An Exploratory Study of Aging and Perceptual-Motor Expertise in Handball Goalkeepers

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Online Publication Date: 01 January 2009
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Few studies have examined the effect of age on skilled perception. The purpose of this study was to determine whether the perceptual-motor abilities of highly skilled performers in dynamic, time-constrained sports exhibited the same pattern of age-related decline seen in other areas. The sample for this study involved five age-specific groups of handball goalkeepers. Each participant completed an eye-tracking task, a temporal occlusion task, and an eight-choice reaction time task. Results revealed age-related declines in motor performance but not perceptual performance. Skilled perception appears resistant to normal age-related declines over time through the use of compensatory mechanisms.

Received 20 May 2006; accepted 17 April 2007.

This research was sponsored by the German Institute for Sport Science (VF 0407/06/47/2003–2004) and the Social Sciences and Humanities Research Council of Canada (grant no. 410-04-1207). It was conducted at the Institute for Sport and Sport Science, University of Heidelberg. The authors would like to thank Sibille Abel, Florian Fath, and Ulrike Langenstein for their helping hand in data collection and data analyses. The authors would also like to thank those who gave them valuable advice and feedback on the current paper: Sean Horton, Norbert Hagemann, and Steve Cobley as well as one reviewer and the section editor.

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Skill maintenance is of increasing importance in aging societies and a comprehensive understanding of the relationship between age and skill is essential. Examinations of abilities ranging from reaction time (Entier, Sibley, Pomeroy, & Kao, 2003; Fozard, Vercruyssen, Reynolds, Hancock, & Quilter, 1994) and memory (Henry, MacLeod, Phillips, & Crawford, 2004) to muscular strength (Kallman, Plato, & Tobin, 1990) and flexibility (Einkauf, Gohdes, Jensen, & Jewell, 1987) imply an inevitable downward spiral of functional ability with age.

Studies of cognitive and motor skills suggest performance can be maintained at high levels in spite of advancing age. For instance, Charness’ (1981) study of chess players found that high levels of performance could be maintained as performers got older. Other examinations of cognitive-motor experts, such as pianists (Krampe & Ericsson, 1996) and typists (Salthouse, 1984), substantiate these findings.

One of the most widely supported explanations for the maintenance of skilled performance over time is that performers make compensatory adaptations (Bäckman & Dixon, 1992). Several theories of compensation exist; for example, the theory of Selective Optimization with Compensation (SOC) advocated by Baltes and colleagues (Baltes & Baltes, 1980, 1990; Marsiske, Lang, Baltes, & Baltes, 1995) views life span development as a dynamic, ongoing process of balancing gains and losses, whereas Salthouse’s compensation model (Salthouse, 1987, 1990) is conceptually grounded in the interaction between experience and performance. However, a common aspect across these theories is the notion that although individual components of a skill may decline with age, it is possible for overall performance to remain the same due to an increased reliance on other aspects of performance. Put more simply, the theory suggests that skilled performers strategically compensate for a decline in one area by developing or improving in another. Empirical support for this notion can be found in studies examining chess players and typists. Charness (1981) found that skilled, older chess players could perform at the same level as younger skilled players despite age-related deficiencies in memory ability. He explained these results by suggesting older players compensate for their declining memory through more efficient information processing (i.e., a more systematic search of the problem space and a better global evaluation of chess positions). In addition, studies have found little decline in expert typing skill with advancing age (Bosman, 1993; Salthouse, 1984); the evidence indicates that expert typists compensate for age-related declines by scanning further ahead in the text, which allows them to begin keystroke preparation
earlier. As a result of this advanced planning, aging typists can offset a deficiency in one area by improving performance in another.

An alternative model, Selective Maintenance, advocated by Ericsson and Krampe (Ericsson, 2000; Krampe & Ericsson, 1996), proposes that expert performance in skilled domains is maintained in very specific capacities through appropriate attention to 'deliberate practice' (i.e., high-quality training activities done with the specific purpose of improving performance). Through extensive focus on appropriate training, experts are able to develop domain-specific mechanisms (e.g., expert hockey players' ability to read offensive patterns of play and predict their opponents' actions; see Starkes, Helsen, & Jack, 2001, for a review of these domain-specific characteristics) that allow them to circumvent general age-related limitations, with these mechanisms more resistant to degradation over time—provided that training persists. To test this hypothesis, Krampe and Ericsson (1996) compared older and younger pianists on a range of performance-related measures. In addition, they compared performers at the expert and amateur levels (i.e., older expert, older amateur, younger expert, and younger amateur). They found that older performers, both amateur and expert, showed the same pattern of age-related decline on general measures of performance, such as reaction time; however, domain-specific measures of performance, such as finger tapping speed and quality of performance, were maintained in older experts. In most cases, differences in domain-specific measures of performance between younger and older experts were accounted for by differences in the amount of training and practice rather than age. Based on these results, the authors concluded that persistent regular training in a domain over time would allow aging performers to maintain their skills.

Researchers have also examined the age-related decline of athletic skill, reporting that cognitive and motor skills appear more resistant to decline than physiological skills such as running, swimming, and cycling. For example, a recent examination of performance in PGA golfers (Baker, Horton, Pearce, & Deakin, 2005) found that although performance among elite golfers consistently declined as the golfers aged, this rate of decline was less than half the rate of physiological skills. All the same, this research indicates that cognitive, motor, and physiological capacities are susceptible to age-related decline, although the rate of decline may be buffered by domain-specific practice.

One area of skilled performance that has not been adequately examined in aging research is perception. Perception has been presented as a critical variable distinguishing highly skilled from lesser
skilled performers (cf. Williams & Ward, 2003). Researchers have consistently reported experts do not differ from nonexperts in visual abilities, rather, the differences lie in the experts' ability to interpret visual information more efficiently and effectively (Abernethy, Neal, & Koning, 1994). For instance, studies examining the visual cue utilization of expert cricket (Abernethy & Russell, 1984), badminton (Abernethy, 1991; Abernethy & Russell, 1987), soccer (Williams & Burwitz, 1993), and squash players (Abernethy, 1990, 1991) reveal that experts use body position cues obtained from their opponents precontact (i.e., before they bowl or before they strike the birdie or ball) to provide information about how best to respond in a situation. Due to the limited utility of post-opponent-contact information (i.e., after the opponent bowls or strikes), experts from these sports have learned to rely on visual cues from the opponent’s arm and wrist position to predict where their opponent will place the ball (cf. Land & McLeod, 2000). They then make the necessary adjustments to attend to their prediction.

Previous examinations of perceptual decline have shown age-related declinations in the ability to perceive motion (Gilmore, Wenk, Naylor, & Stuve, 1992), speed (Norman, Ross, Hawkes, & Long, 2003), and depth (Norman, Dawson, & Butler, 2000) as well as the ability to distinguish two- (2-D) and three-dimensional (3-D) shapes (Andersen & Atchley, 1995; Norman et al., 2000). However, these studies have relied exclusively on the perception of information in novel tasks using nonexpert samples. Research robustly indicates that skilled perception is domain-specific and as a result, general or novel tasks may not be appropriate for investigating the influence of age on skilled perception.

One limitation of many perceptual aging studies is that they only consider one aspect of information processing. This current study tries to overcome this limitation by considering all three stages of information processing: (1) perceptual processes, (2) response selection, and (3) response execution (cf. Wickens, 1992). Although these will be analyzed in the beginning separately, they will be discussed in total. Therefore, we will try to overcome the compartmentalization that is necessary for the results section in the discussion. Our primary research question was whether the perceptual-motor skills of highly skilled performers in dynamic, time-constrained sports exhibit the same pattern of age-related decline seen in other areas of skill? Additionally, the study examined the effect of age on skilled perception in the absence of task-relevant practice (i.e., maintenance practice or deliberate practice).
METHODS

Participants

Five groups of male handball goalkeepers participated in this study. The youngest group (sub-youth) consisted of eight goalkeepers with a mean age of 14.4 years ($SD = 0.5$) from a regional selection, which is the highest selection level for their age. The second group (youth) consisted of five goalkeepers with a mean age of 16.8 years ($SD = 1.1$) from the youth national team. The third and fourth groups (junior and adult, respectively) consisted of nine goalkeepers with a mean age of 19.2 years ($SD = 1.6$) from the junior national team and eight national team goalkeepers with a mean age of 27.3 years ($SD = 5.8$).\(^1\) Finally, the fifth group (senior) consisted of three retired national goal-keepers with a mean age of 46.7 years ($SD = 3.8$), who are no longer actively training or competing. Participants in this group were inactive from training and competing in handball for at least 5 years. Informed consent was obtained before commencing the experiment.

Apparatus

For all tasks, participants stood at a distance of 7-m in front of a normal $2.00 \times 3.00$-m handball goal facing a $2.40 \times 3.20$-m video screen. Above the handball goal a projector (Geha compact 212+) was placed connected to a notebook computer (Acer Travelmate 660LCi), which was used to present the different tasks (Software: NBS Presentation 0.80) as well as send trigger signals to the eye-tracking system. The eye-tracking system was a head-mounted SMI iView X HED with a sample rate of 50 Hz. Participants were asked to wear a common bicycle helmet with two cameras and a sender for wireless transmission. All participant hardware was connected to a battery, which was carried in a daypack. The unit was relatively light (450 g) and participants reported no disturbance from either the helmet or the battery. Eye-tracking signals of eye and scene videos were transmitted wirelessly to a second computer with two receiver units. The body movements of the goalkeepers were recorded by a digital video camera (Panasonic AGDVC-15). These video recordings were then used for the offline analyses of body movements to determine different dependent variables.

\(^1\)The adult participants are from a study by Schorer (2005).
Procedure

Three different tests were conducted with each participant. Following a warm up, participants (i) performed an eye-tracking handball video task; (ii) a temporal occlusion handball video task; and (iii) an eight-choice reaction time task. In each task, participants were asked to conduct real goalkeeper movements. Therefore, at the beginning of a trial they would stand in the middle of the goal and then react to the stimulus (e.g., reach to the lower right corner of the goal).

These tasks were conducted in the order presented above, because the whole body movements caused participants to sweat after a relatively short time and the eye-tracking system became less stable with sweat. This might have resulted into carryover effects, but given the large experience as well as the number of different throwers and throws, we decided that the methodological effect from the decreased stability would be greater and therefore kept the same order for all participants. After the tests, participants filled out a questionnaire on their training history and game experience.

Eye-Tracking Handball Video Task (ET)
Prior to this first task, the bicycle helmet was fitted to the participant’s head and the eye-movement camera and the scene camera were adjusted. The system was calibrated using a 5-point system. A total of 64 scenes were presented to the goalkeepers and the first half of the scenes were accomplished in a duration of 5.5 min. After a short break, the calibration was reevaluated and adjusted if necessary prior to showing the second half of the scenes to the goalkeepers. Their task was to defend the displayed throws. The intertrial interval was set to 5 ss.

Temporal Occlusion Handball Video Task (TO)
The temporal occlusion paradigm, as introduced to sport science by Abernethy and Russell (1987), was used to assess visual anticipation in handball goalkeeping. Participants were presented the above-described videos of handball penalty throws. Each clip was edited at three different points of time. Instead of using an absolute time frame, three points were chosen by the relative timing of the movement, because the duration differences between videotaped penalty-throws were significant. The first temporal occlusion point (TOP 1) was the return point of the movement. For the third temporal occlusion point (TOP 3), release of the handball from the hand was chosen. The second temporal occlusion point (TOP 2) was calculated as the midpoint between points 1 and 3 (Figure 1).
Forty-two edited video clips were then randomized over temporal occlusion points and throws. Participants were to react as quickly and correctly as possible to the presented video tapes. The presentation and the required reactions were as described for the eye-tracking tasks. The intertrial interval was set to 5 s.

Choice Reaction Time Task (CRT)
The third task involved an eight-choice reaction time task with 29 trials. As in the other tasks, participants stood in front of the screen; however, in this task they had to react to the position where the hand-ball was presented. The eight positions were upper left, upper middle, upper right, middle left, middle right, lower left, lower middle, and lower right. For this task, the intertrial interval was set to 3 s.

Dependent Measures and Statistical Analysis

Three dependent measurements were common across all tasks. First measured was the movement initiation time of the goalkeepers, which was defined as the difference from stimuli appearance to the beginning of the movement by the participants. This duration was calculated using an offline video analysis of the whole body movements of each participant in each trial. The video recordings showed a flickering of luminance for the video projector positioned right on top of the goal as soon as a trial (video) began. This was used to represent the moment of stimuli appearance. The beginning of the movement by the participants was defined as the moment where the goalkeeper

Figure 1. Images indicating cut points for temporal occlusion task.
raised his foot. This characteristic proved to be a valid indicator for movement initiation. Second, reaction quality was measured as the percentage of correct reactions. Again, for each trial the direction of the whole-body movement was assessed using the video recordings. If the defending movement was into the correct region, then a one was given for this trial (= save), whereas a zero was noted for the wrong direction (= goal). Although different measures were considered (e.g., being correct in the x- or y-axis), a more game-like approach was chosen. Within the sport of handball, you have either a save or a goal. Third, movement time was calculated as the difference between the start of the movement and the reach to the required region.

Number of fixations as well as relative and absolute fixation durations were counted as additional dependent measures for both eye-tracking tasks. An eye-fixation was defined as a duration of 120 ms or longer.

Due to the range of skills required for the various tasks, each of the three stages of the information-processing model can be considered independently. For stage 1, perceptual processes, the capacity to perceive task-relevant information was measured via the eye-movement measures. Stage 2, response selection, was measured by reaction time in all three tasks, and stage 3, response execution, was evaluated using measures of movement time in all tasks. In addition, general performance was measured via reaction quality.

Instead of using a descriptive statistical approach, a more exploratory data analysis was conducted, because cell sizes were small and varied among the groups (cf. Sedlmeier, 1996). Figures are presented as boxplots, based on a rank scale and, therefore, less influenced by outliers. The line in the middle of the box is the median. The box shows 25% and 75% quartiles and the lines above and below show the highest and lowest values that are not outliers. Circles or asterisk above or below these lines indicate outliers. The width of the boxes allows a relative comparison of cell sizes per group (cf. Benjamini, 1988; Sedlmeier, 1996).

For the inferential statistical analysis, a conservative Exact Test by Kruskal-Wallis for independent samples was calculated, which works well with small samples and rank scales. For the Monte Carlo sampling, the default values with a sample size of 10,000 and confidence levels of 99% were used. Due to the small sample size the exact or asymptotic p value seemed inappropriate; therefore, Monte Carlo p values will be reported. Post hoc comparisons of independent samples were calculated using Mann-Whitney U tests (alpha criterion set on .05). SPSS 12.0 was used for all analyses.
RESULTS

The results section is divided into several parts. The first describes the experience of the various groups of goalkeepers. The second examines results for general performance (measured via reaction quality), whereas the third, fourth, and fifth parts consider perceptual processes (measured via number of fixations, relative and absolute fixation duration), response selection (measured via reaction time), and response execution (measured via movement time), respectively.

Experience

Results for the history of goalkeeper-specific handball training and game experience of the athletes are presented in Table 1.

As expected, significant differences were observed for game experience \((H(4)=24.27; p<.01)\) and goal-keeping training \((H(4)=18.89; p<.01)\). Post hoc tests revealed significant differences for game experience between the adult group and sub-youths \((U=0.00; z=-3.37; p<.01)\), youths \((U=0.00; z=-2.94; p<.01)\), and juniors \((U=3.50; z=-3.32; p<.01)\), as well as between the senior group and sub-youths \((U=0.00; z=-2.46; p=.01)\), youths \((U=0.00; z=-2.26; p=.03)\), juniors \((U=0.00; z=-2.54; p<.01)\), and adults \((U=0.50; z=-2.36; p=.02)\) and between sub-youths and juniors \((U=9.50; z=-2.57; p<.01)\). For goalkeeper-specific training, significant differences were found between the sub-youth group and youths \((U=4.00; z=-2.38; p=.02)\), juniors \((U=6.00; z=-2.93; p<.01)\), and adults \((U=0.50; z=-3.31; p<.01)\), as well as between the adult group and youths \((U=2.50; z=-2.60; p<.01)\) and juniors \((U=8.50; z=-2.67; p<.01)\). No significant differences between seniors and any other group were found due to the high standard deviation of 12 years. This high deviation was caused by the wide range of experiences reported by the seniors (range, 1 to 25 years). However, all seniors were past Olympic medallists.

Table 1. Comparison of game experience and goalkeeper-specific training

<table>
<thead>
<tr>
<th></th>
<th>Sub-youth ((n=8))</th>
<th>Youth ((n=5))</th>
<th>Juniors ((n=9))</th>
<th>Adults ((n=8))</th>
<th>Seniors ((n=3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game experience</td>
<td>5.2 (3.7)</td>
<td>9.1 (1.0)</td>
<td>10.6 (3.5)</td>
<td>18.3 (3.9)</td>
<td>18.3 (1.5)</td>
</tr>
<tr>
<td>Goalkeeper specific training</td>
<td>1.3 (1.5)</td>
<td>3.7 (1.0)</td>
<td>5.0 (3.5)</td>
<td>11.1 (7.0)</td>
<td>13.7 (12.0)</td>
</tr>
</tbody>
</table>

Note. All values are in years. Values enclosed in parentheses represent standard deviations.
General Performance

Results for general performance as measured by reaction quality are presented in Figure 2. No significant differences for reaction quality in ET were observed ($H(4) = 6.86; p = .13$). However, for TO a main effect was found ($H(4) = 9.53; p = .03$) and post hoc tests revealed significant differences between sub-youths and adults ($U = 6.00; z = -2.74; p < .01$) and between sub-youths and seniors ($U = 0.50; z = -2.36; p = .02$), with sub-youth athletes scoring lower on the TO task. No significant effects were found for the CRT data ($H(4) = 8.48; p = .06$).

Perceptual Processes

Results for the analysis of eye movements are presented in Figures 3 to 5. For the number of fixations, a significant effect between groups was found ($H(4) = 22.95; p < .01$), generally indicating that older groups had more fixations than younger groups (Figure 3). Post hoc tests revealed differences between sub-youths and adults ($U = 0.00; z = -3.24; p < .01$), between youths and adults ($U = 0.00; z = -2.84; p < .01$), between juniors and adults ($U = 0.00$;...
This significant difference between younger and older groups was also found for relative fixation duration (Figure 4; $H(4)=13.42; p < .01$), with post hoc tests revealing differences between sub-youths and adults ($U=7.00; z=-2.43; p=.02$), between sub-youths and seniors ($U=0.00; z=-2.44; p=.01$), as well as between juniors and adults ($U=0.00; z=-3.33; p < .01$) and between juniors and seniors ($U=2.00; z=-2.13; p=.04$). In general, these results indicate older groups (adults and seniors) had significantly longer relative fixations than the younger groups (sub-youths and juniors).

This trend continued for the absolute fixation duration. Significant differences were observed between groups (Figure 5; $H(4)=21.47; p < .01$) and post hoc tests revealed differences between sub-youths and adults ($U=0.00; z=-3.24; p < .01$), between sub-youths and seniors ($U=0.00; z=-2.44; p=.01$), between juniors and
Figure 4. Relative fixation duration (in ms) for sub-youth ($n = 8$), youth ($n = 5$), junior ($n = 9$), adult ($n = 9$), and senior ($n = 3$) groups for the ET task.

Figure 5. Absolute fixation duration (in ms) for sub-youth ($n = 8$), youth ($n = 5$), junior ($n = 9$), adult ($n = 9$), and senior ($n = 3$) groups for the ET task.
adults $(U=0.00; z=-3.33; p<.01)$, and between juniors and seniors $(U=0.00; z=-2.50; p<.01)$. Additionally there was a significant difference between youths and adults $(U=1.00; z=-2.68; p<.01)$.

**Response Selection**

Results for movement initiation time are presented in Figure 6. A significant effect between groups was revealed for ET $(H(4)=9.19; p=.04)$. Post hoc tests indicated seniors had significantly lower scores than sub-youths $(U=0.00; z=-2.45; p=.01)$, juniors $(U=2.00; z=-2.13; p=.04)$, and adults $(U=0.00; z=-2.45; p=.01)$. No significant differences were observed for TO $(H(3)=4.11; p=.41)$, but differences were revealed for CRT $(H(4)=11.77; p<.01)$. Post hoc tests revealed that adults had significantly lower movement initiation times than sub-youths $(U=8.00; z=-2.52; p<.01)$, youths $(U=6.00; z=-2.05; p=.05)$, juniors $(U=13.00; z=-2.21; p=.03)$, and seniors $(U=0.00; z=-2.09; p=.05)$.

![Figure 6](image.png)

*Figure 6. Movement initiation time (in frames) for sub-youth ($n=8$), youth ($n=5$), junior ($n=9$), adult ($n=9$), and senior ($n=3$) groups for the ET (dark grey), TO (light grey), and CRT (white) tasks.*
Response Execution

For movement time, no significant differences were observed between the four younger groups for either of the handball-specific tasks (Figure 7; ET: \(H(3) = 6.86; p = .07\); TO: \(H(3) = 2.22; p = .56\)). The seniors were asked to perform the same movements as the younger groups, but due to lower physical fitness they were incapable of completing the required movements and as a result their data were excluded from the inferential statistics, but included in the graph. The median values for the seniors on these tasks were lower than the values for the sub-youth, junior, and adult groups. For CRT, there were significant differences \(H(3) = 7.76; p = .04\) and post hoc tests indicated sub-youths had significantly greater movement times than juniors \(U = 11.00; z = -2.41; p = .02\) and adults \(U = 11.00; z = -2.21; p = .03\).

DISCUSSION

Results from the present study point to the maintenance of skilled perception in the face of advancing age. Without being involved in
training or competition, senior handball goalkeepers performed similarly to current expert players and superior to lower level players. These results are intriguing and suggest several interesting possibilities regarding the nature of skilled perception. First, it suggests that skilled perception is not vulnerable to the same rate of age-related decline as more general measures of perception, which have been found to be age-specific (e.g., Gilmore et al., 1992; Norman et al., 2003). The explanation for this result may lie in the nature of the capacities being compared. Measures of general perceptual abilities have typically examined participants’ aptitude for perceiving novel stimuli, whereas skilled perception deals with individuals’ skill at perceiving highly specific, domain-relevant information. Moreover, the nature of skilled perception for athletes in time-constrained, decision-making sports may be more akin to a problem-solving task. Experts from these sports (including handball goalkeepers; c.f. Schorer, 2005) have learned to rely on advanced visual information provided by their opponent, and once they have learned the necessary sources of this information, it may be highly resistant to memory decay. Evidence from the eye-movement data suggests that seniors and current experts were very similar in the number of fixations and their absolute and relative duration. Future studies should examine this issue in more detail using other skilled perception tasks, which may relate more generally to aging populations. For example, although the general ability to perceive motion and speed declines with age (Gilmore et al., 1992; Norman et al., 2003), perceiving task-specific speed and motion information such as when driving may be maintained to a greater degree.

The current results also indicate that handball goalkeepers are not resistant to all forms of age-related decline. Motor performance, as measured by movement time, was affected as much as previous research would suggest and on these tasks senior goalkeepers were either the same as, or inferior to, their younger counterparts. Interestingly, the reaction time data provided valuable information regarding the specific areas of decline in these players. For the handball-specific task (ET), the senior goalkeepers showed an earlier movement initiation than the adults; however, adults responded more quickly on the more general reaction time task, suggesting that very specific adaptations are occurring. Further evidence of this is found in the measures of overall performance. Senior players’ performance was not significantly different from the other groups on the ET or CRT tasks, but they were significantly better on the TO task, which requires the use of highly domain-specific information at an earlier time.
Schorer (2005) suggested that performers in dynamic, time-constrained sports adapt to the specific performance constraints of their environment. In his view, the expert perceptual system adapts to these constraints to be in the right spot at the right time. If they initiate their movement too late or too early, they will be unable to perform effectively. Data from the current study may indicate that senior goalkeepers adjust their “just-in-time” strategy to accommodate age-related declines such as motor deficits. The lack of difference between the senior and adult groups on the ET task in light of differences on the TO task may at first seem contradictory. If differences in response initiation exist, they should be evident in the ET task as well. However, the TO task was externally paced by occluding the videos early, whereas external timing is missing in the ET task, which could lead to a later decision. Some participants may have a tendency to react early and risk a worse reaction quality, whereas others might decide to have a better reaction quality and a worse reaction time, perhaps suggesting the use of ‘trade-off’ strategies by participants. The superiority of the seniors in the reaction quality in TO suggests they actually learned to anticipate earlier. These results, coupled with previous findings from Bosman (1993), Charness (1981), and Salthouse (1984), reinforce the conclusion that the expert perceptual-cognitive system is highly plastic and capable of reorganization to meet changing environmental demands.

Despite the intriguing results from this study, there were several limitations that restrict their application. First, the data were cross-sectional and as a result may not represent the aging process due to cohort effects. It may be that the senior group was always superior to the other groups (*priori disposition*; Krampe & Charness, 2006) and if so an age-related decline would not be evident in our analyses. However, comparisons of cross-sectional and longitudinal data in highly skilled groups indicates that the rate of loss may be overestimated when evaluating cross-sectional data (Starkes, Weir, & Young, 2003) and as a result, the current data may overestimate performance losses over time. Second, although cursory information regarding training history was collected, it is unclear whether performance in perceptually similar activities may have facilitated maintenance of these abilities as suggested by Ericsson (2000). For example, it is unclear what role watching games may play in maintaining these perceptual skills. Finally, a general limitation of studies of this nature is that examination of genuine expertise is necessarily limited by the fact that the number of experts is, by definition, small, making the establishment of large sample sizes with strong statistical power extremely difficult. This limitation is particularly meaningful in the current
study with regards to the senior group, which had only 3 participants and a high degree of variability in training experience. The current study recognizes these difficulties and, although unable to eliminate them, has attempted to work within these constraints. It is also noteworthy that the senior performers were significantly younger (mean age 46.7 years) than commonly used in studies of aging and expertise. However, longitudinal analyses of performance with age note age-related declines in performance immediately following peak performance (see Bortz & Bortz, 1996, for a review). Although the senior participants were somewhat younger than usual, they provide useful information regarding age-related decline in this sport because peak performance in handball typically occurs in the late 20s or early 30s. Moreover, the period of mid-life is often underresearched but could prove quite valuable for understanding the factors promoting either skill maintenance as seen in many aging experts or the increased rate of decline seen subsequent to this period in ‘normal’ human aging.

It is prudent that the current results be viewed as exploratory, requiring corroboration and confirmation. As previously mentioned, data for this study were collected from a very elite sample of athletes and as a result, the generalizability of their results to ‘normal’ populations is assumed rather than proven. Investigations of the age-related decline in performance for complex, everyday skills (e.g., driving a car) may provide insight into how well this study’s results describe the profile of decline in skilled perception with age. This research could prove valuable for the development of informed policies relevant to our aging population.

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