Talent Development & Excellence
Vol. 8, No. 1, 2016, 15-26

Maintenance of Perceptual Cognitive Expertise in Female Volleyball Players and its Adaptation to Different Time Constraints

Lennart Fischer[1,*], Joseph Baker[2], Judith Tirp[3], Rebecca Rienhoff[1], Bernd Strauss[1], & Jörg Schorer[3]

Abstract: Although some research suggests age-related changes in the visual system are inevitable, other work indicates that expert performers in sport are able to maintain performance despite increasing age. This study examined aspects of skilled perceptual performance among older female experts (n = 6), advanced players (n = 7) and novices (n = 10). As expected, there were skill-related differences among the groups although analyses of differences in perceptual performances between the groups were more mixed. Our results highlight several interesting areas for future work including the possibility that age-related changes in the performance environment might drive maintenance or decline of skill. This research contributes to a surprisingly limited evidence base regarding the influence of age on perceptual skill.

Keywords:
Perception, expertise, fields of vision, aging

Even after three decades of research, the mechanisms of expert performance are still debated (cf. Ericsson, 2012; Starkes & Deakin, 1984; Tucker & Collins, 2012). In 1984, Starkes and Deakin used a computer analogy to distinguish stable qualities such as simple reaction time or efficiency of the central nervous system (termed 'hardware') from capacities that reflect learned skills and the result of practice/experience such as pattern recognition and anticipation (termed 'software'). While some have argued for 'hardware'-like qualities (Yarrow, Brown, & Krakauer, 2009), others argue the primacy of learning in explaining expert performance (Ericsson, Krampe, & Tesch-Römer, 1993). In this study, we focus on skilled performance in the sport of volleyball. While some recent studies have shown that experts are superior in executive control tasks and visuo-spatial attentional processing (Alves et al., 2013) as well as demonstrating better accommodation and saccadic eye movement (Jafarzadehpur, Aazami, & Bolouri, 2007), other research in this area (and in time-constrained interactive sports in general) has focused on differences in temporal occlusion (Abernethy & Russell, 1987; Williams & Davids, 1998) or eye-movements (Helsen & Starkes, 1999; Williams, Davids, Burwitz, & Williams, 1994), tasks that more likely reflect learned anticipation and perception strategies specifically adapted to the demands of volleyball. Ultimately, it seems performance is more complex than the simple hardware versus software dichotomy would suggest.

Complicating this issue further, most research in this area has focused on performance of young adults with very little work considering the factors contributing to maintaining performance as experts age (Baker & Schorer, 2010; Horton, Baker, & Schorer, 2008).

[1] *Institute of Sport and Exercise Sciences, University of Muenster, Münster, Germany*
[*] *Corresponding Author: Email: lennartfischer@web.de*
[2] *School of Kinesiology and Health Science, York University Toronto, Canada*
[3] *Institute of Sport Science, University of Oldenburg, Oldenburg, Germany*

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

http://www.iratde.org

The aim of this study was to investigate how perceptual-cognitive skills are affected by age. It is well known that 'hardware' elements of the perceptual and cognitive systems change with age (Andersen, 2012) and many physiological parameters decline with age, for example muscle strength (Brach & Schott, 2003), reaction time (Etnier, Sibley, Pomeroy, & Kao, 2003), and flexibility (Einkauf, Gohdes, Jensen, & Jewell, 1987). Similarly, cortical and sensory factors show age-related decline (Brach & Schott, 2003). Given the obvious importance of the visual system in skilled perception, age-related changes to this system may have important implications for performance maintenance.

When discussing age-related changes in the visual system it is necessary to differentiate between three categories: optic (i.e. 'hardware'), perceptual, and sensory factors (Andersen, 2012). Many factors of the visual system, including visual acuity, contrast sensitivity, and brightness of the retina are negatively affected by age (Berke, 2009). Different changes in optics influence the visual system and the processing of visual stimuli in older aged athletes; for example, pupil diameter decreases with age while the blur of the eye increases (Berke, 2009). Furthermore, the size of the visual field and brightness sensitivity appear to be important parameters for an optimal visual system (Berke, 2009) and, age-related changes to eye-position (i.e., the eye drops deeper into the orbit which narrows the visual field) could negatively affect vision in older performers. Similar age-related changes in corneal thickness, accommodative focus, and lens opacity have been found (Andersen, 2012), which likely have general effects on performance of the entire visual system (e.g., visual acuity; Berke, 2009). All of these optical changes may negatively affect performance in visually demanding tasks. In fast sport situations, for example, it may be more difficult for older performers to identify important objects because of losses in contrast and luminance sensitivity.

Although these studies emphasize a predictable decline in general biological and physiological parameters with age, research on expertise and aging has shown that despite those losses superior skill can be maintained (Baker & Schorer, 2009; Horton et al., 2008). Theories of aging and skill retention suggest that aging experts are able to a) compensate (Salthouse, 1984) for losses by strategically compensating for a decline in one skill area by developing or improving in another area and/or b) optimize their performance through attention to deliberate practice (Krampe & Ericsson, 1996). Despite the intuitive appeal of both of these approaches, neither has emerged as the dominant explanation for the maintenance of skilled performance with age.

Several studies have examined these approaches in sport and/or motor-related tasks. In one of the earliest examinations of this phenomenon, Charness (1981) noted that skilled, older chess players were able to perform at the same level as younger skilled players despite age-related deficiencies in memory ability. He explained these results by suggesting that older players compensate for their declining memory by using more efficient information processing. More specifically, they perform a more systematic search of the problem space and make a better global evaluation of chess positions. Similarly, aging typists compensate for losses in reaction time by scanning further ahead in the text to be typed, which allows them to begin keystroke preparation earlier (Bosman, 1993; Salthouse, 1984). Similarly, Baker, Deakin, Horton, and Pearce (2007) examined career performance in professional golfers, highlighting the stability of skilled performance over time as well as potential mechanisms of compensation (e.g., golfers appeared to compensate for decreased driving distance by driving more accurately).

In a study of aging handball goalkeepers, Schorer and Baker (2009) found that elements of perceptual skill stayed remarkably stable with age but that motor elements of performance declined with age (i.e., older experts compared to younger experts), even in the absence of training. A subsequent examination (Fischer et al., 2015) focused on the perceptual phenomenon of 'Quiet Eye', which reflects the stability of a performer's gaze during execution of a targeting task (see Vickers, 1996). The authors found that skilled performance in a basketball free throw task was retained in older athletes (i.e., they maintained their superiority over less skilled players) but, interestingly, performance maintenance was not due to the quiet eye, which showed age-related changes (i.e., quiet eye duration *decreased* in older performers). The stability in performance coupled with the decline in quiet eye suggests that perceptual processes change with age in skilled performers. It is possible these changes reflect the influence of compensatory mechanisms in accommodating the age-related changes in the optic system described above, but at the very least, these findings highlighted the gaps in our understanding of the influence of age on skilled perception.

With these gaps in mind, the focus of this study was to investigate differences in performance between female experts, advanced players and novices in older age. As suggested in previous research, groups with higher skill level should have better prediction scores and fewer fixations compared to groups of lesser skill (Schorer & Baker, 2009). We also considered the contribution of different parts of the field of vision to anticipation of an opponent's behavior. On the basis of the results from an earlier study on volleyball expertise in current volleyball players (Schorer, Rienhoff, Fischer, & Baker, 2013), we anticipated that removal of information would lead to decreases in performance. To our knowledge no one has looked at the interaction of field of vision and expertise in master athletes; although we assumed an interaction between these variables, we could not make a specific prediction and therefore, this analysis was seen as exploratory.

Method

Participants

Twenty-three female athletes voluntarily participated in this experiment. The expert participants (n = 6) were from the winning team from the German championships of the western region. The mean age for this group was 49.5 years, SD = 1.6 and they had played volleyball for an average of 31.7 years. The advanced group consisted of 7 players recruited at the same tournament but placing in last position. This group had a mean age of 51.4 years, SD = 2.4 and an average playing career of longer than 30 years (M = 33.4 years). The novice group (Nov), age, M = 55.8, SD = 3.9, consisted of 10 females, some of whom had a basic course in volleyball, but none played regularly. All participants provided informed consent prior to data collection and the study was conducted in accordance with the ethical principles described in the declaration of Helsinki (World-Medical-Association, 2008).

Materials

The stimulus materials were taken from a previous study by Schorer et al. (2013). Videos made of a third league female volleyball team were used and participants were unaware of the skill level of the players. To collect the stimulus videos, a camera was placed 10m away from the net in the middle of the field and filmed all six athletes on the opposite side. In total 106 videos were reviewed by experts for ecological representativeness and eight videos were selected for the test. Each video presented a typical volleyball scenario, starting with a serve from a player standing next to the camera followed by the receiving team (i.e., the team being recorded) having to pass the ball to the setter, who had four different passing opportunities: Position 2, 3, 4 and back court. All videos showed the same backfield player attacking the other backcourt player. These eight clips were manipulated as described below. A total of 72 videos were constructed (2 clips x 4 positions of possible attacks x 3 temporal occlusion conditions x 3 spatial occlusions) for this study. The videos were presented in blocks with the spatial occlusion condition (see below) counterbalanced. The temporal occlusion conditions were included in the spatial occlusion condition in a randomized order.

Spatial occlusion with eye-tracker. The contingent display paradigm was used to occlude the videos and with this paradigm we were able to produce three different vision conditions by experimentally controlling the visual field. The three different conditions were foveal vision only, peripheral vision only and full vision. In the foveal vision only condition (FOV) a limited field of vision, representing the foveal vision (circle of 3° of visual angle) was presented to the participant. The rest of the video was occluded, thus we were able to ensure no information pick up from the periphery. In the second condition, we reversed this display. The foveal circle of 3° was occluded and peripheral and para-foveal fields of vision (PER) was presented to the participants. Finally, participants saw a full video condition without any occlusion.

Temporal occlusion. In the temporal occlusion condition, videos were temporally occluded at three (TO 3 = 120ms), five (TO 5 = 200 ms), and seven (TO 7 = 280 ms) frames prior to the ball contact from the setter. For determining these time frames, a pre-study of four third league volleyball players tested ten different time stamps (nine frames before ball contact prior to the hand-ball contact) was conducted. Results of this pre-study showed that an occlusion later than TO 3 would have a ceiling effect in the prediction; similarly, prediction performance improved above TO 7. Due to these findings we decided to use TO 3, TO 5 and TO 7 in this study.

Apparatus and procedure

The videos were presented on a 17inch video screen (Fujiyama VisionMaster Pro 510 with 100 Hz). All participants were positioned in the same experimental setup (50cm in front of the screen and the height of the seat was regulated so that the participants' eyes were in the middle of the screen). For investigating the gaze behaviour we used a head-mounted eye tracking system (Eyelink II). Prior to the start of the experiment a nine-point calibration and validation was completed. The eye tracker was a binocular system with a recording rate of 500Hz and the fixations were recorded with a minimal duration of 100ms (e.g., Young & Sheena, 1975).

Participants were asked to predict which position (Position 2, 3, 4 and back field) would receive the ball from the attack for each video. The response was given with one of four arrow buttons on the keyboard. Prior to the start of the experiment the participants saw six examples (different to the used videos in the experiment) to become familiar with the experimental setup. After the examples a recalibration was completed to obtain the gaze behaviour.

The duration of the test was approximately 15 minutes for each participant: prior to the beginning of the experiment participants had a brief information session and after the test they completed a questionnaire concerning their age, expertise level, training experience, training routines and most important volleyball achievements.

Statistical analyses

Dependent variables for this study were number of fixations and percentage of correct predictions. We also considered the fixation patterns from the participants as a qualitative variable using heat maps to present the location of the fixation in all vision conditions. The heat maps showed a fixation map for the participants regarding the location and number of fixations in a 2D map highlighted with different colours. The fixated areas were coloured from red to green (red was mostly fixated green at least - non-fixated areas were not highlighted). The background figure shows the relative positions of the different players in the used videos (Buscher, Biedert, Heinesch, & Dengel, 2010; Cutrell & Guan, 2007; Jay, Stevens, Glencross, Chalmers, & Yang, 2006; Schorer et al., 2013).

Analyses of variance (ANOVA) were conducted with expertise and age groups as the between subjects factors. Temporal occlusion and spatial occlusion were analyzed as within subjects factors. If necessary, Greenhouse-Gaisser corrections were executed and the Scheffé-procedure was used for between subject comparisons. Effect sizes were calculated with G*Power 3.1.5 (Faul, Erdfelder, Lang, & Buchner, 2007) and for all other statistical analyses SPSS 22.0 was used.

Results

The results are presented in three parts. First, we present differences in response accuracy followed by analyses of number of fixations. Finally, we present the fixation patterns.

Correct predictions

A three factorial ANOVA with repeated measures revealed significant differences between expertise groups, $F(2,20) = 8.03$, $p < .01$, $f = .90$, and between fields of vision, $F(2,40) = 5.17$, $p = .01$, $f = .52$. As expected, experts outperformed the advanced players and the novices (see Figure 1), but there were only significant differences in the post-hoc-tests between experts and novices, $D = 8.56$, $p < .01$. Also as expected, the best performance was revealed in the full vision condition. With peripheral vision, accuracy remained almost the same, while in the foveal vision condition the percentage of correct predictions decreased (see Figure 2). In contrast to our expectation, no significant differences were found between temporal occlusion conditions, $F(2,40) = 1.02$, $p = .37$, $f = .23$. As can be seen in Figure 3, the means of the temporal occlusion conditions demonstrated the expected order, but differences were small considering the very high standard deviations. No interaction between any factors was found: fields of vision by expertise $Fs(4,40) = 0.43$, $p = .79$, $f = .20$, $1\text{-}\beta = .09$; temporal occlusion x expertise, $Fs(4,40) = 1.08$, $p = .38$, $f = .33$, $1\text{-}\beta = .17$; field of vision by temporal occlusion, $Fs(4,80) = 0.91$, $p = .46$, $f = .20$, $1\text{-}\beta = .09$; field of vision by temporal occlusion by expertise, $Fs(8,80) = 1.41$, $p = .21$, $f = .37$, $1\text{-}\beta = .14$.

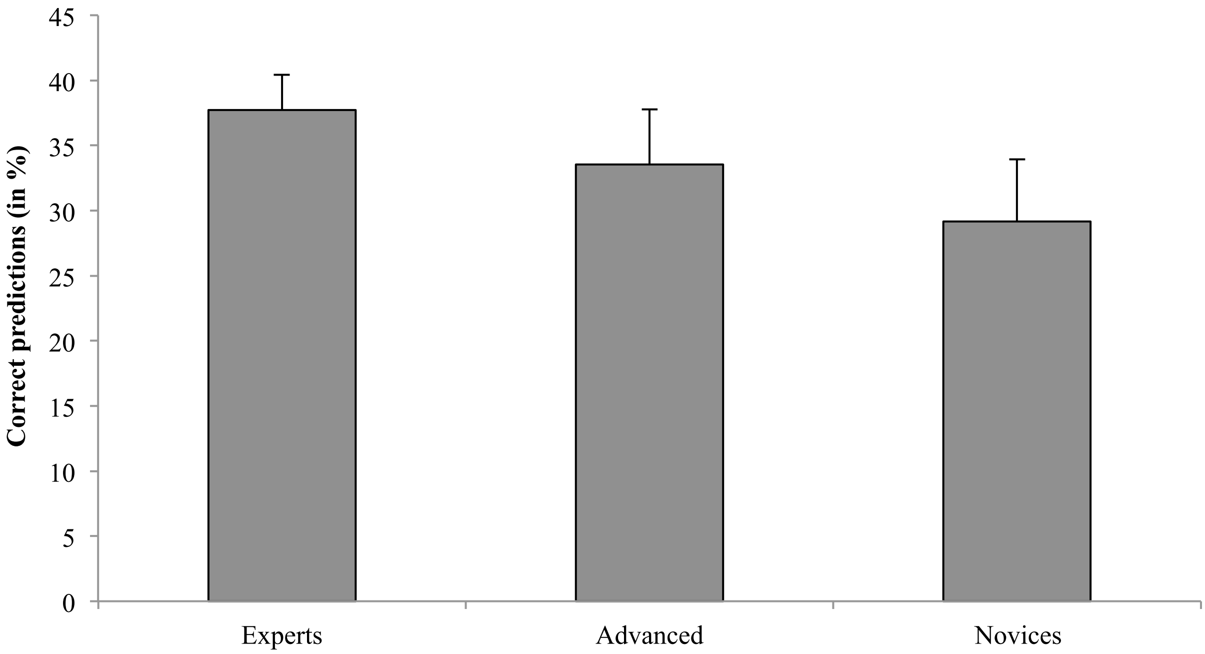

Figure 1. Comparison of correct predictions differentiated by varying skills group (in %)

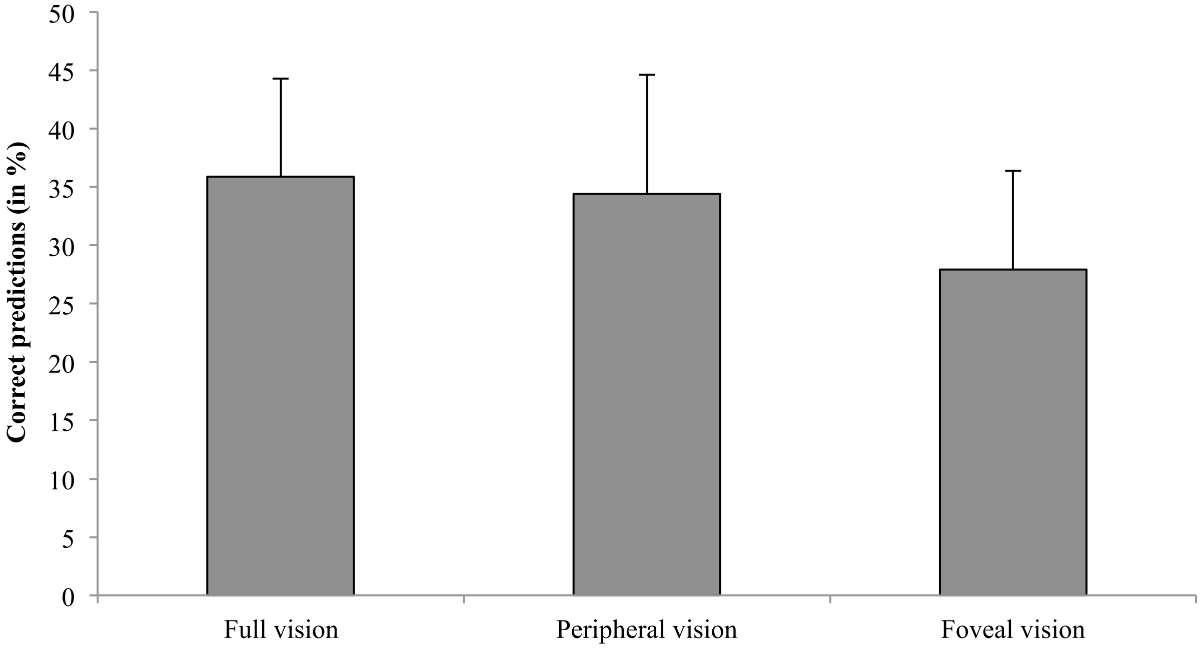

Figure 2. Comparison of correct predictions differentiated by varying fields of vision (in %)

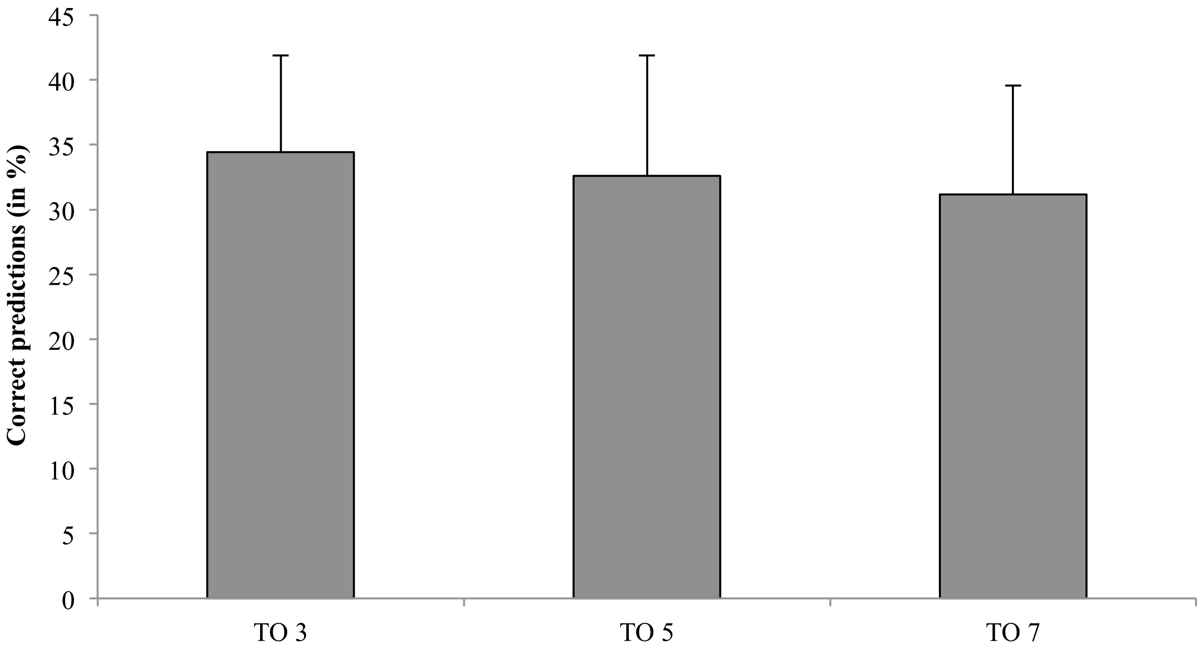

Figure 3. Comparison of correct predictions differentiated by temporal occlusion conditions (in %)

Number of fixations

An analysis of variance with one between (expertise) and two within factors (fields of vision and temporal occlusion) showed significant differences for fields of vision, $F(2,40) = 6.46$, $p < .01$, $f = .56$. As can be seen in Figure 4, the highest number of fixations was demonstrated by participants in the full vision condition. For both other conditions numbers were reduced similarly. There were no significant differences between expertise levels, $F(2,20) = 1.26$, $p = .31$, $f = .35$, or between temporal occlusion conditions, $F(2,40) = 0.81$, $p = .45$, eta = .04, $f = .20$. Additionally, no interactions were significant: fields of vision by expertise $Fs(4,40) = 1.90$, $p = .13$, $f = .44$, $1\text{-}\beta = .28$; temporal occlusion x expertise, $Fs(4,40) = 0.25$, $p = .91$, $f = .18$, $1\text{-}\beta = .08$; field of vision by temporal occlusion, $Fs(4,80) = 0.75$, $p = .56$, $f = .20$, $1\text{-}\beta = .09$; field of vision by temporal occlusion by expertise, $Fs(8,80) = 1.09$, $p = .38$, $f = .33$, $1\text{-}\beta = .12$.

Fixation patterns

On an exploratory level, the heat maps suggested differences between groups. As can be seen in Figure 5, the advanced and expert players showed varying strategies between visual conditions. For the foveal and full vision conditions, they demonstrated a two 'hot-point' strategy with red centers on the setter and the receiver. This strategy was only remotely visible for the peripheral vision condition. For the novices, the strategy of looking for the setter was not evident. In all three conditions, novices mainly looked at the center of the field. In the full vision condition, there was an extension of fixations to a spot above the net for all three groups. This is the spot where the served ball usually went through.

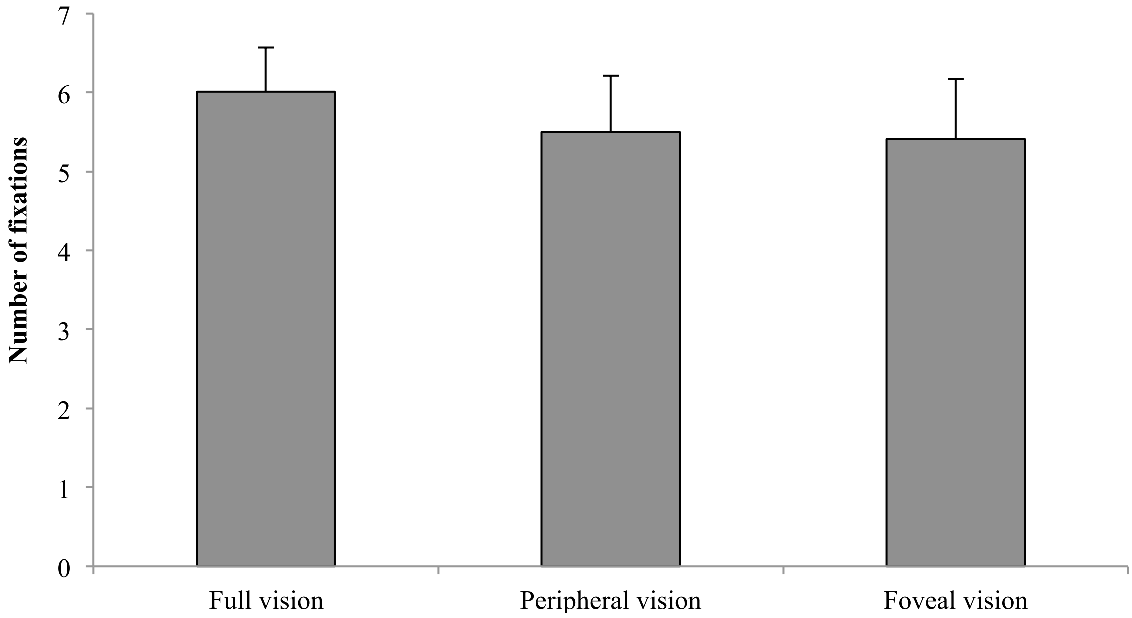

Figure 4. Comparison of number of fixations differentiated by varying fields of vision

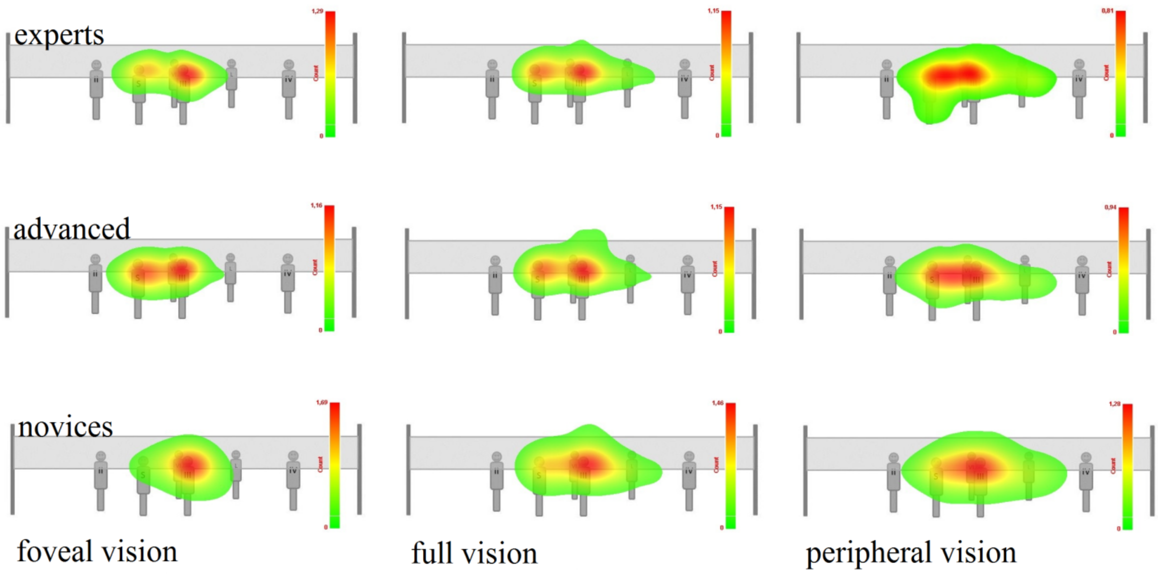

Figure 5. Heat maps of fixations differentiated by skill level and fields of visions

Discussion

Generally, this study examined three objectives. First, we considered prediction differences between varying skill levels of older aged volleyball players. Second, we investigated the contribution of different parts of the field of vision on the anticipation of the opponents' behavior. Finally, we explored the interaction of those two factors. Below we discuss these objectives in turn.

Concerning the expertise effects between the three skill levels, we expected differences in the percentage of correct predictions (Ericsson & Williams, 2007; Gilis, Helsen, Catteeuw, & Wagernans, 2008; Williams & Abernethy, 2012) as well as differences in the number of fixations (Williams & Davids, 1998). We found a large effect for correct predictions (f = .90) with post-hoc tests showing differences between experts and novices, but not between advanced players and the other groups. Previous research with active female players has demonstrated significant differences between all three groups, but in this study the expertise effect (f = 1.13) was considerable bigger (Schorer et al., 2013).

Contrary to our hypothesis, there were no significant differences for number of fixations between expertise groups. Previous research with older experts by Schorer and Baker (2009) also showed no differences in number of fixations between adults and seniors in handball goalkeeping and Schorer et al. (2013) found only slight differences in number of fixations between skill groups in the same volleyball task with young adults. Together, those findings indicate that number of fixations might not be a distinguishing characteristic for older experts in volleyball. This might be partly explained by the affordances of the task presented here, in which a 'logical' sequence of fixations would be from the receiver to the setter of the opposing team. This is partly supported by the heat maps, where all groups show very similar areas of fixations (as can be seen in Figure 5). Additionally, our use of spatial occlusion might explain part of this finding if this resulted in a disturbance of the structure of presented stimuli. While the heat maps do not suggest this (because they look very similar between conditions), the influence of the spatial occlusion task should be explored in further work. For instance, future studies should consider programming an occlusion technique that erases the occluded area with background instead of a black occlusion (cf. Müller, Abernethy, & Farrow, 2006). Alternatively, the lack of differences in fixations might simply reflect an age-related loss in this element of expertise. Future research should investigate this question using tasks in which the afforded sequences of fixations are less determined than in our task.

Our second aim was to investigate the contribution of varying fields of vision for the anticipation of an opponent's behavior. Here similar lines of results were observed for correct predictions as well as number of fixations. For both dependent variables we found significant differences between field of vision conditions: the full vision condition was always solved best, while the foveal vision condition was performed worst. Additionally, fields of vision did not interact with expertise in this study. This is in contrast to a previous study on younger players, in which the interaction of expertise and field of vision was significant and the foveal vision condition was performed better than the peripheral vision condition in experts but not in novices (Schorer et al., 2013). One interpretation of these results is that in older volleyball players, foveal information (mainly from the setter) is less important than peripheral information (including most other players). Initially, this seems counterintuitive because the person often orchestrating the play is the setter; however, the results from the temporal occlusion task might support this hypothesis. As mentioned above, most studies show that occluding vision at earlier stages results in progressively worse effects on prediction accuracy (Baker, Farrow, Elliott, & Anderson, 2009; Farrow, Abernethy, & Jackson, 2005;

Hagemann, Schorer, Cañal-Bruland, Lotz, & Strauß, 2010; Mann, Abernethy, & Farrow, 2010; Müller, Abernethy, Eid, McBean, & Rose, 2010). This was not the case in our study. While the line of results of the means of the three conditions demonstrated the hypothesized direction the variance around them was large. If one assumes that temporal affordances in senior volleyball play less of a role than in junior volleyball, presumably because the game itself gets slower with age, then temporal constraints might not apply for older players as they do for younger ones. Currently, we are aware of no study investigating the temporal constraints of the game in different age groups, but anecdotal evidence from coaches we have interacted with makes this assumption seem reasonable. This would seem especially interesting in the light of the compensation hypothesis (Baker et al., 2007; Charness, 1981; Salthouse, 1984; Schorer & Baker, 2009), which predicts adaptations in one component of skill to losses in another as the result of continued training in a constantly demanding environment. In our case with continued training, the changing environment and its resultant less demanding constraints might lead to a loss of skill. This adaptation would seem logical because skills are ultimately adaptations to the highly specific demands of the performance environment and as this environment changes the skills required should also change. To test this assumption and this adaptation hypothesis, future studies should account for the temporal requirements of varying age groups.

This study adds to a surprisingly limited literature regarding how skilled perception changes with age. Ultimately, our results lead to more questions than answers and provide several interesting avenues for further work. However, given the importance of skill maintenance and age, greater attention to this area would be worthwhile.

References

Abernethy, B., & Russell, D. G. (1987). Expert novice differences in an applied selective attention task. *Journal of Sport Psychology, 9*(4), 326-345.

Alves, H., Voss, M., Boot, W. R., Deslandes, A., Cossich, V., Inacio Salles, J., & Kramer, A. F. (2013). Perceptual-cognitive expertise in elite volleyball players. *Frontiers in Psychology, 4*. doi: 10.3389/fpsyg.2013.00036

Andersen, G. J. (2012). Aging and Vision: Changes in Function and Performance from Optics to Perception. *Wiley Interdisciplinary Reviews: Cognitive Science, 3*(3), 403-410. doi: 10.1002/wcs.1167

Baker, J., Deakin, J., Horton, S., & Pearce, G. W. (2007). Maintenance of skilled performance with age: A descriptive examination of professional golfers. *Journal of Aging and Physical Activity, 15*(3), 300-317.

Baker, J., Farrow, D., Elliott, B., & Anderson, J. (2009). The influence of processing time on expert anticipation. *International Journal of Sport Psychology, 40*(4), 476-488.

Baker, J., & Schorer, J. (2009). Maintenance of skilled performance with age: Lessons from the Masters. In J. Baker, S. Horton & P. L. Weir (Eds.), *Masters athletes: Understanding the role of exercise in optimizing aging* (pp. 66-78). London: Routledge.

Baker, J., & Schorer, J. (2010). Maintenance of skilled performance with age: lessons from the masters. In J. Baker, S. Horton & P. L. Weir (Eds.), *The master athlete. Understanding the role of sport and exercise in optimizing aging* (pp. 66-78). New York: Routledge.

Berke, A. (2009). Alter und Sehen. *Deutsche Optikerzeitung, 4*.

Bosman, E. A. (1993). Age-related differences in the motoric aspects of transcription typing skill. *Psychology and Aging, 8*(1), 87-102. doi: 10.1037/0882-7974.8.1.87

Brach, M., & Schott, N. (2003). Motorisches Lernen im Alter. In H. Mechling & J. Munzert (Eds.), *Handbuch Bewegungswissenschaft-Bewegungslehre*. Schorndorf: Verlag Karl Hofmann.

Buscher, G., Biedert, R., Heinesch, D., & Dengel, A. (2010). *Eye tracking analysis of preferred reading regions on the screen*. Paper presented at the Conference on Human Factors in Computing Systems - Proceedings.

Charness, N. (1981). Search in chess: Age and skill differences. *Journal of Experimental Psychology: Human Perception and Performance, 7*(2), 467-476.

Cutrell, E., & Guan, Z. (2007). *What are you looking for?: An eye-tracking study of information usage in Web search*. Paper presented at the Conference on Human Factors in Computing Systems - Proceedings, San Jose.

Einkauf, D. K., Gohdes, M. L., Jensen, G. M., & Jewell, M. J. (1987). Changes in spinal mobility with increasing age in women. *Physical Therapy, 67*(3), 370-375.

Ericsson, K. A. (2012). Training history, deliberate practise and elite sports performance: an analysis in response to Tucker and Collins review—what makes champions? *British Journal of Sports Medicine*. doi: 10.1136/bjsports-2012-091767

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406.

Ericsson, K. A., & Williams, A. M. (2007). Capturing naturally occurring superior performance in the laboratory: Translational research on expert performance. *Journal of Experimental Psychology: Applied, 13*(3), 115-123. doi: 10.1037/1076-898x.13.3.115

Etnier, J. L., Sibley, B. A., Pomeroy, J., & Kao, J. C. (2003). Components of response time as a function of age, physical activity, and aerobic fitness. *Journal of Aging and Physical Activity, 11*(3), 319-332.

Farrow, D., Abernethy, B., & Jackson, R. C. (2005). Probing expert anticipation with the temporal occlusion paradigm: Experimental investigations of some methodological issues. *Motor Control, 9*(3), 330-349.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191. doi: 10.3758/BF03193146

Fischer, L., Rienhoff, R., Tirp, J., Baker, J., Strauss, B., & Schorer, J. (2015). Retention of Quiet Eye in Older Skilled Basketball Players. *Journal of Motor Behaviour*, 1-8. doi: 10.1080/00222895.2014.1003780

Gilis, B., Helsen, W., Catteeuw, P., & Wagernans, J. (2008). Offside decisions by expert assistant referees in association football: Perception and recall of spatial positions in complex dynamic events. *Journal of Experimental Psychology: Applied, 14*(1), 21-35. doi: 10.1037/1076-898x.14.1.21

Hagemann, N., Schorer, J., Cañal-Bruland, R., Lotz, S., & Strauß, B. (2010). Visual perception in fencing: Do the eye movements of fencers represent their information pickup? *Attention, Perception, & Psychophysics, 72*(8), 2204-2214. doi: 10.3758/APP.72.8.2204

Helsen, W. F., & Starkes, J. L. (1999). A new training approach to complex decision making for police officers in potentially dangerous interventions. *Journal of Criminal Justice, 27*(5), 395-410.

Horton, S., Baker, J., & Schorer, J. (2008). Expertise and aging: maintaining skills through the lifespan. *European Review of Aging and Physical Activity, 5*(2), 89-96. doi: 10.1007/s11556-008-0034-5

Jafarzadehpur, E., Aazami, N., & Bolouri, B. (2007). Comparison of saccadic eye movements and facility of ocular accommodation in female volleyball players and non-players. *Scandinavian Journal of Medicine & Science in Sports, 17*(2), 186-190. doi: 10.1111/j.1600-0838.2005.00535.x

Jay, C., Stevens, R., Glencross, M., Chalmers, A., & Yang, C. (2006). How people use presentation to search for a link: Expanding the understanding of accessibility on the web. *Universal Access in the Information Society, 6*(3), 307-320.

Krampe, R. T., & Ericsson, K. A. (1996). Maintaining excellence: Deliberate practice and elite performance in young and older pianists. *Journal of Experimental Psychology: General, 125*(4), 331-359. doi: 10.1037//0096-3445.125.4.331

Mann, D. L., Abernethy, B., & Farrow, D. (2010). Action specificity increases anticipatory performance and the expert advantage in natural interceptive tasks. *Acta Psychologica, 135*(1), 17-23.

Müller, S., Abernethy, B., Eid, M., McBean, R., & Rose, M. (2010). Expertise and the spatio-temporal characteristics of anticipatory information pick-up from complex movement patterns. *Perception, 39*(6), 745-760. doi: 10.1068/p6438

Müller, S., Abernethy, B., & Farrow, D. (2006). How do world-class cricket batsmen anticipate a bowler's intention? *Quarterly Journal of Experimental Psychology, 59*(12), 2162-2186. doi: 10.1080/02643290600576595

Salthouse, T. A. (1984). Effects of age and skill in typing. *Journal of Experimental Psychology: General, 113*(3), 345-371. doi: 10.1037/0096-3445.113.3.345

Schorer, J., & Baker, J. (2009). An exploratory study of aging and perceptual-motor expertise in handball goalkeepers. *Experimental Aging Research, 35*(1), 1-19. doi: 10.1080/03610730802544641

Schorer, J., Rienhoff, R., Fischer, L., & Baker, J. (2013). Foveal and Peripheral Fields of Vision Influences Perceptual Skill in Anticipating Opponents' Attacking Position in Volleyball. *Applied Psychophysiology and Biofeedback, 38*(3), 185-192. doi: 10.1007/s10484-013-9224-7

Starkes, J. L., & Deakin, J. (1984). Perception in sport: a cognitive approach to skilled performance. In W. F. Straub & J. M. Williams (Eds.), *Cognitive sport psychology* (pp. 115–128). Lansing, NY: Sport Science Associates.

Tucker, R., & Collins, M. (2012). What makes champions? A review of the relative contribution of genes and training to sporting success. *British Journal of Sports Medicine, 46*(8), 555-561. doi: 10.1136/bjsports-2011-090548

Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 342-354. doi: 10.1037//0096-1523.22.2.342

Williams, A. M., & Abernethy, A. B. (2012). Anticipation and decision making. In G. Tenenbaum, R. Eklund & A. Kamata (Eds.), *Measurement in sport and exercise psychology* (pp. 191-202). Champaign IL: Human Kinetics.

Williams, A. M., & Davids, K. (1998). Visual search strategy, selective attention, and expertise in soccer. *Research Quarterly for Exercise and Sport, 69*(2), 111-128.

Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1994). Visual-search startegies in experienced and inexperienced soccer players. *Research Quarterly for Exercise and Sport, 65*(2), 127-135.

World-Medical-Association. (2008, 6. November 2009). Declaration of Helsinki - Ethical principles for medical research involving human subjects. from http://www.wma.net/en/30publications/10policies/b3/index.html.
Yarrow, K., Brown, P., & Krakauer, J. W. (2009). Inside the brain of an elite athlete: the neural processes that support high achievement in sports. *Nature Reviews Neuroscience, 10*(8), 585-596. doi: 10.1038/nrn2672
Young, L. R., & Sheena, D. (1975). Survey of eye movement recording methods. *Behavior Research Methods & Instrumentation, 7*(5), 397-429.

The Authors

Lennart Fischer is a teacher in mathematics, physical education and computer science. Furthermore he is PhD Student at the University of Muenster in the Institute of Sport and Exercise Sciences. His research interests are the life-span especially perceptual expertise, visual attention and eye tracking.

Joe Baker is head of the Lifespan Health and Performance Laboratory at York University in Toronto, Canada. His research considers the development and maintenance of expertise across the life-span from multiple perspectives.

Judith Tirp is a PhD Student in the Department of Sport and Movement Science at the University of Oldenburg. Her research examines factors in perceptual-cognitive expertise.

Rebecca Rienhoff finished her PhD at the University of Muenster in the Institute of Sport and Exercise Sciences. Her specific research interests during the PhD focus on the field of expertise, especially perceptual expertise, attention and motor learning.

The Authors (continued)

Dr. Bernd Strauss is a professor for Sport Psychology in the Institute of Sport And Exercise Sciences at the University of Muenster, Germany as well as Co-Editor-in-chief of Psychology of Sport and Exercise (Elsevier). His research focusses on Expertise in Sports, social processes and research methodology.

Dr. Jörg Schorer is a full professor at the University of Oldenburg. He is currently the vice-dean at the School of Humanities and Social Sciences and Head of the Institute of Sport Science. His research looks at expertise in sport across the life-span.