelos de pensamiento" cuyos contenidos, junto a las reglas funcionales o razones, explican y clarifican la estructura de contenido de la representación mental. Se defiende también que el análisis del contenido es meta-científicamente más similar a la lingüística, con sus métodos básicos de

explicación y análisis de contenidos, que a las ciencias naturales, que es el modelo que mas comúnmente subyace a la psicología experimental actual.

Palabras claves: Psicología orientada al contenido, ajedrez, procesamiento de información.

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