

BRIEF REPORTS

Expertise and Age Effects on Knowledge Activation in Chess

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Novice, intermediate, and expert chess players of various ages, playing with two chess pieces on a quarter-section of a chessboard, performed a simple task to detect that the king is in check or is threatened with being in check. Age slowed response for both tasks. An interaction of task and skill revealed differences in diminishing response time between check and threat tasks as skill increased; experts were equally fast on both tasks. Measures of speed and working memory were negatively related to age but unrelated to skill. Skill did not mitigate age-related effects on speed of detection. These results suggest that knowledge-activation processes necessary to assess basic chess relationships slow with age, even in experts.

Keywords: age, chess, mitigation, threat, check, pattern recognition, anticipation, expertise, skill, knowledge

Studies have reported a consistent decrease in higher-level cognitive abilities requiring attention and memory with age in late adulthood (e.g., Verhaeghen & Salthouse, 1997). This decrease has sometimes been attributed to age-related changes in working memory capacity, speed of processing (Salthouse, 1991), or attention processes (e.g., inhibition failure, which is the failure to keep irrelevant information from entering working memory, to remove irrelevant information from working memory, and to prevent the return of attention to stimuli previously discarded; Hasher & Zacks, 1988). A potential counterweight to age-related decline is skill-related improvement. Experts in digit span can recall 80–100 digits, far in excess of the 7–9 digits recalled by untrained individuals (Ericsson & Kintsch, 1995), and chess experts show a similar advantage over novices for memory of briefly presented chess positions (Chase & Simon, 1973). A critical question is how age and skill trade off.

The literature is mixed on whether there is differential age-related decline as a function of skill (Salthouse, 2006), possibly due to different demands on attention, speed, or working memory (Taylor, O'Hara, Mumenthaler, Rosen, & Yesavage, 2005). The strongest evidence for expertise-related mitigation stems from studies directly assessing perceptual and motor skills (e.g., Bosman, 1993; Krampe & Ericsson, 1996, for music performance; Salthouse, 1984, for typing), but other findings have been mixed (Meinz, 2000; Morrow, Menard, Stine-Morrow, Teller, & Bryant,

2001). Part of this discrepancy may lie in the measures used (e.g., recall, recognition, and perceptual and motor performance). A study by Masunaga and Horn (2001) revealed age-related decline in recall memory but not in recognition, for skilled players of "Go," a Chinese strategy game. Meinz and Salthouse (1998) showed little skill-related mitigation for recall of music passages, and Charness (1981a) noted that skill made progressively less of a positive difference with increased age in a recall task in chess. Furthermore, skill-related mitigation was not evident for unaided recall of messages in air-traffic control, but it did occur when pilots could take notes (e.g., Morrow et al., 2001; Morrow et al., 2003).

Another important variable in assessing degree of mitigation of age-related effects by skill is level of skill, because relationships with performance may not be linear across the range of skill. Support for mitigation of age-related effects might be expected from Ericsson and Kintsch's theory (1995) of long-term working memory. According to this theory, experts process large amounts of information in the form of "chunks" and patterns (templates) (Gobet & Simon, 1996) that are stored in long-term memory but can be rapidly indexed and activated by domain-specific cues held in working memory. Thus, older experts may be able to circumvent age-related decline on domain-relevant tasks by drawing on acquired knowledge, even when measures of speeded response are recorded (e.g., for typing digraphs [Bosman, 1993] or for playing music [Krampe & Ericsson, 1996]). Mireles and Charness (2002) found support for this hypothesis with a neural net simulation of a chess task using serial recall. Their results suggested that preexisting structured knowledge could offset declines in the efficiency of neural transmission even on a recall task.

We focus on a relatively constrained recognition task involving the relationship of *check* or *threat of check* in a game between two chess pieces on a partial chessboard. We were motivated to use these tasks because of the rapidity with which experts perceive or *apperceive* (Saariluoma, 1990) relevant features of chess positions. For instance, de Groot and Gobet (1996) found that experts could

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encode two or more chess pieces in a single fixation and scan a larger area of the board in shorter time than players of lesser skill could. Researchers have noted that eye movements of experts were guided by the saliency of specific chess pieces and that experts extracted relationships in parallel, whereas less skilled players engaged in slower serial processing. Furthermore, for extraction of information, experts used an enhanced *visual span*, as evidenced by fewer fixations overall and a greater proportion of fixations between, rather than on, individual pieces to determine relationships among pieces (Charness, Reingold, Pomplun, & Stampe, 2001; Reingold, Charness, Pomplun, & Stampe, 2001; Reingold, Charness, Schultetus, & Stampe, 2001. For recent reviews of chess expertise, see Gobet, de Voogt, and Retschnitzki (2004); Gobet and Charness [in press]).

There are also important parallels from this research to the *anticipation* advantage in the sports domain. Theory argues that experts develop optimal visual-search strategies through experience, so that skilled players encode early perceptual cues to anticipate their opponents' actions and hence, direct their own actions accurately and quickly (e.g., Williams, Ward, Knowles, & Smeeton, 2002). Such advanced prediction is necessary to be able to respond quickly enough to return a high-speed tennis serve or to hit a fast baseball pitch. In the domain of chess, Burns (2004) revealed that 81% of variance in chess rating was accounted for by the performance of players in *blitz* chess, a form of the game that allows less than 5% of the normal time for a chess game. This finding suggests that early perceptual advantages help experts bypass computation and search.

To test the anticipation construct, this study compares the ability of players to detect proximal and distal relationships in chess. Two processes could be invoked to assess whether a king is in check or is threatened with a check. A fast process of pattern recognition (pattern matching) could allow a player to "see" that a king is in check or is threatened, much as skilled readers can recognize a word with a single fixation. When the entire array of pieces is not a chunk, the player would have to imagine a change in the position of a piece and use pattern matching on the updated internal representation to verify a check relationship, a process that could take up to 130 ms per square for diagonal moves (Church & Church, 1983). In that case, players would take considerably longer to respond than if they saw the piece already in position to capture the king, so check judgments would be faster than threat judgments. In addition, as pattern vocabularies grow with skill level (Gobet & Simon, 1996), expert players might have chunks or templates that directly represent the threat relationship, making threat detection as rapid as check detection.

The results of Reingold, Charness, Schultetus, and Stampe (2001) indicate that for check detection, experts will be faster and more accurate than less skilled players. We propose that these patterns will extend to threat detection, so that response time differences will widen with increased level of skill. We hypothesize that expert chess players will show a smaller difference in response time across tasks than less skilled players do; less skilled players may be forced to use slower processes because they have a more limited knowledge base.

General slowing with age was reported by Salthouse (1996). We predict that older participants will show a greater difference in response time across conditions than young participants will, because slowing due to age will add a time increment for each added process. If acquired skill does mitigate age-related decline in

cognitive efficiency, this study should reveal an interaction of age and skill that results in differences between response times for younger and older players that will narrow with increased skill.

Method

Design and Participants

This study had a $2 \times 3 \times 2 \times 2$ mixed-model factorial design. Age (young and older) and skill (novice, intermediate, and expert) were between-subjects variables. The tasks (check and threat) and the practice block (1–2) were within-subjects variables. The study participants were 29 young players aged 17–44 years ($M = 33$, $SD = 7.3$) and 30 older players aged 45–81 years ($M = 60.7$, $SD = 11.7$). The mean number of years of education for all players was 16.4 ($SD = 3.38$), and no significant differences existed for age, $F(1, 53) = 0.392$, $MSE = 11.9$, or rating, $F(2, 53) = 1.014$, $MSE = 11.9$. Values were considered to be statistically significant at $p < .05$. Furthermore, no interaction of age and skill was observed for education level, $F(2, 53) = 0.128$, $MSE = 11.9$, $p > .05$.

Players were termed *experts* if they had ELO ratings (Elo, 1965, 1986) ranging of 2,195–2,540 ($N = 20$, $M = 2,377$, $SD = 112.6$); *intermediates* if they possessed ELO ratings of 1,700–2,060 ($N = 19$, $M = 1,816$, $SD = 128.2$); and *novices* if they were unranked players ($N = 20$). ELO ratings of unranked players were estimated to be below 1,200; these ratings could not be reliably measured by the move-selection component of the Amsterdam Chess Test (ACT) (van der Maas & Wagenmakers, 2005). For comparison purposes, the mean rating for a tournament player in the U.S. Chess Federation is approximately 1,600. Players who were not rated internationally by the Fédération Internationale des Echecs were assigned ratings on the basis of the midpoint of the rating category assigned by their country's chess federation. An analysis of variance (ANOVA) revealed no interaction of age and skill for intermediates and experts, $F(1, 35) = 0.931$, $MSE = 0.023$. This finding shows that there was skill equivalence for young and older players within the rating groups. Similarly, an ANOVA showed no confounds of skill in the novice group, $F(1, 18) = 0.043$, $MSE = 1.161$, $p > .05$. A caveat is that if play decreases with age, ratings for older players may not estimate chess skill level as accurately as ratings for younger players. These ratings show high stability; $r = .96$ for reported peak rating and current rating in the data set described by Charness, Tuffiash, Krampe, Reingold, and Vasyukova, 2005. Due to expected age-related declines in skill (Elo, 1965), older players may be slightly overrated compared with young players. Expert and intermediate participants were recruited from Moscow, and novice participants were recruited from Tallahassee, Florida. All had normal or corrected-to-normal vision and were paid a stipend.

Apparatus and Materials

The Digit Symbol Substitution Test (DSST) (Wechsler, 1981) was administered to participants to assess general speed of information processing, a construct that Salthouse (1992) has shown to mediate age-related differences in a wide variety of cognitive measures. Scores represent the number of correct substitutions made within 90 s.

To provide an index of working memory capacity, we also administered a modified number version of the Dobbis and Rule (1989) *n*-back lag task. This task requires rapid updating and selection of working memory contents. Each trial consisted of a visual presentation of 10, 11, or 12 numbers, in the 0-back, 1-back, and 2-back conditions, respectively, presented at a rate of one per second on a computer screen. For 0-back, participants were instructed to respond with numbers aloud, as soon as they appeared. In the 1-back, the participant was to respond with the previous number presented; no response would be given when the first number was displayed and the appropriate response on presentation of the second number would be the first number. In the 2-back, the participant was to respond with the number presented two previously; when the first and second numbers were shown, no response was to be made and when the third number appeared, the appropriate response would be the first number. The score for each lag

condition was the number of correct responses up to the point of the first error (maximum score = 10).

Simplified chess positions, which will be described, were displayed on a 17-inch monitor at a resolution of 640 × 480 pixels. The experimental interface was created by E-Prime Technologies (PSTNet, 2001). Responses were made with the right and left index fingers by using the “r” to indicate a “Yes” response and the “z” to indicate a “No” response.

The stimulus display was composed of a 4 × 4 portion of a chessboard that occupied the full 640 × 480 pixel screen containing two chess symbols. One piece was a black king located one-half of the time in the top right or top left corner of the board. The second piece was a white rook, knight, queen, or bishop placed in any legal position not occupied by the king. Participants were asked to determine whether the king was already in check, for the check detection task, and whether the king could be placed in check in one move, for the threat detection task.

We used a 4 × 4 chessboard, rather than a 3 × 3 chessboard (Reingold, Charness, Pomplun, & Stampe, 2001), to produce sufficient numbers of check and threat trial types. One-half of the trials of each type (check or threat) required a “Yes” response. “No” check positions could become “Yes” threat positions. Queen or rook plus king positions were always “Yes” threat positions and sometimes “No” check positions.

Procedure

Participants were interviewed to gather information about their chess experience and current ELO rating. We then administered the DSST to assess psychomotor processing speed and the *n*-back lag task to assess working memory processing capacity. Participants were told the procedure, given examples showing a check or threat to the king, and offered the opportunity to ask questions during the practice set.

Written instructions were presented on the screen, and practice blocks, consisting of eight trials per condition followed. On presentation of the diagram, accuracy and response times were measured. To prevent corrections, we recorded only the first response.

The screen informed the participant whether to perform check or threat detection and also provided a reminder “to respond as quickly and accurately as possible.” Blocks consisted of 16 trials, and 64 trials were presented for each condition. Trials within blocks were repeated in random order to test for practice effects, comprising a total of 128 trials. The participant controlled the start of the second block of trials by pressing the spacebar.

On the basis of results from pilot work, the participant was shown an orienting screen before each diagram presentation within a block. The word “CHECK” or “THREAT” was shown in the center of the screen, and the words were translated to Russian for players from a site in Moscow. A diagram appeared on the screen 1.5 s later. This process eliminated the participant’s need to recall which task to perform and reduced the chance of a participant inadvertently switching tasks within a block.

Results

Accuracy

Accuracy was extremely high, particularly for intermediate and expert players. A repeated-measures ANOVA on errors for task type (2, check–threat) × skill (3, novice–intermediate–expert) × age (2, young–older) revealed (1) a main effect of task on accuracy, $F(1, 53) = 112.63$, $MSE = 0.695$, $p < .01$, with lower accuracy on threat (97.9% correct) than on check trials (99.5% correct), and (2) a main effect of rating, $F(2, 53) = 9.74$, $MSE = 1.398$, $p < .01$. This analysis revealed highest levels of accuracy for experts, followed by intermediates, and then novices (99.2%, 98.7%, and 98.1%, respectively). No main effect of age was revealed, $F(1, 53) = 0.102$, $MSE = 0.142$, $p > .05$, and no interactions were significant.

Ability Measures

An ANOVA for performance on the DSST revealed the expected main effect of age, $F(1, 53) = 164$, $MSE = 47.6$, $p < .01$, showing that older adults were 1.5 times slower than young adults ($M = 45.7$ vs. 69.2). No differences existed across levels of skill, $F(2, 53) = 2.303$, $MSE = 47.6$, $p > .05$, and age and skill did not interact, $F(2, 53) = .09$, $MSE = 47.6$, $p > .05$.

All participants attained perfect scores of 10 for 0-back and 1-back conditions. Therefore, analysis of performance on the 2-back lag was the only condition used in an ANOVA. Results revealed the expected main effect of age, $F(1, 53) = 20.6$, $MSE = 5.57$, $p < .01$; young adults attained higher scores than older adults did ($M = 9.25$ vs. 6.47). No differences existed across levels of skill, $F(2, 53) = 1.23$, $MSE = 5.57$, $p > .05$, and age and skill did not interact, $F(2, 53) = 1.58$, $MSE = 5.57$, $p > .05$.

Response Times

Means across the medians for conditions were computed to correct for potential outliers, because of the insensitivity of standard detection procedures with few trials per condition. Only accurate trials were included in analyses. A repeated-measures ANOVA of task (2, check–threat) × block (2, first–second) × age (2, young–older) × skill (3, novice–intermediate–expert) revealed main effects of practice, $F(1, 53) = 74.3$, $MSE = 16,800$, $p < .01$; task, $F(1, 53) = 90.6$, $MSE = 43,840$, $p < .01$; age, $F(1, 53) = 13.7$, $MSE = 256,557$, $p < .01$; and skill, $F(2, 53) = 53.2$, $MSE = 256,557$, $p < .01$. Mean values are shown in Table 1.

An interaction of task and skill revealed the hypothesized differential perceptual advantage for experts on threat trials; no performance differences existed across conditions for players of highest ability, $F(2, 53) = 30.6$, $MSE = 43,840$, $p < .01$, (Figure 1, panel A). An interaction of task and age revealed a greater difference in response times across conditions for older players than for young players, $F(1, 53) = 4.79$, $MSE = 43,840$, $p < .05$ (Figure 1, panel B). Furthermore, an interaction of block and skill revealed greater gain for less skilled players; as level of skill increased, performance time differences across blocks decreased, $F(1, 53) = 9.09$, $MSE = 16,800$, $p < .01$. Thus, novices reduced mean response time by 242 ms from the first to the second block,

Table 1
Mean Median Response Times by Age, Skill, and Task

| Skill level | Age group | Block | Task type | |
|--------------|-----------|-------|--------------------------|-------------|
| | | | Response time in ms (SE) | |
| | | | Check | Threat |
| Novice | Young | 1 | 1,255 (121) | 1,681 (122) |
| | | 2 | 1,019 (105) | 1,464 (111) |
| | Older | 1 | 1,556 (109) | 2,260 (216) |
| | | 2 | 1,326 (57) | 1,975 (140) |
| Intermediate | Young | 1 | 878 (86) | 975 (110) |
| | | 2 | 785 (69) | 907 (112) |
| | Older | 1 | 1,012 (47) | 1,191 (81) |
| | | 2 | 846 (33) | 1,024 (60) |
| Expert | Young | 1 | 684 (16) | 744 (30) |
| | | 2 | 635 (15) | 679 (23) |
| | Older | 1 | 835 (40) | 964 (54) |
| | | 2 | 777 (33) | 850 (57) |

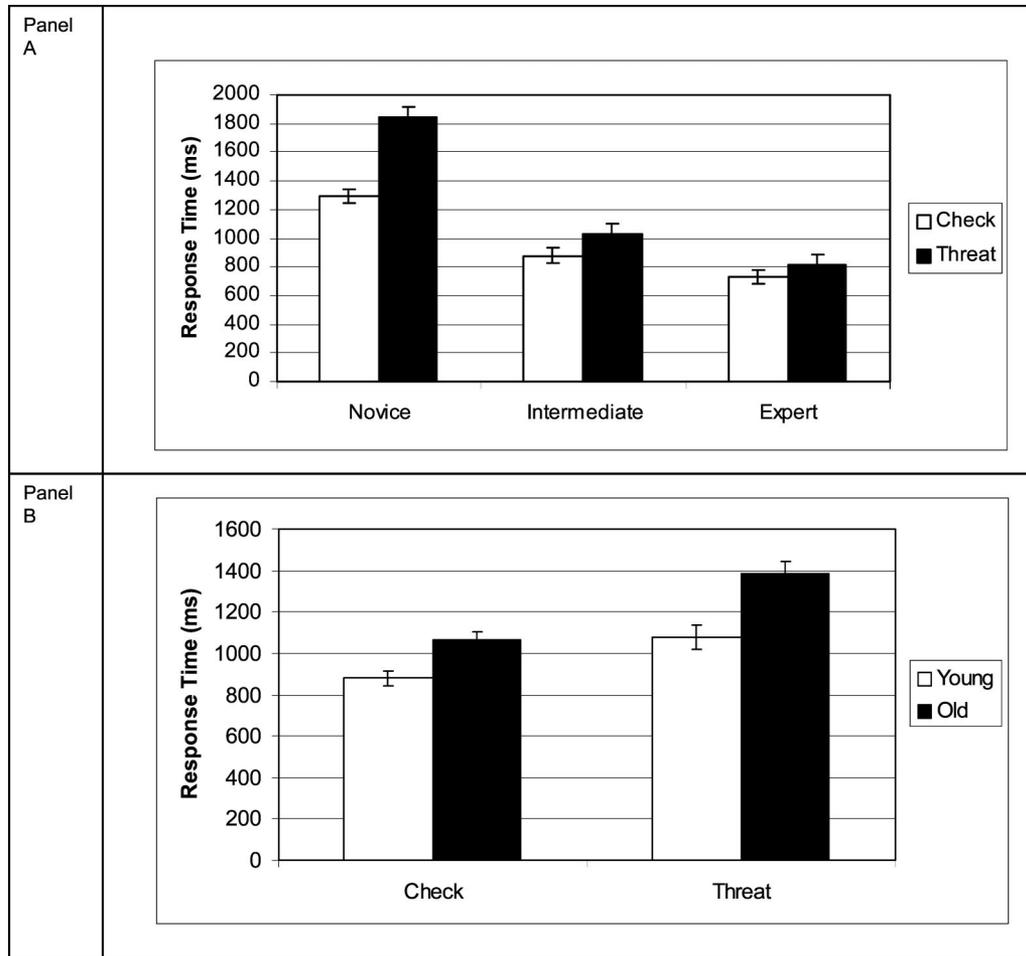


Figure 1. Panel A. Mean median response time by task type by skill (with standard error bars). Panel B. Mean median response time by age and task type (with standard error bars).

$t(38) = 2.93, p < .01$, compared with 123 ms for intermediates, $t(36) = 1.45, p > .05$, and 72 ms for experts, $t(38) = 0.87, p > .05$. Contrary to a prediction of mitigation, results did not reveal the hypothesized interaction of age and skill, $F(2, 53) = 1.95, MSE = 249,765, p > .05$. This finding suggests that level of expertise did not mitigate age-related slowing in response time across tasks. However, a posteriori power for this interaction, with a partial eta-squared = .068, was only .39. Thus, even for highly skilled players, aging took a toll on processing speed.

Planned contrasts showed differences between novices and intermediate players in both the check task, $t(37) = 6.01, p < .01$, and the threat task, $t(37) = 7.89, p < .01$. Differences also existed between intermediate and expert players in the check task, $t(37) = 2.16, p < .05$, and the threat task, $t(37) = 2.07, p < .05$. Furthermore, results revealed differences between the check and threat tasks for both novices, $t(38) = 6.41, p < .01$, and intermediates, $t(36) = 2.15, p < .05$. However, no differences existed between tasks for experts, $t(38) = 0.88, p > .05$. These findings support our hypothesis that experts possessed chunks or templates permitting rapid recognition of threats as easily as checks.

Discussion

This study sheds new light on conflicting previous findings that in some domains, age-related decline can be mitigated with compensatory strategies, such as typing (Bosman, 1993; Salthouse, 1984;), but that in other domains, it emerges regardless of skill (Charness, 1981a; Meinz, 2000; Morrow et al., 2001). The tasks we used minimized working memory load and attentional demand, factors believed to confound results in other research on expertise and aging-related effects (Morrow et al., 2001). Thus, the presence of the task \times age interaction and the absence of an age \times task \times skill interaction argue that in speeded performance, even for experts, aging takes a toll on processing.

From a skill perspective, this study examined whether chess experts possess an earlier perceptual advantage over less skilled players, allowing them to foresee distant relationships as quickly as they see near relationships. As the interaction of task and rating revealed, experts were about as quick to recognize a threat as they were to recognize a check, and that the gap in response time increased as the level of skill decreased. Thus, results of this study (1) lend credence to the theory of chunks and templates (Gobet &

Simon, 1996); (2) replicate and extend previous research using tasks to detect check (e.g., Reingold, Charness, Pomplun, & Stampe, 2001a); and (3) support the notion that experts maintain an earlier perceptual advantage over less skilled players in chess. Such a perceptual advantage is a critical component of chess expertise that strongly differentiates level of skill.

Furthermore, the study replicates and extends the finding that basic abilities are not good predictors of skill in chess (Chase and Simon (1973), for recall of random chess positions; Waters, Gobet, & Leyden (2002), for a spatial ability measure). Here, neither a working memory (*n*-back task) nor a speed of processing measure (DSST) related significantly to skill level, even in older adults, although both measures related as expected to age group.

An important caveat is that although it is necessary, when playing chess, to determine a threat in evaluation of potential moves, other knowledge-dependent factors may determine the final choice of a move, because everyone performs some search during problem solving (Charness, 1981b). Hence, moderate age-related slowing in rapid-recognition tasks may not be a significant barrier to performing expertly during normal tournament play.

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