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Perceptual-Cognitive Training of Athletes

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This present article discusses an approach to training high-level athletes' perceptual-cognitive skills. The intention herein is to (a) introduce concepts in regard to what may be required by athletes to optimally process sports-related visual scenes at the perceptual-cognitive level; (b) present an experimental method of how it may be possible to train this capacity in athletes while discussing the necessary features for a successful perceptual-cognitive training outcome; and (c) propose that this capacity may be trainable even among the highest-level athletes. An important suggestion is that a simple difference between sitting and standing testing conditions may strongly influence speed thresholds with this task, which is analogous to game movement dynamics in sports, indicating shared resources between such high-level perceptual-cognitive demands and mechanisms involved in posture control. A discussion follows emphasizing how a perceptual-cognitive training approach may be useful as an integral component of athletic training. The article concludes with possible future directions.

Keywords: perceptual-cognitive training, sport, athlete, concussion, injury

One of the most formidable tasks for the brain of an athlete during game play is to perceive and integrate complex moving patterns while allocating attentional resources in different key areas of the dynamic scene. One must integrate the information over variable visual field areas (i.e., one cannot attend only to a small area). Furthermore, the movements of the players and the object of play (such as the ball or puck) can be extremely fast and variable, and they can abruptly change speeds. The trajectory paths of these elements can also be quite unpredictable, with sudden changes in direction and shape with numerous occlusions and segmentations, such as objects blocking the view of others or disappearing from view. As the level of the sport increases, the rapidity at which these mental tasks must to be performed also increases. Notwithstanding basic physiological capacities and hard work, the combination of complexity and speed of the perceptual-cognitive

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processing required by athletes may potentially be one of the main determining factors as to whether athletes will graduate to and function well at superior levels.

Indeed, a defining characteristic of dynamic team sports such as football, hockey, soccer, rugby, and basketball, is the need to pay attention to several members of the opposition as well as key teammates during critical phases of play. For example, when a defender is responsible for blocking an oncoming attacker in possession of the ball or puck, the athlete must anticipate his or her strategy by perceiving opportunities for (a) oncoming movement into free space by judging distances between oneself and other defenders, (b) passing to other attackers, (c) determining the likelihood of teammates intercepting points (a) or (b) above, and (d) further passes by potential attacking receivers. At elite levels, these perceptions need to be based on moment-by-moment tracking, especially as attacking play will regularly involve concerted efforts to move along unpredictable paths to temporarily deceive defenders.

Sports science research has established that how an athlete perceives and reacts to a set of stimuli is a crucial element of top-level competitive sports (Williams, Davids, & Williams, 1999). Skilled athletes are proficient in the anticipation of opponent actions, and it has been noted that they are superior to novices in pattern recall and strategic awareness in team sports such as soccer (Williams, 2000). This kind of awareness is believed to be a constituent of skill rather than a characteristic of experience (Williams & Davids, 1995). Studies have also suggested that playing experience is not necessarily a determining factor when testing visually determined anticipatory ability between elite and subelite players (Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007).

Training All Aspects Except Perceptual-Cognitive Function

Physical preparation, training and rehabilitation tools, and coaching and conditioning techniques have all improved dramatically over the past 20 years. With the advent of new performance recording and statistical analysis systems across many team sports, high-level game strategy also has the potential of significant advancement (Barris & Button 2008). Even techniques that attempt to modulate brain activity via biofeedback and neurofeedback are making their way into some training protocols. Yet while these other techniques are available, there has still been very little inclusion of dynamic perceptual-cognitive training in the professional sport domain. While not much has been researched or written on the topic, herein, we propose the possibility that these perceptual-cognitive abilities are both a critical component of elite performance generally, and that they are trainable, and we suggest that perhaps there may be room to consider the need for conditioning higher-level visual processing of dynamic scenes and to be able to implement this at a practical level.

There is often a misconception that training low-level vision is sufficient; however, it may not be. Good vision is critical, of course, including binocular vision, visual field, and other visual modalities. Yet, good visual capacities should not be confused with what the brain needs to process in complex dynamic scenes. One of classic methods introduced in sports is the reaction time training for lights that appear in the peripheral visual field (Wood & Abernethy, 1997). However efficient this process may be to sharpen reflexive responses to lights flashing on and off in the periphery, this is nonetheless a very low-level visual processing requirement. Researchers specializing in visual motion perception have suggested that what is required to detect and react to a stationary light flash (temporal processing) is quite different than what is required for processing complex motion in dynamic visual scenes (Blaser & Sperling, 2008). Sports specific studies show that the former does not differentiate elites athletes from their novices counterparts, whereas the latter clearly does (Mori, Ohtani, & Imanaka, 2002), and that evidence for training visual function to improve sport performance is generally lacking (Starkes & Anderson, 2003). Rather, it may be the ability to process relevant perceptual cues and enhanced search strategies that define the top-level athlete. This possibility has been previously suggested in a meta-analysis on cognitive functioning visual systems among soccer players (Mann, Williams, Ward, & Janelle, 2007), and Garland and Barry (1990) further proposed that it is the perceptual-cognitive abilities of sport participants that give them the edge. While research conducted to date couples perceptual cognitive ability with elite ability in a compelling way, studies have not shown that improvements in perceptual cognitive function actually lead to elite performance. While this may be due to the relatively new emergence of this area of sports science as well as the challenges of implementing substantially relevant training regimes to monitor the effects, efforts to improve perceptual-cognitive functioning for the enhancement of athletic performance must be seen as experimental at this time until further empirical investigation clarifies this relationship.

Brain Plasticity and Modulation

In a broad manner, we have so far outlined perceptual-cognitive ability as higher level processing of complex visual information and discussed its possible role generally within sports and at elite levels. Before discussing a training methodology that has recently been implemented in elite team sports, a preceding question should be asked: Are these abilities trainable? Mahncke and colleagues (2006) have suggested in the neuroscience domain that capacities are trainable and the brain is high in plasticity. That is, there are clear underlying neural reorganizations of neural tissue and networks when learning new capacities (Draganski & May 2008) or when new brain networks take over damaged brain tissue (Bridge, Thomas, Jbabdi, & Cowey, 2008). For instance, brain-imaging studies have shown complete reorganization to allow for sensory substitution (Kupers, Chebat, Madsen, Paulson, & Ptito, 2010), and network reorganization has been demonstrated after training (Ma et al., 2010).

Perceptual-Cognitive Training

The perceptual-cognitive training program we propose is comprised of four features that are assumed to reflect an optimal training condition. It includes (a) distributed attention on a number of separate dynamic elements known in the literature as multiple object tracking (MOT; Cavanagh & Alvarez, 2005), (b) a large visual field, (c) speed thresholds, and (d) stereoscopy (binocular depth cues). We will first describe such a task, and then elaborate on the specific necessary elements mentioned above.

Figure 1 illustrates the primary stages of a given perceptual-cognitive task. First a predetermined number of spheres (typically eight) are presented in a 3D virtual volumetric cube space (see Figure 1a). The spheres are typically all identical, then, a subset of spheres (typically four) is indexed via highlighting (here, halos; see Figure 1b) for a brief period of 1 s. Then, the spheres return to their original color and start moving within the restricted 3D virtual space. During this movement, the spheres can collide and consequently suddenly change direction, and they can cross over others, thus occluding their view (see Figure 1c). Finally, the spheres stop moving after a predetermined time, and the observer has to identify the spheres that were initially indexed with halos (see Figure 1d). The subject is then given feedback on the response by having the spheres identified by revealing the appropriate indexed stimuli (see Figure 1e). The main task starts at a given speed, and if all four spheres are not correctly identified, the next trial will be slower. If the four spheres are correctly identified, then the next trial will be faster. Trials are repeated like this following a staircase procedure, and ultimately, a speed threshold is established (Levitt, 1971).

MOT

The MOT task was first introduced by Pylyshyn and colleagues (Pylyshyn, 1994; Pylyshyn & Storm, 1988) to determine how people track multiple elements. Generally, MOT is a task where observers are asked to maintain attentional focus on a limited number of preselected subgroup of elements in a dynamic scene where all elements interact either by bouncing off each other or occluding one another. Although the original work was developed in support of the FINST theory (for FINgers of INSTantiation), which proposes that multiple elements have individual indexes (Pylyshyn, 1991), recent research generally proposes that multifocal attentional mechanisms are necessary to process such information (Cavanagh & Alvarez, 2005). Notwithstanding the mechanisms underlying this capacity, the ability to track multiple elements (including players and the ball or puck) is a capacity that is highly solicited in sports and in particular, team sports. Figure 2 illustrates a soccer goalkeeper's perspective in a given game situation. The keeper must be able to attend to the ball, teammates, and opponents during game play. Therefore,

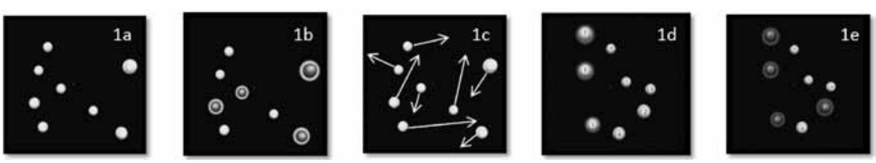

Figure 1 — Illustration of the five critical phases in a standard perceptual-cognitive core training session: (a) presentation of randomly positioned spheres in a virtual volumetric space, (b) identification of the spheres to track during trial, (c) removal of identification and movement of all spheres with dynamic interactions, (d) observer's response by identifying the spheres, (e) feedback is given to the observer. If the observer correctly identifies all four spheres, the task is repeated at a faster speed. On the other hand, if the observer makes a mistake, the task is repeated at a slower speed.

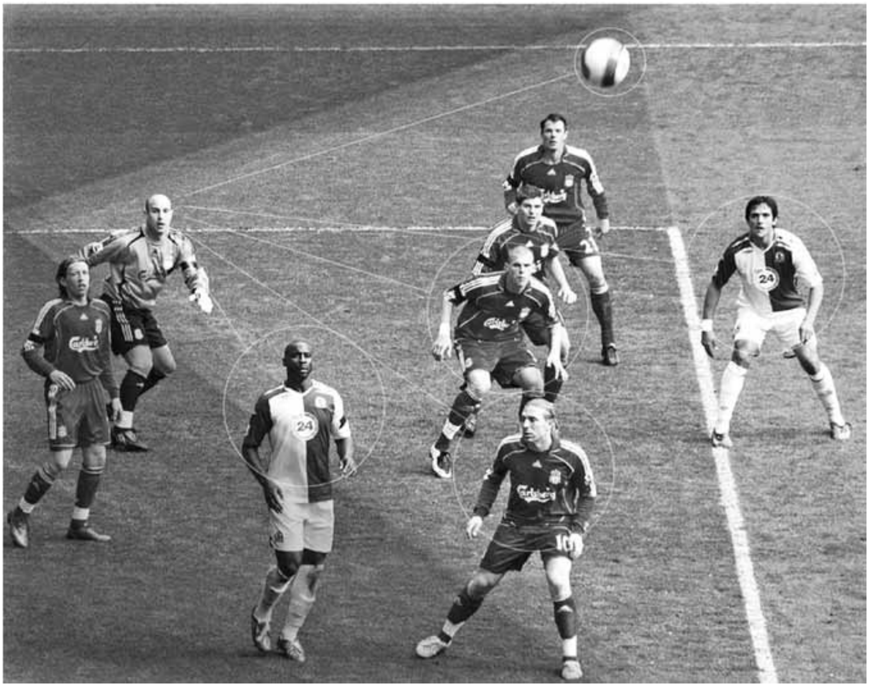

Figure 2 — Illustration of several core principles from a goalkeeper's (GK) perspective during live action that relates to the perceptual-cognitive task: (a) the GK must track multiple elements, (b) the GK must track these elements using central but also large portions of the peripheral visual field, (c) the GK must efficiently use information from a large area of the visual field, (d) the GK must process all of this information at very fast speeds.

improving the capacity to maintain the tracking capacity of multiple elements theoretically becomes a desirable trait to train. Previous studies have shown that most people can generally track four to sometimes five elements depending on the condition and population (Fougnie & Marois, 2006). Healthy adults generally can track four elements, while older adults appear to be limited to three under standard conditions (Trick, Perl, & Sethi, 2005). This ability to track multiple objects in a dynamic sports environment has been identified as potentially important to reacting swiftly and effectively (Willams, Hodges, North, & Barton, 2006). As we will discuss later, when tested on this isolated ability, elite athletes average higher than sub-elite athletes, but with variation, and also with capacity for improvement across all levels.

Large Visual Field

In team sports, critical information arises throughout the athlete's visual field, and as an individual's central field of focus is approximately 3 degrees, most action occurs in the peripheral visual field (Knudson & Kluka, 1997). Figure 2 illustrates that the important integration area required to process the dynamic situation is distributed over a large visual field. A general misconception is that team sport athletes continuously change their focus moment-by-moment to cover variously distributed sources of information (“search strategy”). However, during intensive play, these distinct attentional needs are so numerous and so widely spread that such a fluidity of temporary fixations would leave the athlete with a very high ratio of perceptual blur, continually saccading from point to point (Williams, Davids, Burwitz, & Williams, 1994). This segmentation of concatenated snapshots may then leave the athlete largely uniformed on movement evolving throughout the scene. Studies have shown that a defining characteristic between elite and subelite athletes is the ability to centralize gaze direction to spread attention, thereby increasing rates at which critical information can be acquired and assimilated (sometimes referred to as “saccadic suppression”; Williams, 2002).

Similarly, as the ball is tracked, critical information can confront the athlete anywhere within the visual field. A further need to centralize gaze comes from the advantage of reading body language cues of key opponents (especially those in possession) to anticipate immediate moves or passes (Nagano, Kato, & Fukuda, 2006; Savelsbergh, van der Kamp, Williams, & Ward, 2005). In these situations, players must concentrate on both a localized region and the dynamics of the surrounding scene, simultaneously. Overall then, the needs for sustained peripheral attention are frequent, and for the elite team sport athlete, this in turn increases both attentional capacity and attentional load. The capacity to deal with a large and dynamic visual field is thus theoretically likely to be an advantage for experts across team sports, affording a greater range of game action cues from peripheral sources while fixating on a central point in the scene (Haywood, 1984).

Therefore, it is viable to suggest that an important component of a MOT training system for sport is a large visual field, for which a CAVE (Cave Automatic Virtual Environment) type environment is employed (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992). For instance, one perceptual-cognitive program uses controlled light conditions, and an 8 ft square quality projection affords a large visual field. To support an effective distribution of attention, an instructed part of the training task is to focus on a “visual pivot,” a small dot in the center of the screen, throughout the tracking phase. Shifting attention between objects without eye movement has been suggested (Sears & Pylyshyn, 2000). The cubed virtual volume means that the tracking demands are spread optimally throughout the visual field, with no bias toward horizontal over vertical motion.

Speed Thresholds

One possible methodological advantage of using speed as a dependent variable in a perceptual-cognitive system such as the one previously mentioned is that the values can vary on a continuous ratio scale. This contrasts with the limitation of the “number of tracked elements” method most frequently used in standard MOT experiments. Typical experiments will use a fixed speed and will assess the percentage of correct responses for a given number of items (Fougnie & Marois, 2006). For instance, a number of observers can be established as being able to track four objects simultaneously as an upper limit, but there could still be large differences in the individual capabilities to track the elements. As will be discussed in more detail later, this becomes clear when using speed as the dependent measure, where it appears that large individual differences between high-level athletes can be observed.

With speed suggested to be a possible relevant and controllable measure of perceptual-cognitive MOT demands, it is also important to take into account the concept of "interaction," namely, that when the spheres increase movement speed, they collide and cross over more frequently. When spheres collide with each other and the boundaries of the virtual volume, sudden changes in direction need to be addressed by the observer to avoid losing track and are generally anticipated for a better handle on trajectory expectations (Lordanescu, Grabowecky, & Suzuki, 2009). Sphere crossovers, once correctly predicted or detected as not being collisions, require allocation of working memory resources to maintain subvisual tracking while out of sight (Zhang, Xuan, Fu, & Pylyshyn, 2010). For MOT using four targets, as opposed to 2–3, the occlusions themselves create an additional level of difficulty (Zelinsky & Todor, 2010). The sphere interactions may also occur simultaneously and in multiple places within the virtual volume. Competent trajectory tracking, then, widens MOT demands on perceptual-cognitive functions. Increases in speed may create more of these events, with higher speeds increasing the challenge of MOT, not just in velocity, but also the rate of interactions. This fits with previous research that has found that occlusions impact complex tracking effectiveness (Todor & Zelinsky, 2010).

An interesting behavior observed at just above threshold levels is a "juggling effect," whereby a relatively small increase in speed appears to create functional collapse in MOT capability (the equivalent of hitting a mental wall).[1]

Binocular 3D (Visual Stereoscopy)

When viewing the world with both eyes open, the image from the external world has slightly different perspectives, and these differences on the retina are called retinal disparities. It is this information that is used by the brain to construct the solid binocular three-dimensional (3D) impression that individuals perceive (Julesz, 1971). There remain questions as to what the additional benefit is of stereoscopy over the panoply of monocular depth cues available, but particularly, the champion of all monocular depth cues used to estimate relative depth is called motion parallax (Faubert, 2001). This debate recently drew attention when a paper by Oliver Sacks appeared in The New Yorker magazine (2006), reporting a striking recovery of binocular depth perception by Dr. Susan Barry after 50 years of life without it. Nevertheless, there is some evidence that stereoscopy can improve the ability to perform natural tasks (Sheedy, Bailey, Buri, & Bass, 1986), and online correction during reaching (Greenwald, Knill, & Saunders, 2005). The question then is whether the binocular 3D information can help with the speed threshold MOT task we are discussing here. We have seen that in a number of experimental conditions, the binocular 3D condition always generated superior speed thresholds than the binocular condition without disparity, with an average of 50% gain in the conditions tested (Tinjust, Allard, & Faubert, 2008). Therefore, the binocular 3D advantage may not be dependent on the afferent-efferent-reafferent combination of brain signals necessary for motor control. Rather, it may be an inherent property of visual processing, and it is proposed herein that the binocular 3D may possibly help relieve the spatial limitations of attention inherent in two-dimensional scenes (Intriligator & Cavanagh, 2001) when rapid decisions are required by the perceptual system during fast moving scenes.

Finally, it should be noted that a general but potentially important design facet of 3D-MOT may be the rudimentary simplicity of the task, which includes (a) fixating on the visual pivot, (b) tracking the indexed spheres, and (c) repeating with speed changes. This leaves little room for technique or strategy, and the approach after experience with many sessions remains essentially the same, likely making the effects of "practice" largely negligible. The high degree of functional isolation is intended to allow for measurement of actual perceptual-cognitive performance and directly associated training gains. Although the MOT task utilizes a high-degree of task specific functional isolation, the mental resources activated are potentially significantly large and require efficient integration across several domains of neurological functions. These perceptual-cognitive demands include complex motion integration, distributed attention, fluid-rapid processing, and visual working memory.

Our interest in using perceptual-cognitive tasks to improve perceptual-cognitive abilities was not restricted to athletes. Indeed, one can easily envision that the same kind of ability required to process fast dynamic scenes in sports is analogous to what is required when traveling through dense crowds or when driving. These tasks can be particularly challenging for older individuals or persons that have neurobiological alterations (Faubert, 2002; O'Hearn, Landau, & Hoffman, 2005). We have previously discussed perceptual-cognitive processing among other populations, such as healthy aging individuals (Faubert, Giroud, Tinjust, & Allard, 2009). It has been suggested that healthy aging affects perceptual-cognitive processes (Faubert, 2002), which can directly affect the capacity to process complex motion information (Bennett, Sekuler, & Sekuler, 2007; Habak & Faubert, 2000; Tang & Zhou, 2009) and divide attention throughout the visual field (Richards, Bennett, & Sekuler, 2006). Previous studies have shown that MOT was reduced in healthy aging (Sekuler, McLaughlin, & Yotsumoto, 2008; Trick et al., 2005). If deemed useful, the question then is whether this ability can be improved in all populations. A previous experiment by our own research team on perceptual-cognitive training of this task demonstrated that both young and older observers can significantly improve their perceptual-cognitive abilities (Faubert et al., 2009). For instance, four groups (two young groups, two older groups) took part in a 5-week program. The two control groups were tested the on the first week and the fifth week, while the experimental groups were trained further during weeks 2, 3, and 4. The training periods lasted approximately 30 min. The results in week 5 showed dramatic improvements in perceptual-cognitive abilities for the experimental conditions, as compared with the control conditions, even if the experimental groups started initially with identical values for given age category controls. This improvement varied from 30% to 70% over the controls. Furthermore, the trained older observers obtained scores that were statistically identical to the young control observers. Demonstrating that trained older observers can become as efficient as untrained young adults at this type of task (which has ecological relevance) is quite encouraging. We also conducted an unpublished pilot study with high-level athletes in a laboratory setting, which preliminarily showed gains in perceptual-cognitive abilities of 50% from this kind of training program.

Convergence With Sports Training Methodology

One might assume that athletes would already be proficient at perceptual tracking from constant exposure and conditioning over their athletic careers. Anecdotally, we have seen greater initial 3D-MOT capacity among elite athletes, yet major gains appear to be achievable with relatively minimal training. Here, it is important to expand on an earlier point regarding a lack of implementation of perceptual-cognitive training; specifically, that the progressive overload principle employed widely (Stone, Collins, Plisk, Haff, & Stone, 2000) for athletic physiological conditioning is generally left unattended for the cognitive domain (Kremer & Fleck, 2007).

There are many abilities that need to be managed for high-level sport performance, such as attention to biomechanical skill and assertion of physiological resources. Professional training regimes often involve breaking these down into their constituent elements (such as passing drills, shot practice and speed, and strength and cardio-vascular conditioning) and then training them at optimal levels. Isolated cognitive skills, however, rarely appear to overload to any significant degree.

In terms of perceptual-cognitive conditioning in competition, upper threshold 3D-MOT demands at decisive game moments on the field tend to be sporadic and quite brief. To take two examples, an estimate for the average time a professional player gains possession of the ball per soccer game is around 50 s (Carling, 2010), and typical NFL games contain plays mostly around 4–5 s with an average total of only 11 min of actual playtime (Biderman, 2010).

Taking into account the supposition that both isolation and overload needs for perceptual-cognitive conditioning appear to be inadequately attended to, a key value of perceptual-cognitive training is that it appears to be an ideal fit with sport science driven training methodology. Advantages may be accentuated compared with physical or skill based isolation and overload regimes. This may principally be because neuroplasticity appears to provide scope for significant functional gains within very short periods of training stimulation; indeed, evidence has been presented for activation-dependent cortical plasticity producing neuroanatomical structural changes within 5 days of intervention (May, Hajak, Gänßbauer, Steffens, Langguth, Kleinjung, & Eichhammer, 2007). Other possible qualities include training sessions that can be applied in acute packets (6–8 min per session), precise control of training quantity over time, and accurately recorded measurement and monitoring of the training process.

Perceptual-Cognitive Findings With Professional Athletes

In-field perceptual-cognitive training programs have been implemented at various stages throughout 2010 with world-class teams in the English Premier League (2), the National Hockey League (3), and rubgy (2). Although gathered data currently remains confidential, there are broad trends upon which initial comment can be made. Of course, the trends we mention will require empirical examination in future research to substantiate the anecdotal information provided herein. The most surprising anecdotal trend is a wide spread in initial perceptual-cognitive baselines (established after three core sessions), with the three highest player thresholds being between 90% and 170% greater than the lowest three within the same top tier team. This large ability contrast may hypothetically indicate a much more diverse variation of overall performance attributes from athlete to athlete than generally estimated, with greater related skill-set compensations of strengths over weaknesses. Additional investigation is necessary to better understand such findings.

Similarly unexpected has been the consistency with which the majority of athletes seem to improve; anecdotally, there appear to be no distinctly emergent trends that differentiate relative thresholds gains between lower and higher initial scorers. In addition, considering the preconditioned state of these elite athletes in general, it has been surprising how improvements have evolved over time. Within the NHL, a sport renowned for perceptual intensity, players have anecdotally shown relative gains in average Core thresholds of around 40% with 30 min of actual tracking stimulation time (15 sessions).

One challenge to obtaining data from competitive elite teams is the lack of control on usage, mainly through inconsistency of use at both individual and team levels (often influenced by hectic competition schedules and time on the road). Not surprisingly, this is a challenge inherent to any sports science driven studies that are conducted with elite teams across different sports as well as continents, and who are in the early stages of assimilating a new training approach. As of yet, it has been difficult to ascertain any upper limits on improvements with sustained long-term training. Anecdotally, improvement curves do appear to plateau over time, yet no ceiling has been found, even across those elite athletes who have trained beyond 40 sessions. Inconsistency of use has, however, allowed retention of gains to be examined, and losses of perceptual-cognitive form over extended breaks from training (1–2 months) have appeared negligible. While there can be significant fluctuations in thresholds from session to session, once threshold averages over three sessions or more increase, they appear to remain stable on a three-session basis (which may hypothetically be especially useful for concussion assessments). Similarly, positive training gains appear to remain even when athletes complete sessions interspersed by 2 or more weeks at a time. It is possible that a feedback effect between perceptual-cognitive training and in-field 3D-MOT conditioning may be mutually supportive. That is, as the total movement information the athlete perceives in-field becomes increased, this may provide greater stimulation than pretrained levels. These are hypotheses in need of further investigation and formal empirical testing.

This may also provide some explanation for why we have found that some athletes seem to have widely contrasting levels of 3D-MOT dexterity, initially; once they begin to operate at higher 3D-MOT levels, habitual mental activity may sustain the ability. Future empirical investigation should seek to determine whether those athletes who have endured prolonged injury bouts have significantly lower initial baselines. If they do, it may perhaps suggest perceptual-cognitive regression through long-term absence of game conditioning. If this was the case, it may imply that the challenge of returning to "game shape" is relevant cognitively, as well as physically.

Shared Resources

It is not so unusual to see professional athletes make low-level motor control mistakes such as ball fumbles or inaccurate passes and shots during highly charged game situations that rarely occur during practice. While there could be numerous reasons for this, one possibility is that the extremely high perceptual-cognitive demands that occur in particular game play situations deplete resources that are normally allocated to motor control behaviors such as ball handling or puck manipulation. It is theorized that practicing motor control could increase automaticity and reduce the demands during game situations. As suggested above, we believe that theoretically, the reverse may also be true, and that perceptual-cognitive training could possibly reduce processing requirements in critical game situations and consequently reduce the number of errors when manipulating objects.

One could theorize that posture maintenance is the most basic of the body controls and that high-level professional athletes already have success in this regard. It is possible, therefore, to test the above assumption about shared resources in its simplest form by testing perceptual-cognitive demands while players are standing as opposed to the usual sitting down position. If standing would affect the thresholds obtained with perceptual-cognitive techniques in high-level athletes, this would lend some support to the possibility that perceptual-cognitive functions and motor control mechanisms share common resources. The following section shows data that we have obtained with three professional teams from distinct sports while the players were sitting down along with data from another team that performed the same testing conditions while standing throughout the training sessions.

Group Trends

Standard Testing Condition. While preserving anonymity, Figure 3 shows the results that have been obtained in the field from three professional teams in three very different sports. We show an example of an English Premier Team club, a hockey team from the National Hockey League, and a rugby team from the European Rugby that were all tested in the standard sitting down position to isolate the perceptual cognitive function and minimize any influence from other mechanisms involved in posture control. The field data represent geometrical mean thresholds for the teams on a log scale as a function of training session. The data show a little more variance as the number of sessions increase because fewer players have completed trials. To compare with the measures made in the laboratory where a threshold was taken as the average of three testing sessions, each measure on the sessions scale represents the average of the three previous sessions. What can be seen from the graph is that, on average, the three professional sports teams show identical perceptual-cognitive progression. The data are well fit with a simple log regression and the R2 values are extremely high ranging from 0.88 to 0.97. That means that 88–97% of the variance of the data can be explained by this fit. The highest R2 value in the Figure comes from the team with the most players tested for each session number. The functions show an expected rapid progression that slows down but they also indicate that the teams have not saturated in their improvements.

Standing Condition. Data obtained from an additional NHL hockey team are shown where all the testing was performed in identical conditions as the other three teams except for the unique fact that the players were standing up while conducting the measures. The results suggest that the players' thresholds are directly affected by the fact that they were tested standing up. The magnitude of this effect is quite surprising and clearly demonstrates the link between balance control mechanisms and perceptual-cognitive demands solicited by perceptual-cognitive techniques,

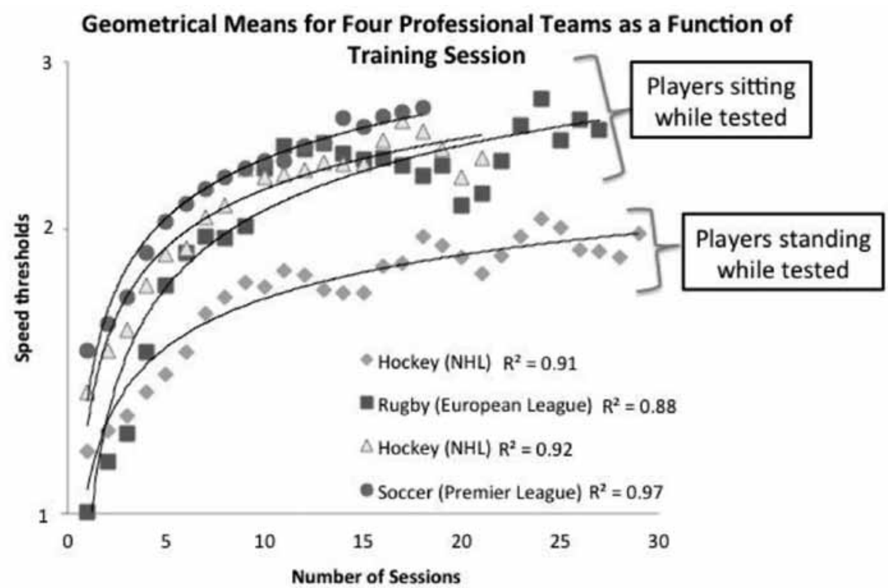

Figure 3 — Geometrical speed threshold means for four professional teams from three different sports as a function of testing session. The teams represent a soccer team from the English Premier League (circles), an ice hockey team from the National Hockey League (triangles), and a rugby team from the European Rugby League (squares). The measures for these three teams were obtained while the players were sitting down. A fourth team is show (NHL) where the players were tested while standing up (see text). The data represent a cumulative geometrical average of the last three measured thresholds. The functions are very well fit by logarithmic regression functions, which account for between 88–97% of the variance. The fits show that the teams have not reached asymptotic levels with the measures that are presently available, and they also show very good correspondence across sports when the conditions are the same. However, the team tested while standing shows dramatically different speed thresholds and slower learning progression speeds.

which we believe are similar to the kinds of perceptual-cognitive demands in many game play situations. Like the other functions, we do see a rapid increase, although this increase is not as dramatic as when the players are sitting down. Further, we see that the slow portion of the curve demonstrates a shallower slope, meaning that the learning progression is not as rapid as when the players are sitting down. This may have implications as to what the ideal conditions for training may be when the desire is to integrate perceptual-cognitive functions with motor responses. It can be suggested from these results that a prior consolidation of ability is required before adding different levels of motor load.

High-level Amateur Versus Professionals

What are the components that distinguish the high-level amateur athletes and the professionals? This remains unknown but we can assume that there are both genetic predispositions and environmental factors that come into play. However, it is not unreasonable to suggest that the basic physical abilities between high-level amateurs and professionals that are both within similar age ranges could be quite minimal. Can perceptual-cognitive abilities be one of the distinguishing factors? We do not presently possess the answer, but perceptual-cognitive measures can potentially help determine whether brain functional capacity for processing dynamic visual scenes is one of these distinguishing factors.

Hypothesized Benefits: In-Field Performance

For performance in the field, there appear to be three main possible advantages of increasing perceptual-cognitive thresholds. Firstly, there may be an expanded capability to perceive and process player movement patterns across a wider visual field (for example, being able to effectively monitor movements of four players instead of three). This would therefore likely improve the foundation upon which tactical awareness and intelligent decision making are based (though not directly training these skills). Secondly, it may possibly improve the efficiency with which a subthreshold amount of player tracking is managed, in turn possibly freeing up resources for other attentional demands or simply relieving some of the pressure of sustained concentration. Finally, it may assist with dual perception tasks, such as reading key opponent body language without compromising awareness of surrounding player movements. These hypothesized advantages await empirical investigation.

Hypothesized Benefits: Concussion Assessment

Perceptual-cognitive training appears to be an excellent candidate for a structured cognitive activity that elicits mental resources, known to be severely degraded by the effects of concussions (also termed mild traumatic brain injuries [mTBIs]). Based on the global integration of central cognitive functions outlined earlier (such as complex motion integration and working memory), perceptual-cognitive training could be sensitive to the debilitating influences of concussion. Further, it has been demonstrated that complex motion processing is particularly sensitive to concussion-related damage (Brosseau-Lachaine, Gagnon, Forget, & Faubert, 2008). Although in need of empirical investigation, we assert that once perceptual-cognitive baselines are established, several hypothesized advantages may help medical staff monitor a concussed player:

1. The ability to retest the player with a controlled and accurately measured perceptual-cognitive test that can be compared directly to his or her own established normative level. In the case of an "elevated baseline," whereby the athlete has made considerable gains in thresholds over his or her initial baseline (e.g., +40%), the impacted drop in perceptual-cognitive test scores may be relatively more pronounced. As perceptual-cognitive training is a performance-training tool through which the athlete has recorded at threshold his or her levels while in competitive shape, perceptual-cognitive training may offer an ideal assessment for determining timing of return to play. This is particularly important for medical staff, as they often have no structured reference point for return to game shape, due to dependence on following mTBI symptoms (which are often alleviated well before return to competition is considered).

2. As perceptual-cognitive training conditions are designed to be precise and consistent, both environmentally and functionally, retesting may present an experiential reference for the athlete to judge his or her own cognitive normality. However, return-to-play biases have to be taken into account by medical staff, as is standard.
3. There is some evidence that mild cognitive stimulation can improve recovery rate (Novack & Johnston, 1998), particularly in postacute phases (Cappaa et al., 2003). Based upon this principle, perceptual-cognitive training may be able to provide a safe and controlled method for implementing this stimulation in punctual and progressive doses.

Hypothesized Benefits: Reduced Injury Risk Through Collision Awareness

Although perceptual-cognitive techniques are believed to train the capacity to track multiple elements generally, it may have a particular benefit for increasing this capacity across the peripheral visual field. If so, this may be because attending to the periphery is more demanding, and this attention can be easily compromised under demanding performance conditions. But additionally, and contrary to intuition, there is some evidence that information may be processed more quickly through peripheral vision rather than via the fovea, providing a significant advantage when under time pressure (Smeeton, Williams, Hodges, & Ward, 2005). Laboratory research has also shown that peripheral vision search methods have resulted in fewer errors than following objects with changes in gaze direction (Haywood, 1984). Due to the time compressed nature of critical phases of team sport games and the abundance of complex visual stimuli, effective peripheral awareness can potentially provide key sport performance advantages, possibly including better utilization of informative cues to minimize action-response times and make more effective play decisions (Hagemann, Strauss, & Cañal-Bruland, 2006).

On this basis, it is possible to hypothesize that increased awareness of player movement in the peripheral visual field may also assist athletes in preemptive avoidance of injury threatening collisions. If this is the case, this could be a crucial edge for reducing injury risks, as impact avoidance is often an athlete's first line of defense. A study published by Garraway and colleagues (1999) concluded that in rugby, 52% of injuries occur when an opponent comes from within the athlete's peripheral vision. Another study looked at the effects of peripheral vision narrowing among high school varsity soccer players, finding significant mediating effects of the narrowing of peripheral vision on injury incidence (Rogers & Landers, 2005); a similar finding was made with regard to intercollegiate sport (Williams & Andersen, 1997). In this context, possible gains in perceptual-cognitive dexterity may be considered by sport organizations from both a medical as well as a performance perspective, particularly as injury downtime of key players commonly threatens a team's competitive status throughout the season, as well as sometimes having a pivotal influence on the games in which a sudden collision injury is suffered.

Conclusion

The present article discussed the theoretical possibility that perceptual-cognitive abilities can be isolated and trained. Herein, we discussed the features of a perceptual-cognitive training program, suggested the potential benefits of such training, discussed what may be required by athletes to optimally process sports-related visual scenes at the perceptual-cognitive level, and proposed that this capacity may be trainable among high-level athletes. It is hoped that future research will continue to investigate perceptual-cognitive training components and programs to further build the theoretical bases for such interventions and examine their efficacy.

End Note

[1]Speeds above an individual's threshold tend to be perceived distortedly, seeming far faster and more difficult than they actually are. This can be observed by manually controlling speed like a dial and getting verbal responses from the participant ("I can handle that," "that's too fast"), with a fine zone of upper comfort and little tolerance above it.

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