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Developing and testing a structured visual skills screening tool for use in sports vision training: an exploratory study with field hockey participants

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ABSTRACT

The field of sports vision is becoming increasingly popular with more research and a rise in practitioners aiming to improve the performance of athletes through training their visual skills. However, whilst it has been suggested that different sports have different visual requirements, there is no easy way to screen for these without having to rely on extensive testing of the visual abilities of elite athletes within the sport, which is often not a practical option. Consequently, in this paper, we designed and tested a screening questionnaire to elicit visual skills information from experts within the sport of field hockey in a quick and easily applicable manner. Descriptions of 23 visual skills were rated on a 5-point Likert scale by 481 participants to show how important they are perceived to be for field hockey players. All participants were involved in field hockey as players, coaches, or umpires. The same questionnaire was completed at a second time point by 129 of the original respondents to assess stability over time. Principal components analysis showed that the 23 visual skills loaded onto four visual skillsets. The perceived importance of these differed, with a perception that skills associated with visual interception and spatial positioning are more important than skills associated with maintaining focus on and recognising visual objects. Our findings suggest that the tool could be useful both to guide the focus of visual skills research in different sports and as a practical aid to coaches looking to systematically select the focus of visual skills training for their players.

1. Introduction

A fast ball sport such as field hockey places incredible demands on the human visual system. Players are required to perform interceptive actions, identify and co-ordinate the body to pass the ball to moving teammates, track the movements of opposition, all whilst making technical and tactical decisions in short periods of time. To enhance these visual skills, many athletes and sports teams are implementing training strategies specifically aimed at improving them, however research to support the effectiveness of such training programmes has varied in both quality and outcomes.

For example, Wimshurst et al. (2012) trained the visual systems of players within an Olympic field hockey team, which brought about changes in their visual skills. However, the study did not look at transfer to on-field performance. Clark et al. (2012) did find that six weeks of vision training improved in-match batting averages of baseball players and Wimshurst et al. (2018) similarly found that six weeks of vision training improved visual and sport-specific skills of elite cricket players beyond the changes seen in a matched control group. In a review of the topic, Laby and Appelbaum (2021) looked at previous literature that has attempted to monitor changes in sports performance following a vision training programme. From the 13 studies included in their review, they concluded that some supported the hypothesis that vision training improves sports performance, whereas others do not. One reason given for the diverse findings is that some studies used general vision training paradigms with no consideration for the actual visual requirements of the sport in question. They noted that "*Just as all sports entail different movement dynamics, it is thought that different visual abilities are essential to success*" (pg. 723). This supports the need to develop a method of identifying which visual abilities may be important for a particular sport before any training intervention is run.

However, at present, there seems to be no generally accepted systematic approach to understand which visual skills might be important for which sports. One possible way to generate a picture of different skill's importance to a sport is to work out which visual skills elite athletes in that sport demonstrate that are not present (or to a lesser

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extent) in athletes from different sports. Past research has offered some support to this notion by demonstrating that different sports may draw on different visual skills. For example, Laby et al. (2011) reviewed the visual functions of 157 Olympic-level athletes from a variety of sports. They did find some statistical differences including that stereoacuity was worse in archers than soccer players, softball players, and speed skaters; and contrast sensitivity at higher spatial frequencies was better in softball players than speed skaters, track-and-field athletes, and volleyball athletes. Similarly, Burris et al. (2020) used the Nike SPARQ sensory system to examine the visual skills of 2317 athletes. They found that athletes who play interceptive sports such as tennis and baseball display better visual clarity, contrast sensitivity, and simple reaction time, whereas athletes classified as more strategic such as soccer and basketball players, have higher measures of spatial working memory.

In their Modified Perceptual Framework, Hadlow et al. (2018) propose that to be considered worthy of training, a visual skill should discriminate not only between athletes from different sports, but also between athletes of different skill levels. However, evidence in this area is mixed and at times contradictory with some studies finding expertise-based differences and others not (for review see Hodges et al., 2021). Even if there are clear differences between experts and novices within a given sport, in order to understand where these differences lie (and hence which visual skills are important within that sport) there are a number of challenges to overcome. Notably, being able to access and have time to test truly elite athletes on a wide range of visual skills is just not practical for most researchers, and particularly not for practitioners working in the applied field. As noted by Lochhead et al. (2024), the logistics involved with conducting carefully controlled and sufficiently powered studies with elite athletes is extremely challenging and the willingness of athletes and teams to give their time to take part in such studies is low – particularly given their desire to not reveal information which could compromise their competitive advantage. Further, even if a team or group of athletes are willing to be screened, the number of 'elite' athletes within a given sport is likely to be low. If they need to be screened on all visual skills that might be relevant, the likely result is a research study with extremely low statistical power and a heightened chance of Type II errors due to the high number of analyses that would have to be carried out in order to consider the impact of the large number of visual skills that could be tested.

Given the above noted challenges, it is perhaps not surprising that a recent systematic review in this area found that the visual skills selected for testing and training within the literature were not based on any particular framework. Instead, authors appear to select their intervention approach based on their own motivations, the availability of testing equipment, and what the participants and their coaches were willing to allow (Lochhead et al., 2024).

Thus, there is a clear need to develop tools that more systematically hone the focus for visual skills research and training in an efficient way and in the present work we attempt to develop such a tool and test it within the sport of field hockey. Sneyimani et al. (2023) attempted to identify the essential visual skills for field hockey through conducting a systematic review of the existing research literature. Their review included 26 papers which all mentioned and discussed the 'essential visual skills for field hockey players' and they ended up with a list of 11 visual skills. They specifically state that the purpose of their review was to "*create a starting point for future studies…and eventually create sport-specific exercise programmes and testing batteries*" (pg 2). Whilst their systematic review represents an excellent starting point, there were some limitations. Notably, there was very limited quality assessment of the included articles and as found by Lochhead et al. (2024), the strength of evidence for selecting each visual skill identified in each paper is unclear. Therefore, although the visual skills identified may well be important to hockey, it is premature to conclude that they are the most, or only, important visual skills and there is a clear need to check the validity of the skills identified.

In an attempt to provide a way of working out which perceptual tasks would be important to a particular sport, Erickson (2007) stated that "*Personal participation in the sport activity by the practitioner offers the most intimate insights into the visual task demands encountered by the athlete.*" (p. 8). He goes on to state that "*…many crucial insights into the visual task demands of a sport activity can be acquired by extensive interaction with the athlete or other experts.*" (p. 8). Thus, Erickson argues that the best way to identify the visual skills that are important to a given sport is to gather evidence from coaches, players and those closest to the game.

The field of expert knowledge elicitation has developed a range of systematic methods to help experts make their implicit knowledge explicit (e.g. Shadbolt & Smart, 2015). The focus on systematicity is important to help limit biases resulting from mechanisms such as heuristic search of memory. If we look at knowledge elicitation within the field of sport psychology, it is common practice to use questionnaires or self-report measures to elicit information from athletes or coaches before implementing an intervention to improve the area of interest. For example, the Performance Profile (Butler, 1989; Butler & Hardy, 1992) asks athletes to identify and rate themselves on attributes they perceive to be essential to their performance. The results of this are then often used for psychological interventions such as goal setting (Butler, 1997), motivation (D'Urso et al., 2002), confidence building (Butler et al., 1993), and also to facilitate discussions when athletes' ratings are compared to those given by coaches (Dale & Wrisberg, 1996).

Therefore, the purpose of the present paper was to create and test a screening tool to identify experts' perceptions of the visual skills most required in field hockey. Experts are considered those who personally participate in the sport in some way, as per the advice given by Erickson (2007). Experts were asked to rate the importance of a range of visual skills, proposed in the literature to be important in field hockey, to establish a valid item pool. The factor structure of the identified visual skills was determined, and the test-retest validity of the resultant sub-scales was assessed by asking participants to complete ratings at two points in time. The purpose of this work is to produce a novel and systematic way to rate the perceived importance of different visual skills in field hockey in an efficient manner. This will then allow for potential comparison within and between other sports, to inform training goals for individual players, and to provide a starting point for future research to systematically narrow down a broad range of possible visual skills to a more manageable number for potential testing with elite athletes in a given sport and further intervention development.

2. Method

2.1. Design

The study was designed as an online questionnaire-based trial to investigate the perceived importance of various visual skills to playing hockey. To evaluate stability of opinions, participants were asked to complete the questionnaire at two separate time points, four weeks apart. Ethical approval was granted by the local university's ethics committee. All participants gave informed consent to take part in the study.

2.2. Sample

A group of 481 participants, consisting of hockey players, coaches and umpires completed the questionnaire at time one (T1). Of those participants, 129 went on to complete the questionnaire at time two (T2). Participants were recruited using a snowball sampling technique utilising a social networking site, as well as emails sent out to various hockey clubs, coach and umpire registers. Players, coaches and umpires were all included in the sample in order to access as many people as possible who are regularly involved in the sport of hockey. Although it is recognised that the roles of coach/player/umpire all require different perceptual skills, the questionnaire asked participants to respond based on what they perceive the demands to be on players only.

At T1 the respondents comprised 287 males and 194 females, mean age = 28, standard deviation = 10.54. Of the respondents, 380 described their primary role within hockey as a player, with 65 being umpires and 36 coaches. The respondents were primarily British (N = 465) with seven Australians, two New Zealanders, three Irish, one South African, one Italian, one German, and one Belgian.

At T2 the 129 respondents could be broken down into 65 males and 64 females. The mean age was 31.12 with a standard deviation of 12.85. Ninety-five of the respondents were primarily hockey players, with 19 umpires and 15 coaches making up the rest of the sample. At T2, 125 respondents were British, three were Australian and one was Irish.

Participation in the study was voluntary and participants who completed the study at both time points were entered into a prize draw to win one of three hockey related prizes.

2.3. Measures

2.3.1. Demographics

Participants were asked for their age, sex, nationality and their contact details (but these were only needed if the person wished to be included in the prize draw).

2.3.2. Hockey history

Information was gathered regarding the individual's main role in hockey (as a player, coach or umpire), their highest level of competition as a player and if and when they last regularly played competitive hockey. They were also asked if they were qualified as either a coach or umpire and if so, what their highest level of qualification was. Finally, they were asked how many years they had been involved in hockey and in which country they had primarily been involved.

2.3.3. Free response questions

Before seeing any of the visual skills-specific questions, participants were asked for their own thoughts on which visual skills they perceived to be the most important to a hockey player.

At the end of the questionnaire participants were again given a free response question asking them to describe any visual skills that they perceived are important to hockey but that had not been covered in the list they had been given.

2.3.4. Visual skill items

Participants were given a brief description of a visual skill and then asked to rate its importance to a hockey player on a scale ranging from 'not at all important in hockey' (1) to 'vital importance in hockey' (5). There were 23 visual skills listed in the questionnaire and these include all the different skills that can be found listed in sports vision text books (Wilson & Falkel, 2004; Loran & MacEwen, 1995; Erickson, 2007) as well as key sports vision papers (e.g. Christenson & Winkelstein, 1988; Ciuffreda & Wang, 2004; Zupan et al., 2006) including the systematic review of visual skills in field hockey by Sneyimani et al. (2023). The visual skills with their descriptions can be seen in Table 1 along with a reference to where the definition came from:

2.4. Procedure

An online questionnaire was developed for the study. A link to the questionnaire was posted on the social networking site 'Facebook' and emailed to hockey clubs, teams and mailing lists for coaches and umpires.

Following a brief explanation of the study, participants were asked if they consented to take part and were informed that they were free to withdraw at any point. If participants clicked that they were not happy to continue, they were directed to a page thanking them for their time. If participants did agree to continue, they were directed to a page asking if they were currently involved in hockey as either a player, coach, or umpire. If they clicked 'no' they were directed straight to the end of the

Table 1
Visual skills and descriptions.

Visual Skill	Description	Refs.
Static Visual Acuity	The ability to see fine detail of a stationary object while you are also stationary	Rigg (1965)
Dynamic Visual Acuity	The ability to detect details of an object while either the object or you are moving	Ao et al. (2014), Sneyimani et al. (2023)
Peripheral Awareness	The awareness of things going on around you that you are not directly looking at	Buys and Ferreira (2008), Sneyimani et al. (2023)
Depth Perception	The ability to accurately judge the distance between yourself and other objects, or between two objects.	Loran and MacEwan (1995), Sneyimani et al. (2023)
Eye–hand Co-ordination	The processing of visual input to guide actions and movements of the hands	Mashige (2014), Sneyimani et al. (2023)
Eye–foot Co-ordination	The processing of visual input to guide actions and movements of the feet	Thapa et al. (2016)
Colour Perception	The ability to distinguish between objects based on the wavelength of the light they reflect	Potgieter and Ferreira (2009)
Contrast Sensitivity	The ability to use differences in brightness between objects and their background to pick them out	Potgieter and Ferreira (2009)
Visual Memory	The ability to recall something based purely on its visual representation	Millard et al. (2023), Sneyimani et al. (2023)
Focus flexibility	The ability to quickly change the focus of your eyes between objects that are different distances away	Buys (2002)
Fast Saccadic Eye Movements	The ability to move your eyes very quickly from one point to another, or to follow a moving object that is travelling very quickly	Cline et al. (1997), Sneyimani et al. (2023)
Smooth Pursuit Eye Tracking	The ability for your eyes to smoothly follow an object as it moves (can only happen on objects moving relatively slowly)	Buys (2002)
Speed of Recognition	The ability to quickly recognise a familiar object or pattern	Kumar (2011), Sneyimani et al. (2023)
Coincidence Anticipation	The ability to predict when a moving object will arrive at a certain destination	Starkes (1987)
Vergence	The ability to move the eyes towards each other or away from each other in order to follow an object as it moves closer or further away	Cline et al. (1997)
Accommodation	The process of the eye changing the strength of its focus to be able to keep an object in clear focus as it moves closer or further away	Cline et al. (1997), Sneyimani et al. (2023)
Visual Reaction Time	The time it takes to produce a physical response to a visual stimulus	Ludeke and Ferreira (2003), Sneyimani et al. (2023)
Balance	The ability to maintain a centre of gravity within the base of support with minimal postural sway	Pollock et al. (2000)
Visualisation	The process of focusing your concentration on an image of what you want and seeing it as already having manifested	Durai (2016)
Visual Concentration	The ability to remain focused on the task even when there are other visually distracting things going on around you	Ludeke and Ferreira (2003)
Direction of Motion	The process of inferring the direction of a moving object based on visual cues	Gray and Regan (2006)

(*continued on next page*)

Table 1 (*continued*)

Visual Skill	Description	Refs.
Speed Judgements	The ability to infer the speed an object is moving at based on visual information	Rushton and Duke (2009)
Visual Search	Using the eyes to scan the environment for a particular object or feature among other objects or features	Williams (2000)

questionnaire and thanked for their time. If they confirmed that they were currently involved in hockey, they could proceed to the demographics part of the questionnaire. Following the demographic section of the questionnaire, participants were given an explanation of what is meant by a 'visual skill' and asked to describe what they perceived to be the three most important visual skills for a hockey player. Following this free choice question, participants had to rate the 23 items (described in Section 2.3) on a scale of one to five depending on their perceptions of importance to a hockey player (1 = not at all important in hockey, 5 = vital importance in hockey). After these 23 items came a further free choice question that asked if there were any other visual skills that should be considered important to hockey but that had not been covered in the previous list. Finally, participants were thanked for their time and informed that they would be emailed when it was time for them to complete the second questionnaire.

After a four-week period, everyone who had completed the questionnaire at T1 was sent a link to the second questionnaire. This comprised exactly the same set-up and questions as the initial questionnaire but was at a different web link so that the two different time points could be kept separate.

2.5. Statistical analysis

Means and standard deviations were calculated for each of the 23 visual skills so that their perceived importance could be considered. Following this, a principal component analysis was conducted to assess the underlying structure of the 23 visual skill items. Then reliability analysis was employed to see whether each factor formed a reliable scale. Krippendorf's alpha was used to see if there was agreement in scale-scores between participants. A two-way analysis of variance was conducted to assess whether there was any difference in perceived importance of visual skills between participants with different levels of competition experience and finally, a three-way analysis of variance added time to this analysis to see whether perceptions were stable over time.

3. Results

A chi-square test showed a significant difference in the highest level of competition experience for the different roles ($\chi^2(8, N = 481) = 18.70$ $p = .017$; Table 2). Coaches and umpires were more likely to have progressed beyond club level than players, but umpires were less likely to have reached the highest, senior international, level of competition.

3.1. Perceptions of importance

Table 3 shows descriptive statistics for the 23 visual skills items.

Table 3
Mean and standard deviation of responses to the 23 visual skills items. Skills were rated on a scale from 1 = not at all important in hockey to 5 = vital importance in hockey. Skills are listed in order of perceived importance across all participants.

Visual skill	Mean	Std. Deviation
1. Eye-hand co-ordination	4.88	.346
2. Visual reaction time	4.84	.389
3. Coincidence anticipation	4.73	.516
4. Peripheral awareness	4.71	.476
5. Fast saccadic eye movements	4.69	.537
6. Speed judgements	4.63	.582
7. Depth perception	4.59	.620
8. Balance	4.54	.638
9. Eye-foot co-ordination	4.42	.694
10. Direction of motion	4.37	.735
10. Visual concentration	4.37	.685
12. Visual search	4.32	.801
13. Focus flexibility	4.30	.751
14. Dynamic Visual Acuity	4.28	.999
15. Accommodation	3.99	.834
16. Speed of recognition	3.95	.890
17. Vergence	3.87	.960
18. Smooth pursuit eye tracking	3.56	1.058
19. Colour perception	3.48	.924
20. Visualisation	3.38	1.017
21. Visual memory	3.22	1.130
22. Contrast sensitivity	3.20	.983
23. Static Visual Acuity	2.51	.986

From the above table we can see that those involved in hockey rate the following visual skills as most important: eye-hand co-ordination, visual reaction time, coincidence anticipation, peripheral awareness, and fast saccadic eye movements.

3.2. Dimension reduction analysis

To assess the underlying structure of the visual skills items, a principal component analysis was run, with varimax rotation, using the scores for the full sample of 481 participants at time 1. The KMO value was 0.87 indicating 'meritorious' sampling adequacy (Kaiser, 1974) and the KMO values for individual items ranged from 0.57 to 0.831, which are all above the acceptable minimum of 0.5 (Kaiser & Rice, 1974). Kaiser's criterion suggested extraction of six factors with eigenvalues that exceeded 1. However, the average communality after extraction was < 0.6 and given the sample size is >250 the use of Kaiser's criterion may not be optimum (Field, 2005). Visual inspection of the scree plot suggested a more parsimonious four factor solution explaining 44.41 % of the variance. Table 4 shows the factor loadings after rotation.

The items loading on factor 1 suggest that it represents those visual skills involved in tracking and predicting the time and location of arrival of moving visual objects such as the match ball. The items loading on factor 2 suggests that it represents visual skills involved in recognition such as the use of previously stored visual representations to aid recognition of current visual objects and scenes (e.g. players and player positions on the pitch). The items loading on factor 3 suggest that it represents visual skills involved in distinguishing visual objects from the background and keeping them in focus at different distances. The items loading on factor 4 appear to be those relating to a player's sense of their own location in space.

To see whether the items loading on each factor could be combined

Table 2
Observed count of highest level of competition attained by players, coaches and umpires retained in the sample (expected values are shown in brackets).

	Highest level of competition					
Current role	Club	Club 1st team	National league	Junior international	Senior international	Total
Player	97 (87.7)	163 (169.9)	73 (75.8)	17 (20.5)	30 (26.1)	380
Coach	4 (8.3)	15 (16.1)	9 (7.2)	5 (1.9)	3 (2.5)	36
Umpire	10 (15)	37 (29.1)	14 (13)	4 (3.5)	0 (4.5)	65

Table 4
Summary of Principal Component Analysis of 23 visual skills showing the highest loading for each item. Items loading > 0.40 on a factor are shown in bold.

	Rotated factor loadings			
	Visual interception	Visual recognition	Object focus	Spatial positioning
Speed judgements	**.679**			
Direction of motion	**.646**			
Coincidence anticipation	**.616**			
Visual reaction time	**.593**			
Fast saccadic eye movements	**.530**			
Focus flexibility	**.462**			
Visual concentration	**.443**			
Visual memory		**.664**		
Static Visual Acuity		**.647**		
Visualisation		**.636**		
Speed of recognition		**.604**		
Dynamic Visual Acuity		**.536**		
Smooth pursuit eye tracking		**.438**		
Visual search		**.425**		
Accommodation			**.682**	
Vergence			**.668**	
Contrast sensitivity			**.612**	
Colour perception			.369	
Eye-foot co-ordination				**.715**
Eye-hand co-ordination				**.527**
Depth perception				**.487**
Balance				**.438**
Peripheral awareness				.391

to form separate scales, each representing a visual skillset, reliability analyses were conducted. Reliability for 'visual interception' was acceptable (α = 0.75). Reliability for 'visual recognition' was also acceptable (α = 0.73). Reliability for 'object focus' was a little low (α = 0.67). Finally, reliability for 'spatial positioning' was also a little low (α = 0.60). Reliabilities for object focus and spatial positioning could not be improved by the removal of any items. Consequently, we decided to retain all items and treat these as integral scales for exploratory purposes, given that the scales make conceptual sense and that reliabilities of 0.6 and greater are often considered acceptable (Taber, 2018).

To assess the extent to which there was consistency in the ratings of importance of the different visual skillsets across respondents, we computed Krippendorf's alpha. Agreement between respondents was moderate (α = 0.50) suggesting some consistency in views about more and less important visual skillsets.

3.3. Differences in the perceived importance of visual skillsets

To compare the relative perceived importance of the four sets of visual skills identified in our principal components analysis, and whether this differed by highest competition experience level, we conducted a two-way analysis of variance (visual skillset (4) – visual interception, visual recognition, object focus, spatial positioning; competition level (5) – club, club 1st team, national league, junior international, senior international) on the time 1 scores (to include all 481 participants), with repeated measures on visual skillset. The Greenhouse-Geisser correction to the degrees of freedom is reported when the assumption of sphericity was not met. There was a main effect of visual skillset ($F(2.54, 1211.03) = 509.71$, $p < .0005$, $\eta_p^2 = 0.52$; see Table 4). Bonferroni adjusted multiple comparisons, based on estimated marginal means, showed that all visual skillsets were perceived to be of significantly different importance from each other ($p's < 0.05$), except for the difference between visual recognition and object focus. From the mean scores, it is clear that visual interception and spatial positioning were perceived to be the most important skillsets. There were no other significant main effects or interactions ($p's > 0.05$). Notably, competition experience level did not make a difference to the relative perceived importance of different sets of visual skills.

To explore the stability of perceptions over time, we conducted a three-way analysis of variance (visual skillset (4) – visual interception, visual recognition, object focus, spatial positioning; time (2) – time 1, time 2; competition experience level (5) – club, club 1st team, national league, junior international, senior international) with repeated measures on the first two factors. Only the 129 participants who completed measures at both times were therefore included in this analysis. As before, there was a main effect of visual skillset ($F(2.25, 279.49) = 140.71$, $p < .0005$, $\eta_p^2 = 0.53$; see Table 5). Bonferroni adjusted multiple comparisons based on estimated marginal means showed that visual interception and spatial positioning were judged to be significantly more important than visual recognition and object focus ($p's < 0.05$). There were no other significant main effects or interactions ($p's > 0.05$), including no effects of time. Perception of the relative importance of the different sets of visual skills was stable over time.

3.4. Free response questions

Participants were asked at the beginning of the questionnaire to list their perception of the three most important visual skills for a hockey player. Wording around responses varied but the most popular themes within the data related to 'watching the ball' and 'awareness of other players'. Other commonly noted requirements included 'scanning', 'peripheral awareness', and 'hand-eye co-ordination'. Through review it was felt that the majority of these visual skills listed were covered within the 23 skills in the main questionnaire.

Following the completion of the questionnaire, participants were asked to describe any visual skills they considered important to hockey

Table 5
Observed mean (and standard deviations) for each skill set at time 1 & 2 by highest competition experience level.

Highest Competition Experience Level	Time 1 (*N* = 481)	Time 1 (*N* = 129)	Time 2 (*N* = 129)
	Visual Interception		
Club	4.53 (0.43)	4.59 (0.35)	4.59 (0.39)
club 1st team	4.57 (0.37)	4.59 (0.36)	4.61 (0.38)
national league	4.55 (0.36)	4.53 (0.35)	4.55 (0.31)
junior international	4.60 (0.41)	4.75 (0.38)	4.70 (0.49)
senior international	4.58 (0.40)	4.77 (0.24)	4.89 (0.12)
Total	4.56 (0.38)	4.59 (0.35)	4.61 (0.37)
	Visual Recognition		
Club	3.54 (0.62)	3.59 (0.68)	3.59 (0.61)
club 1st team	3.60 (0.63)	3.54 (0.50)	3.61 (0.50)
national league	3.60 (0.55)	3.59 (0.54)	3.56 (0.55)
junior international	3.76 (0.58)	3.73 (0.65)	3.68 (0.74)
senior international	3.68 (0.69)	4.09 (0.46)	4.11 (0.31)
Total	3.60 (0.61)	3.60 (0.57)	3.62 (0.55)
	Object Focus		
Club	3.59 (0.63)	3.48 (0.65)	3.73 (0.78)
club 1st team	3.67 (0.66)	3.68 (0.57)	3.81 (0.53)
national league	3.49 (0.69)	3.39 (0.84)	3.67 (0.66)
junior international	3.92 (0.56)	4.03 (0.65)	3.84 (0.53)
senior international	3.77 (0.59)	3.85 (0.55)	4.10 (0.45)
Total	3.64 (0.66)	3.59 (0.68)	3.77 (0.63)
	Spatial Positioning		
Club	4.57 (0.41)	4.53 (0.48)	4.60 (0.31)
club 1st team	4.66 (0.32)	4.67 (0.25)	4.69 (0.33)
national league	4.60 (0.33)	4.58 (0.36)	4.61 (0.33)
junior international	4.69 (0.43)	4.70 (0.43)	4.63 (0.38)
senior international	4.64 (0.32)	4.68 (0.30)	4.80 (0.20)
Total	4.63 (0.35)	4.61 (0.36)	4.65 (0.32)

but that had not been listed. Of the 481 respondents, only 38 added something to this free-response question. The key points raised in this section either used different language to describe an area covered in the questionnaire (e.g. ability to distinguish different teams by colour – which should have been covered by the question asking about 'colour perception'), or described a situation very specific to field hockey such as being able to read the body language of opposing players, or positioning yourself in the correct location based on where you think the ball is going to travel. Although these things are not necessarily covered by a single item on the questionnaire, they are covered by combining several different questions. For example, positioning yourself on the pitch could be broken down into a combination of dynamic visual acuity, visual scanning, and fast saccadic eye-movements (to pick information up from the surrounding area), combined with visual memory (to recall how previous scenarios played out and use this to put your body in the best location). Therefore, although no new 'visual skills' were identified through these free-response questions, the answers that participants did give suggests that at times, they may not have understood the initial question if they did not feel it was an area that had been covered.

All free responses can be seen in the supplementary material.

4. Discussion

4.1. Summary

Twenty-three visual skills that have previously been suggested are important in field hockey, as well as a range of other sports, were identified. A total of 481 field hockey experts were then asked to rate the perceived importance of these skills to playing hockey. Initial analysis showed that the five visual skills perceived as most important in field hockey are eye-hand co-ordination, visual reaction time, coincidence anticipation, peripheral awareness, and fast saccadic eye movements. Further analysis showed that the 23 skills could be reduced to a set of four visual skillsets: visual interception; visual recognition; object focus; spatial positioning. The perceived importance of these visual skillsets for field hockey differed, with a very clear perception that skills associated with visual interception and spatial positioning are more important than skills associated with maintaining focus on and recognising visual objects. These differences in perceived importance were stable over time and did not differ by competition experience level.

4.2. Practical implications for coaches

One purpose of the proposed screening tool is to allow coaches or psychologists working within sports to have a quick and easy method to gain insight into the visual skills perceived as most important for that sport. This then gives a starting point for assessing and training these visual skills; rather than starting with all 23, a more manageable number can be selected based around the rankings given by the users of the tool. For instance, the list(s) of skills associated with the visual skillset(s) judged as most important in a sport could be used to inform whole team level visual skills training interventions focused on that skillset(s).

However, this does not take into account the individual differences that are likely to be present between athletes, even within the same sport. An example of this in a non-visual context is provided by James et al. (2005) who attempted to analyse the performance of individual playing positions within rugby union. They not only found significant differences between all tested playing positions, but also between individuals who were in the same playing position. They put this down to variations in individual's style of play and therefore suggested that multiple profiles would be necessary for each position. This individual variation in playing style is something that should also be considered from a visual skills perspective. For example, in field hockey, there may be two players who both play in a central midfield position at the highest level. One player is strong, powerful and excels at winning tackles and then making simple passes to keep possession. The other player may be fast and creative, excelling at making long passes to create scoring opportunities for their team. Based on these descriptions, we should assume that not only their physical profile, but also the specific aspects of their visual system required for their style of play, would differ. Erikson (2007) notes that personal participation in a sport activity may yield crucial insights yet, if asked, these two players would likely place different weighting on the importance of the visual skills required to succeed in field hockey as they have different personal experience and ability profiles. Therefore, although the current study is valuable in ensuring that the developed measure has the necessary reliability and validity to be useful, it may be that the practical application of the tool lends itself to more individualised screening. After all, if we are going to be efficient in our training, insight into factors that relate to the development of sport performance (in this case, visual skills) needs to be highly relevant for athletes and their coaches (Stam et al., 2020). And with open skill, multi-player invasion sports such as field hockey, individual differences may be crucial to tailor training to the specific roles each player will take on.

Another possibility is that the visual skillsets judged as most important in a sport could be used to form the basis of a player or coach completed checklist of perceptions about a player's relative ability on each of those visual skills. This could be used in the same way as (or in combination with) the Performance Profile developed by Butler (1989). As noted previously, Butler's Performance Profile is considered a useful tool, particularly to help provide a basis for goal setting, identifying strengths and weaknesses, raising athlete self-awareness, facilitating discussion within a team, and helping the athlete focus on what's important (Weston et al., 2010). The Performance Profile is necessarily blank – allowing the athlete (sometimes in consultation with a coach or teammates) to decide for themselves which aspects of the technical, tactical, physical and psychological aspects of their sport they consider to be important. The screening tool developed within the present study would allow for the Performance Profile to be populated with the specific visual skills perceived to be important for the sport, and then these could be used by the athlete to structure their assessment of their current skill level, which could then be used to inform individual training priorities on a player-by-player basis. Assessment of individual differences in visual skills profiles and individualised training approaches based on the screening tool should be a goal for future research.

Similarly to the present example of field hockey, using the screening tool to gain the perceptions of experts currently involved in any given sport is potentially far more efficient than having to conduct a systematic (or other) review of the literature, or extensive skills testing, adding support to the benefits of using this tool in the applied setting.

4.3. Implications for future research

Our findings indicate that visual skills for field hockey can be separated into broad skillsets, each of which are comprised of a group of individual skills. This is important from a research perspective as it helps to guide researchers to the set of skills that may be most important for a given sport, enabling research to focus on topics such as understanding and developing interventions for these most relevant skills and for comparison across sports.

In the present case, it could be seen that eye-hand co-ordination was perceived as the most important visual skill for success in field hockey. This was closely followed by visual reaction time (Table 3). These suggests that these may be key visual skills to focus on for the development of new training interventions. Further, providing some evidence of the concurrent validity of the present screening tool, these two visual skills are both also found in the 11 visual skills considered essential for field hockey, as shown in the systematic review of the literature by Sneyimani et al. (2023). In fact, of the 11 visual skills identified within this systematic review, five match with the top five found via our screening tool.

Interestingly, there were some differences between the skills that were identified as most important by field hockey experts in the present

study and those that have been identified as objectively better in players of other interceptive sports. For instance, contrast sensitivity formed part of the cluster of 'object focus' skills in the present study, which field hockey experts perceived as relatively less important, whilst previous work has found that players in the related fast ball sports of softball, baseball and tennis have higher contrast sensitivity than, for instance, speed skaters (e.g. Burris et al., 2020; Laby et al., 2011). This difference might appear to indicate that expert perceptions of importance are not aligned with the *objective* importance of different skills. However, the origins of objective differences and the extent to which the associated skills can be trained is unclear from these comparison studies. For instance, it may be that individuals with higher contrast sensitivity are indeed more successful in fast paced, interceptive sports, but they may have pre-existing higher ability rather than enhanced ability through training. Further, in our present work it wasn't that field hockey experts regarded contrast sensitivity as not important to field hockey (mean scores on the 'object focus' skillset, including contrast sensitivity, indicate it is important), just that they regarded it as less important than some other skills.

Importantly, our analysis did show that there was agreement on the perceived importance of the different visual subsets between all groups of participants, regardless of experience level. This suggests that anyone involved in playing a given sport would give similar ratings – therefore reducing the need to access elite level athletes to utilise the tool to gain an initial oversight of the importance of each visual skill.

The reliable identification of particular skillsets perceived to be of importance in field hockey suggests that application of the tool developed in the present work may yield similar insights into the relative importance of the different skillsets in other sports, and this should be a target for future research.

4.4. Limitations and future directions

The current study took an exploratory approach to see if we could differentiate clusters of visual skills that experts agreed differed in importance in the sport of field hockey. Whilst we were successful in this ambition, the structured visual skills screening tool developed could be further improved through additional work.

First, this should focus on further establishing the validity of the tool, for instance, through studies that train the visual skills that are perceived to be most important and evaluating whether the training improves match performance more than training skills that are perceived to be least important.

Second, research should collect data with new samples of participants from other sports to confirm that the factor structure observed generalises to new samples beyond field hockey.

Third, the reliabilities for the object focus and spatial positioning subscales were a little low. Some work to further improve these might be beneficial. For instance, adjustments to the wording describing each of the skills loading on those skillsets may improve rater interpretation and reliability of responding. As noted through review of the free-response questions, some visual skills the authors presumed were covered were still bought up by respondents, suggesting perhaps that they had not fully understood the descriptions given to each visual skill. This appears to be a problem not just for the current study, but in the field of sports vision as a whole. When looking for standardised definitions of various visual skills, there appears to be very little consensus. For example, when looking for a definition of 'contrast sensitivity' the following were all found:

- the ability to notice differences in brightness of adjacent areas (Mashigie, 2014)
- measures the ability of the athlete's visual system to process temporal or spatial information about objects and their background under varying lighting conditions (Ludeke, 2003)
- measures the smallest amount of contrast needed to detect a visual stimulus (Millard et al., 2023)

Further, even the names assigned to each visual skill are not consistently applied throughout the literature. An example of this would be the different terms found to describe how well an individual can see colour. Terms used include 'colour sensitivity' (e.g. Millard et al., 2022), 'colour discrimination' (e.g. Chaliburda et al., 2023), 'colour vision' (e.g. Ludeke, 2003), 'colour perception' (e.g. Mashigie, 2014). These differences might seem insignificant here, but if visual skills are not consistently referred to using the same terminology and using standard descriptions, it lowers the ability to conduct and replicate quality scientific research. Therefore, fourth, it is suggested that future work is carried out to produce consensual names and definitions for the visual skills commonly associated with sports performance and that these are adopted throughout the field.

5. Conclusion

The present study has created and tested a structured screening tool for the visual skills perceived to be most important in a sport. It was tested in field hockey where four visual skillset factors emerged - visual interception; visual recognition; object focus; spatial positioning – with the perceived most important skills in agreement with previous systematic review work supporting scale validity. Supporting scale reliability, the tool provided responses that were stable over time.

This tool supports being able to screen for the visual skills that are perceived to be important by participants in any given sport. Thus, the tool offers coaches and practitioners a way of identifying those skills considered most important for team training and intervention. Further, the tool has potential for use by players and coaches as a way of identifying individual training needs, as these may differ even within the same sport or playing position. Future research should evaluate this possibility.

The tool may also prove useful for researchers to guide the focus of visual skills research, intervention development and evaluation in field hockey, and potentially in other sports. Therefore, further work needs to explore if the tool works equally as well in other sports, and to follow-up with training studies focused on the identified visual skills.

Finally, there is a need for more standardised definitions of visual skills to be used in the sports vision literature and to ensure that these are well understood by respondents to maximise the applicability of the tool.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajsep.2025.04.001.

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