HEMISPHERIC SPECIALIZATION FOR SKILLED PERCEPTUAL ORGANIZATION BY CHESSMASTERS

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Abstract—The right cerebral hemisphere may be relatively specialized for parsing simple visual stimuli according to default rules, such as the Gestalt laws of perceptual organization, whereas the left cerebral hemisphere may be relatively specialized for overriding such default rules. We extend this model to 'semantically rich domains' by performing a divided-visual-field experiment on 16 chessmasters. Such subjects are able to recall and recognize complex chess positions by *chunking* the basic elements of the stimuli—the chess pieces—into meaningful groupings according to certain rules that are specific to the semantic structure of the chess domain. We show that the right hemisphere is superior to the left at parsing according to the default rules of chess chunking, but that the left hemisphere is superior to the right at grouping pieces together in violation of those rules. These results suggest that the right hemisphere is better able to acquire and apply new sets of default parsing rules for specific contexts. We conclude, consistent with other neuropsychological evidence, that the right hemisphere is critical for chess skill.

INTRODUCTION

COMPUTATIONAL ANALYSES of the problems that must be solved by any artificial or biological perceptual machine [30] suggest that the human visual system requires both a rule-following 'default' and a rule-violating 'override' mode of parsing to efficiently process the varied stimuli we encounter in everyday life. The visual system will employ as its default the parsing strategy most likely to yield meaningful groupings of stimulus elements, but it can also override this strategy (perhaps with some sort of attentional control or serial search process) when necessary to solve a problem at hand [39]. For example, boundary contours of objects are often indicated by edges, or sets of collinear points, so the visual system should usually group such points together when organizing an image. However, when two distinct objects of similar color and texture are juxtaposed in a scene, the visual system must overcome its tendency to incorrectly combine the objects into a single whole.

Recent divided-visual-field studies [38, 39] have shown that the two cerebral hemispheres differ in their abilities for perceptual organization. Specifically, the right hemisphere has been shown to perform better than the left at parsing according to Gestalt principles [40], such as the laws of collinearity and similarity involved in the above examples. The left hemisphere outperforms the right, however, when a parse that violates one or more of these principles is necessary. The contrast between the abilities of the two hemispheres to perform the two

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types of parsing tasks is further evidence that separate processes exist in the brain for parsing in the two different modes [21]. However, the studies that have shown these lateral differences have all used fairly common or semantically neutral stimuli such as capital letters [38] or meaningless combinations of line segments [39]. In a 'semantically rich domain' [35], specific relationships among elements are essential for solving problems within the domain. For optimal performance, the visual system must encode stimuli in ways that make explicit these useful relationships rather than the simple perceptual regularities. For example, to play blitz chess (in which each player has 5 min to complete the entire game), a chessmaster must instantly recognize a tremendous variety of meaningful patterns in each board position in order to quickly narrow his search to the most plausible good moves; he clearly cannot make a leisurely examination of the board, checking each legal move, one-by-one, for all of his pieces.

Perceptual organization to facilitate pattern recognition and recall in knowledge-intensive domains has been regarded as a paradigmatic manifestation of the *chunking* memory phenomenon [6, 16, 31, 36] since the pioneering work of CHASE and SIMON [7, 8]. Skill at forming chunks enables the chessmaster to hold in memory a game position containing 20 or more pieces by breaking it into smaller parts, just as most people can retain a seven-digit telephone number by rehearsing it as a sequence of one three- and two two-digit subsequences. When it is virtually impossible to chunk the stimulus elements, however, as in a chessboard of randomly distributed pieces containing no familiar patterns, there are no differences between subjects of different skill levels in the domain [7, 8].

DE GROOT [12] showed that the chessplaying abilities of three subjects (a grandmaster, an expert, and a beginner) correlated well with recall memory for briefly exposed 'realistic' chess positions from actual games, and that the top-level player was able to reconstruct over 75% of such a position after viewing it for only 5 sec. CHASE and SIMON [7] replicated this result and extended the methodology by analyzing the recall protocols of a chessmaster to deduce the memory structures used in the task. As this subject placed pieces on the board one-by-one to reproduce a realistic position, he made relatively long pauses between groups of one to eight pieces. This finding suggests that memory of a position is organized into variable-size 'chunks', or patterns stored in long-term memory, and that the content and location of each chunk can be associated and retained within a single 'slot' in short-term memory.

Analysis of which piece combinations formed chunks showed that the 'glue' holding chunks together is a set of relationships based on the elements of the game. The strongest were defense (pieces of the same color defending one another) and the combinations of attack/proximity, defense/proximity, proximity/color/type (king, queen, rook, etc.), and defense/proximity/type. Groups of pieces participating in a combined attack against the enemy king also tended to be chunked together. By contrast, simple matches of color and piece type were usually insufficient to group pieces into the same chunk [7]. All of these results were subsequently replicated with symbolic and pictorial diagrams of chessboards [8, 17], providing further evidence that the chunk memory structures are based more on chess-specific representations than on purely bottom-up perceptual factors (such as conformity with the Gestalt principles).

Although there are other chess tasks, such as evaluating positions and choosing moves, on which performance varies for chessplayers of different skill levels [23–25], the reliable correlation between chunking ability and playing ability shows that chunking is an important component of chess cognition. Since the phenomenon has also been demonstrated in other domains, such as electronic circuit diagram analysis [14] and the games of bridge

[4, 5] and 'Go' [33], understanding chunking by chessmasters will give us insight into the perceptual processes required in knowledge-intensive problem-solving.

The default/override framework of VAN KLEECK and KOSSLYN [39] can be extended in two ways to predict hemispheric differences in chunking ability. At first glance, it might seem that parsing according to the chess chunking rules described above should usually require override of the visual system's default parsing rules, since the chunking rules generate groupings that would violate many of the Gestalt principles. The chess position diagrammed in Fig. 1 is an example of this conflict. The highlighted pieces in set A would be chunked
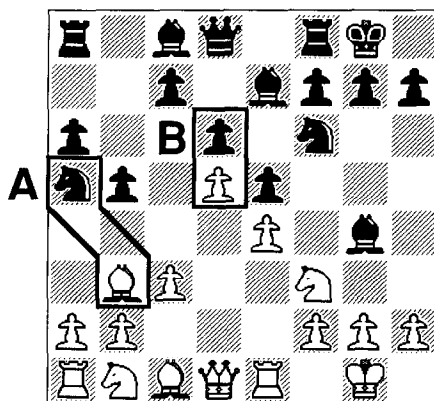

Fig. 1. Rules of chunking in chess positions in opposition to Gestalt principles of perceptual organization. Pieces in group A are likely to be remembered together because of the attack relationship, but pieces in group B are unlikely to be recalled together despite the similarity and collinearity relationships.

together by most chessmasters despite the fact that such a grouping is in tension with the Gestalt principles of proximity, similarity, and collinearity; by contrast, the pieces in set B would probably *not* be chunked together even though they are proximal, similar in shape, and collinear, each to greater degrees than those in set A. If override is therefore necessary to impose the domain-specific organization on the stimulus—the 'pure override' hypothesis— and the left hemisphere is superior at overriding default schemes of perceptual organization, then chess positions should be chunked and remembered better by the left hemisphere.

Alternatively, the rules of perceptual organization for a particular domain could supplant the pre-existing domain-independent rules and 'become' the visual system's default rules for use within the context of that domain. By this view, one component of skill acquisition would be the learning of new parsing rules that enable more efficient and relevant encoding of stimuli peculiar to the new domain. BIEDERMAN [2] described an experiment in which subjects apparently did this as they were trained to determine the sex of newborn chicks by searching for and closely examining the shape of a particular anatomical structure. In the case of chess, as a player's skill increases with practice, his visual system will adapt to 'see' a chess position as a collection of meaningful groupings of pieces, using as its defaults the chunking rules. Accordingly, by this view—the 'acquired defaults' hypothesis—chess positions should be chunked and remembered better by the right hemisphere, because of its superiority at applying default schemes of perceptual organization.

Provisional evidence of three types, all supporting the acquired defaults account, comes from the neuropsychological studies of chess skill described by CRANBERG and ALBERT [11].

First, a survey of tournament chessplayers that included both masters and amateurs showed that 18.6% were not right-handed (i.e. they were either left-handed, converted, or ambidextrous), a significantly greater proportion than the 10.0–13.5% in the normal population [11]. Because left-handers usually have larger right hemispheres than do right-handers, left-handers may be relatively better at acquiring chunking rules and making them the defaults. Second, EEG testing of a chessmaster playing blindfolded (without sight of the board) usually showed normal left-hemisphere activity but abnormally high right-hemisphere activity [11]. Third, analyses of 10 cases of chessplayers who suffered brain damage showed that ability remained intact in three strong amateurs who became aphasic following left-hemisphere lesions [19, 34, 37]. Additionally, one subject with 'left-hemisphere dysfunction' due to hypoglycemia shortly after birth, but with 'relatively preserved right-hemisphere function', was able to learn to play chess at a level near that of the average tournament player [11].

Together, these observations suggest that the right hemisphere is somehow critical for the development and manifestation of chess skill. This is clearly consistent with the acquired defaults hypothesis, that the right hemisphere's superiority at acquiring and applying sets of default parsing rules enables it to better organize chess positions for memory and other types of processing necessary to play the game.

To test the alternative hypotheses, we performed a divided-visual-field experiment on a group of 16 chessmasters. The use of the divided-visual-field paradigm was possible because reliable skill differences in chess memory have been found with stimulus presentations as brief as 150 msec [15], a duration well below the upper limit of 200 msec recommended for divided-visual-field studies [1]. The experiment focused on the question of parsing by testing ability to determine whether the piece configurations in briefly exposed 4 × 4 fragments of chess positions (taken from actual master-level games) were contained within previously studied complete 8 × 8 positions.

We adapted the design used by VAN KLEECK and KOSSLYN [39] with an embedded-figures task, which required subjects to determine whether a small line drawing was embedded within a larger figure. They reasoned that if the right hemisphere is superior at applying default parsing rules, then it should perform better than the left hemisphere when the constituent is a 'good part' parsed from the whole in accordance with the Gestalt laws of perceptual organization, but that for 'bad parts' that violate those rules, the left hemisphere should perform better than the right. We applied this idea to the chess domain, in which the default rules are those that group sets of pieces into chunks, good parts correspond to fragments of chess positions that contain only pieces from a single chunk, and bad parts correspond to fragments containing pieces drawn from more than one chunk. The acquired defaults theory predicts, therefore, a right-hemisphere advantage for single-chunk fragments and a left-hemisphere advantage for multiple-chunk fragments. In contrast, the pure override hypothesis would predict at least a left-hemisphere advantage for single-chunk fragments. (Presumably, multiple-chunk fragments would be processed in accordance with the Gestalt laws, and could result in either a left- or right-hemisphere advantage depending on the specific stimuli used.)

METHOD

Subjects

Sixteen male chessplayers (mean age 24.36, range 18–35) volunteered to participate as paid subjects. All were right-handed as measured by the Edinburgh Handedness Inventory [32] (mean laterality quotient 81.06, range

26.32–100.00) and had normal or corrected-to-normal vision. Although some were familiar with the general idea of chunking from reports in the chess literature, and 14 had participated in a previous divided-visual-field experiment with chess stimuli (not reported here), none were aware of the specific purposes or predictions of this experiment.

Fourteen subjects were 'official' chessmasters, having been awarded the Master title by the United States Chess Federation (USCF), and two were judged by an experimenter familiar with their skill to be at the Master level. The USCF ratings of all 16 subjects ranged from 2149 to 2467, with a mean of 2302. (Although a player's rating can decrease, once it reaches 2200 the player receives the Master title, and once it reaches 2400 he receives the Senior Master title.) Three subjects had also received the international title of FIDE Master.

Stimuli and apparatus

Four subjects, three titled chessmasters and one player judged by an experimenter familiar with his skill to be of equivalent strength, participated in a pilot study to help select the test stimuli. (These subjects did not participate later in the main experiment.) This task consisted of 48 trials presented in a single pseudorandom order. Stimuli were photocopies of 48 pictorial diagrams of chess positions from international tournament games played in 1987 and 1988. Twenty-four of the positions were classified as endgames (16 or fewer pieces) and 24 were classified as middlegames (17 or more pieces). In each trial, subjects studied a diagram for 30 sec and then had 15 sec to reconstruct the position from memory with a standard chess set and board. During the reconstruction, the experimenters recorded the order in which pieces were placed on the board and the groups which were placed together (suggesting chunk boundaries). Videotapes of each session were reviewed to verify this data.

The 16 endgames and 16 middlegames on which the pilot subjects best performed this recall task were used in the main experiment. Study diagrams (8 × 8) for each of the 32 positions were drawn with a special type font. Each position was depicted only from the white player's point of view, as is customary in chess publications.

From each position two sets of pieces were chosen such that one set included pieces drawn from a single chunk and the other set included pieces drawn from two separate chunks. Pieces were assigned to the same chunk if a majority (or in a few difficult cases, a plurality) of the pilot subjects grouped them together when reconstructing the position. The sets chosen for a position had the same number of pieces, either two or three. Sixty-four 'fragments' were created by arranging the pieces from each set on 4 × 4 portions of chessboards. The pieces were placed on squares of the same colors and in the same relative locations as they appeared in the 8 × 8 position from which they were taken. Note that a fragment was *not* a complete 4 × 4 excerpt of the position from which its pieces were taken. Figure 2 shows an example of a study position and the fragments associated with it, drawn in a font similar but not identical to that used for the stimuli.
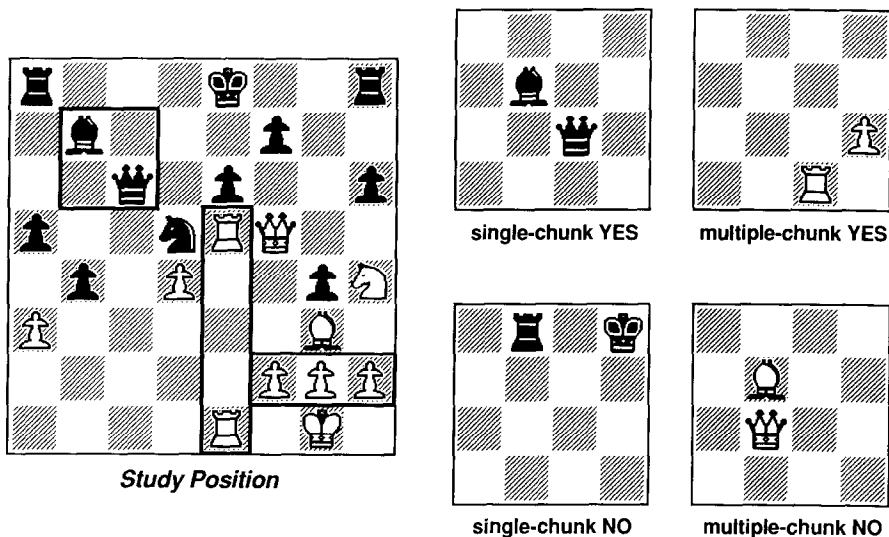

Study Position

single-chunk YES   multiple-chunk YES

single-chunk NO   multiple-chunk NO

Fig. 2. Examples of stimuli. The standard 8 × 8 chess position at left is an example of those studied at the beginning of a trial; the heavy lines (which were *not* present on the actual stimuli) show the particular chunks used to create fragment stimuli. The 4 × 4 fragments at the upper right are the single-chunk or 'good' (left) and multiple-chunk or 'bad' (right) parts associated with the position. Distractor examples are shown at bottom right. Note that the fragments did not contain all of the pieces within their 4 × 4 region of the complete 8 × 8 position—the task was to determine if the pieces in the fragment had appeared in the same *relative* configuration in the study position.

The diagrams were square, with each side measuring 7.7 cm, and subtended 8.75 degrees of visual angle when viewed at a distance of 50 cm (enforced with a chin rest). The fragments, rendered in the same font as the diagrams, were square, with each side measuring 3.8 cm, and subtended 4.35 degrees of visual angle. Stimuli were presented with the MacLab program [10], which recorded responses and latencies, on an Apple Macintosh Plus computer with a Polaroid CP-50 polarizing screen filter to reduce glare.

Procedure

Each subject was tested individually in a single session of approximately 1 hr on 256 experimental trials. At the beginning of each trial, a large exclamation point appeared in the center of the computer screen for 400 msec to inform the subject that the next chess position was about to appear. The screen was then blank for 250 msec. The diagram then appeared in the center of the screen for 3000 msec, during which time subjects had been instructed to memorize the position. The diagram was replaced by a mask for 500 msec, followed by a centered fixation point for 250 msec, and then a fragment with its inner edge 1 cm (1.15 degrees of visual angle) to the left or right of the fixation point for 150 msec. Subjects were to decide as quickly and accurately as possible whether the pieces in the fragment appeared on the same squares relative to one another in the full position studied. The fixation point remained on the screen while they made their response, after which the mask reappeared for 500 msec before the next trial began.

The experimental trials were divided into four blocks of 64, presented sequentially, with subjects allowed a brief rest after completing each block. Within each block, the 32 study positions appeared twice, with no position appearing a second time before each had appeared once. Furthermore, each block contained equal numbers of single- and multiple-chunk fragments, left- and right-visual-field presentations, and yes and no responses. Within the 256 total trials, each of the 128 position/fragment pairs appeared once in each visual field. Trials were arranged in a single overall pseudorandom order, with the constraints that no position type, fragment type, correct response, or visual field of presentation appeared more than three times in a row.

Half of the subjects received the trials as described above; the others received them with left- and right-visual-field presentations reversed. In each of these groups of subjects, half indicated 'yes' responses by pressing the '.' (period) key with their right hand and 'no' responses by pressing the 'z' key with their left hand on the computer keyboard; the other half responded 'yes' with their left hand and 'no' with their right hand.

To ensure that the subjects understood the task, especially the possibly counterintuitive criteria for responding 'yes' and 'no', they were shown examples of the stimuli on paper and tested on a set of eight practice trials, none of which appeared later in the experiment.

RESULTS AND DISCUSSION

We initially considered only 'yes' trials, those in which the fragment displayed included a part of the position studied, because we expected to find evidence of differences in visual parsing only when a correct parse of the stimulus was necessary in order to make a correct response. Error rates and mean response times were subjected to separate analyses of variance with identical designs. The factors were hemisphere (left or right), fragment type (single- or multiple-chunk), and position type (endgame or middlegame). In the error rate analysis, all responses were included; in the response time analysis, trials were eliminated from consideration if either the incorrect answer was given or the time exceeded twice the mean of the other trials in that cell of the design for the particular subject. All effects and interactions not noted were nonsignificant, $P > 0.10$ in all cases.

The most interesting results are illustrated in Fig. 3. As predicted, single-chunk fragments were processed faster when presented initially to the right hemisphere, and multiple-chunk fragments were processed faster when presented initially to the left hemisphere, $F(1, 15) = 8.47$, $P < 0.02$, for the interaction of fragment type and hemisphere. Contrasts revealed that subjects responded faster to multiple-chunk fragments presented initially to the left hemisphere (1915 msec) than to the right hemisphere (2074 msec), $F(1, 15) = 12.36$, $P < 0.005$. For single-chunk fragments, there was a nonsignificant trend in the predicted direction, towards faster responses by the right hemisphere (1643 msec) than by the left hemisphere (1670 msec), $F < 1$. There was also a main effect of fragment type, with single-chunk fragments processed faster than multiple-chunk fragments (1656 vs 1994 msec), $F(1, 15) = 34.32$, $P < 0.0001$. We interpret this result as a validation of our premise that the task tapped chess-specific abilities of the subjects.
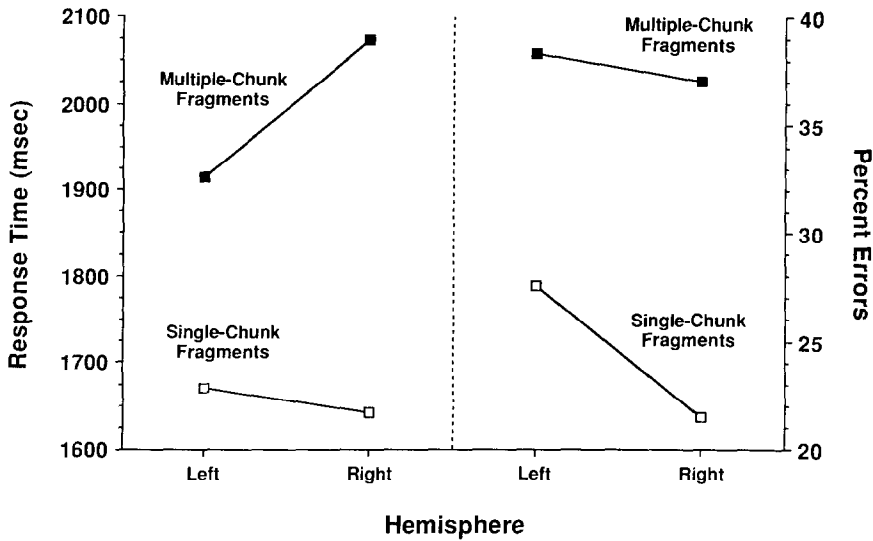
Fig. 3. Mean response times and error rates for single-chunk and multiple-chunk fragments presented initially to the left and right hemispheres (correct 'yes' responses only).

The interaction between fragment type and hemisphere was also significant in the error rates, $F(1, 15) = 6.35$, $P < 0.03$. Here, contrasts showed that single-chunk fragments were processed more accurately by the right hemisphere (21.4%) than by the left hemisphere (27.6%), $F(1, 15) = 20.12$, $P < 0.001$, but that there was no significant accuracy difference between hemispheres in processing multiple-chunk fragments (left hemisphere 38.4%, right hemisphere 37.1%), $F < 1$. In general, single-chunk fragments were processed more accurately than multiple-chunk fragments (24.5% vs 37.7%), $F(1, 15) = 22.57$, $P < 0.001$, for the main effect of fragment type, mirroring the results with response times. Interestingly, fragments of endgame positions were processed more accurately than were fragments of middlegame positions (25.7% vs 36.7% errors), $F(1, 15) = 16.72$, $P < 0.01$. It is possible that the more complicated middlegame positions placed greater loads on the subjects' short-term memories, resulting in lower accuracy.

The results suggest the possibility of speed/accuracy trade-offs. To verify that the left hemisphere did not sacrifice accuracy for speed on the single-chunk stimuli and that the right hemisphere did not trade speed for accuracy on the multiple-chunk stimuli, we conducted two regression analyses. For the single-chunk stimuli we obtained two hemispheric difference scores by subtracting the mean right-hemisphere response time from the mean left-hemisphere response time and the right-hemisphere error rate from the left-hemisphere error rate for each subject. (These calculations were performed on the trimmed data set used for the ANOVAs described above.) In this case, the correlation between response times and error rates was $r = 0.1630$; the same analysis for the multiple-chunk stimuli yielded a similar small positive correlation of $r = 0.1693$. Since these analyses did not reveal significant negative correlations between response times and error rates, we concluded that there were no speed/accuracy trade-offs.

Next, we repeated the ANOVAs using only the data from the 'no' trials, which were trimmed in the same way as those for the 'yes' trials. In the response time analysis, there was a significant effect of position type, with fragments paired with endgame positions again

processed faster than fragments paired with middlegame position (1436 vs 1923 msec), $F(1, 15) = 203.28$, $P < 0.0001$. Additionally, there was an interaction between fragment type and position type, $F(1, 15) = 11.66$, $P < 0.01$, with multiple-chunk fragments rejected faster than single-chunk fragments following endgame positions (1387 vs 1486 msec) but slower following middlegame positions (1974 vs 1872 msec). In the error rate analysis, the only significant effect was again that of position type: fragments paired with endgames were rejected more accurately than those paired with middlegames (12.6% vs 24.0% errors), $F(1, 15) = 31.13$, $P < 0.0001$. As discussed previously, this persistent effect can be attributed to the lower short-term memory load imposed by the simpler endgame positions.

As expected, these results indicate that the right hemisphere is more accurate at parsing chess positions into parts according to a set of acquired chunking rules, and that the left hemisphere is faster at grouping pieces into parts that violate those rules. Despite the strength of this evidence, it is possible that perceptual factors not related to chess knowledge could have accounted for the observed interactions between visual field and fragment type: Perhaps the single-chunk fragments happened to be organized in better accordance with the Gestalt principles than were the multiple-chunk fragments.

The obvious way to address this question would be with control experiments, testing either non-chessmasters on the same task or a group of chessmasters on a variant task with meaningless symbols in place of the chess piece characters in the stimulus diagrams. Unfortunately, both tasks would be prohibitively difficult for the subjects, so we performed an additional regression analysis on the collected data. The dependent variable was the difference between the left- and right-visual-field mean response times across subjects for each of the 64 fragments presented in 'yes' trials. As before, these means were computed from the trimmed data set used for the 'yes' trial ANOVA. In addition to type (single- or multiple-chunk), each fragment was coded for seven other independent variables: Number of pieces (2–3), collinearity of pieces (0–2), proximity of pieces (0–1), similarity of piece color (0–1), similarity of piece type (0–2), degree of occupied square color similarity (0–1), and degree of contrast between piece and square colors (0–2). Figure 4 shows the coding of a sample fragment.
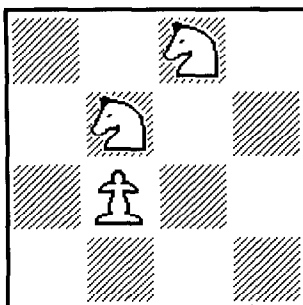

Fig. 4. A fragment stimulus, coded for the independent variables used in the regression analysis as follows: Type: multiple-chunk; Number of pieces: three; Collinearity: medium; Proximity: low; Piece color similarity: high; Piece type similarity: medium; Square color similarity: low; and Contrast: medium.

As anticipated, the only variable entered in the stepwise regression was fragment type, which correlated $r = 0.2475$ with the response time difference, $F(1, 62) = 4.05$, $P < 0.05$. A correlation matrix of the variables showed that no other independent variable correlated above $r = 0.11$ with the response time difference. In a similar stepwise regression with error rate difference as the dependent variable, none of the independent variables were entered. These results reinforce the conclusion that the hemispheric asymmetry observed in this experiment is due primarily to the semantic content of the stimuli. They also provide additional support for the hypothesis that the right hemisphere can acquire and apply sets of context-specific default parsing rules while the left hemisphere is superior at overriding such rules when necessary.

CONCLUSIONS

Our experimental results can be interpreted within the default/override framework for visual parsing proposed by VAN KLEECK and KOSSLYN [39]. The right hemisphere was superior at identifying chess position fragments containing a single chunk, but the left hemisphere was better with multiple-chunk fragments of equivalent size. This finding strongly supports the hypothesis that the right hemisphere is more adept at acquiring the chess-specific chunking rules, which the visual system uses in place of its defaults within the context of chess. Furthermore, it is consistent with findings that left occipital lobe lesions impair perception of multipart objects [26, 27], since the multiple-chunk fragment stimuli used here—with which the left hemisphere was relatively superior—contained elements of two 'parts' in the context of chess.

One could argue that these results show merely that the right hemisphere is better than the left at an 'easy' version of a perceptual task. Indeed, it has been suggested that the left hemisphere is somehow better at 'hard' tasks, but recent experiments involving judgements of different types of spatial relations [22, 29] have provided strong evidence against this idea. KOSSLYN et al. [29, Experiment 3] presented subjects with identical sets of stimuli, a small dot and a horizontal bar, and asked them to decide either whether the dot was above the bar or whether it was within a specified distance from the bar. The metric task (distance judgement) was more difficult, as it engendered greater response times and error rates, but was performed better by the right hemisphere. By contrast, the easier categorical task (above/below judgement) was performed better by the left hemisphere. Therefore, task difficulty alone cannot explain hemispheric differences in perceptual processing unless we consider it a factor in some domains, such as chess, but not in others, such as judging spatial relations.

Neuropsychological findings and the results of our divided visual field experiment provide converging evidence that the right cerebral hemisphere is critical for chess skill. Chunking, the expert player's ability to efficiently encode positions into memory, is a fundamental component of such skill because representations of positions must be used in other important operations in chess cognition such as position evaluation, move selection, and forward search. Chunking in chess and similar semantically rich domains can be understood as the imposition of a perceptual organization on the stimulus that arranges its elements into useful groupings. Thus, we conclude that the right hemisphere is critical for chess skill because it is best at using chunking to encode normally-structured positions into memory.

We should also note that we are by no means proposing that the right hemisphere is completely responsible for chessplaying ability, nor do we suggest that the left hemisphere is incapable of parsing according to default rules, Gestalt or otherwise. EFRON [13] has justly

criticized such 'absolute localization' notions of hemispheric asymmetry. We prefer to believe that the brain uses distinct processes (or perhaps 'weakly modular subsystems', as proposed by KOSSLYN and KOENIG [28]) for default and override parsing, that both processes are implemented within each hemisphere, and that the right hemisphere default parsing process and the left hemisphere override parsing process are relatively more effective than their contralateral counterparts. Such a 'relative specialization' model is sufficient to account for the results of divided-visual-field experiments without proposing radical schemes of information processing segregation between the hemispheres. Thus, our specific contribution is to provide evidence, by demonstrating performance advantages for stimuli presented initially to the right hemisphere, that the default parsing process can adapt to follow rules specific to a typical semantically-rich domain, namely chess.

Finally, we offer a speculative explanation of the disproportionately small number of women who play in tournaments and reach the highest levels of achievement in chess. The surprising fact that fewer than 2% of the world's grandmasters are women, despite chess being not primarily an athletic sport, is often ascribed to social and cultural factors. Our theory can be combined with recent findings on the variability of functional cerebral asymmetry during the menstrual cycle [9, 20] to provide a neuropsychological account for this phenomenon.

HEISTER et al. [20] found that the usual right-hemisphere advantage for a face decision task gradually declined throughout their subjects' menstrual cycles, actually reversing in the premenstrual phase. This change was caused by a decline in right-hemisphere performance (not an increase in left-hemisphere performance), suggesting that physiological changes during the cycle decrease the 'activation' of the right hemisphere and retard its performance on tasks to which it is otherwise suited. CHIARELLO et al. [9] obtained a similar pattern of results with a line orientation task, but both groups observed no cyclical change in the usual left-hemisphere superiority on lexical decision tasks. According to our theory of chess skill, the possible deactivation of the right hemisphere could adversely affect the chunking abilities of female chessplayers during the later phases of their menstrual cycles. In long competitions such as matches and tournaments, this could result in poorer overall performance.

Further development of these ideas awaits replication and greater understanding of the asymmetry shift results, as well as studies of the chess skills of female players. We can be certain, however, that the use of concrete computational theories like the visual parsing model of VAN KLEECK and KOSSLYN [37], which was extended in this article, is a promising approach.

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