Human Perceptions of Artificial Surfaces for Field Hockey

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Abstract Measuring the performance of a sports surface is typically derived from a series of field and laboratory tests that assess the playing properties under simulated game conditions. However, from a player's perspective their own comfort and confidence in the surface and its playing characteristics are equally if not more important. To date no comparative study to measure playing preference tests has been made. The aim of this research was to develop a suitable method for eliciting player perceptions of field hockey pitches and determine the key themes that players consider when assessing field hockey pitches. To elicit meaningful unbiased human perceptions of a playing surface, an individual subjective analysis was carried out, using interviews and inductive analysis of the recorded player statements. A qualitative analysis of elite hockey players (n = 22) was performed to obtain their perceptions immediately after a competitive match. The significant surface characteristics that emerged as part of an inductive analysis of their responses were grouped together and formed five general themes or dimensions: player performance, playing environment, pitch properties, ball interaction and player interaction. Each dimension was formed from a hierarchy of sub-themes. During the analysis, relationships between the dimensions were identified and a structured relationship model was produced to highlight each relationship. Players' responses suggested that they perceived differences between pitches and that the majority of players considered a 'hard' pitch with a 'low' ball bounce facilitating a 'fast' game speed was desirable. However, further research is required to understand the relative importance of each theme and to develop appropriate measurement strategies to quantify the relevant engineering properties of pitch materials.

Keywords*: Artificial sports surface, field hockey, human perception, inductive analysis, structured relationship model*

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Introduction

Manufactures often elicit user perceptions to develop products. The importance of understanding user requirements and receiving product feedback is a vital part of any product design process. Perceptions are formed subjectively; therefore, developing a method to understand them can be difficult. To date there have been few attempts to develop a suitable approach for measurement of the perceptions relating to sports equipment (e.g. Hocknell *et al*., 1996; Merkel and Blough, 1999; Roberts *et al*., 2001) and these studies identified the individual's response; furthermore none have elicited perceptions of the playing surface as a product. However, many different forms and designs for sports pitches exist.

Sports surfaces can be categorised into two groups (a) natural, formed by the suitable preparation of an area of land to includes grass, ice and snow or (b) artificial, constructed with material prepared by human work using synthetic or manufactured materials including synthetic turf and wooden boards (Nigg and Yeadon, 1987). Surfaces vary significantly depending on the sport specific requirements, although some are designed for multi-sport usage. Nigg and Yeadon (1987) suggested the quality of a sports pitch could be assessed with respect to technical specification, sport functional properties, safety consideration, and cost factors. However, players' requirements should ideally be considered when developing and testing a playing surface to ensure it meets their needs. In general, current sports surfaces are designed and built based on experience of what has worked well in the past. New products are emerging in the market, and many make great claims for their improved playability properties. A player needs to be comfortable and confident with the sport surface they play on (i.e. it should be safe, consistent and allow the player to perform and maximise their skills during a game). A better understanding of the surface's playing characteristics, and their importance to the players, will aid both design and assessment of the sports surfaces in use and help develop surfaces for the future.

In the UK, currently each pitch is constructed on a site-specific basis and to the requirements of the user/operator brief, although all the pitches, when new, must pass a series of (mainly) mechanical playing performance related tests. However, many of the pitch key components can be varied in design and further affected by the construction techniques. Feedback from the users and experimental evidence (Fleming *et al.*, 2002) has suggested that many of the field hockey pitches in use vary in the way they play and 'feel' during play, nevertheless there existed little objective measured information to substantiate these claims nor a way of utilising player feedback in the design of future pitches in any rationale way. There exists, in general, a lack of published peer reviewed data regarding the design and performance of artificial sport surfaces (Fleming *et al.*, 2002). This results in difficulty for validating designs, innovating materials, and determining the efficacy of the claims as to the specific benefits of products.

The aim of this research was to develop an understanding of field hockey players' perceptions of the surface upon which they play by developing a suitable method to elicit their opinions. This paper describes the methodology used to elicit players' perceptions of artificial sports surface for field hockey. An inductive content analysis of players' responses is presented and a structured relationship model is developed and used to illustrate relationships between the obtained dimensions.

Design and Operation of Field Hockey Pitches

In the UK field hockey water-based pitches have, in many cases, superseded the more traditional 'sand-based' design. Water-based pitches require a tremendous amount of watering before, and sometimes during, a game and therefore the pitch needs to be pervious. No sand infill of the synthetic carpet is used and despite a denser synthetic carpet pile the watering produces a less abrasive surface for player-surface contact during falls/slips. Currently in the UK there are approximately 40-50 water-based pitches and these are the chosen surface for premier league matches and international competition by the Federation Internationale De Hockey (the world governing body for field hockey).

The pitch system comprises many layers; Figure 1, shows a typical construction for a water-based field hockey pitch (Fleming *et al.*, 2002). The synthetic turf is the only prefabricated part of the system, the other layers being formed from their constituent parts insitu. The compacted fill (often the natural soils found at the site), the sub-base (a compacted graded aggregate), and the asphalt (a hot-rolled blend of aggregate and stiff bitumen binder) layers form the pitch foundation. The foundation needs to provide a stable platform for construction vehicles, allow pitch drainage, and remain very flat for its design life of 25 years or more. The shockpad and synthetic carpet form the surface system and together provide the player-surface and ball-surface characteristics. The shockpad is often formed from recycled shredded rubber particles bound together on site and laid by a paver (similar to the asphalt) termed an insitu shockpad, although it can be provided in the form of a foam layer as part of the carpet backing (termed an integral shockpad) or supplied prefabricated in rolls.

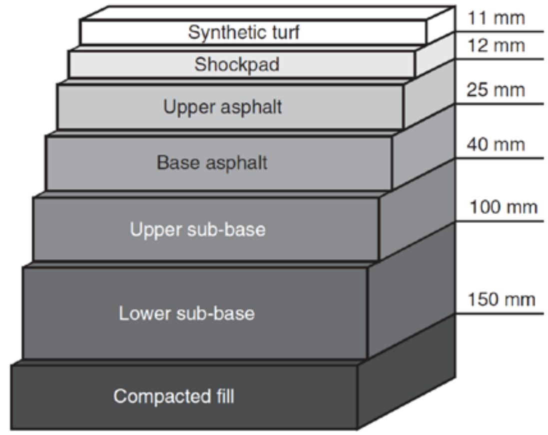

Fig 1.The 'typical' structure for a water-based artificial pitch for field hockey

There exists a series of synthetic pitch playing performance tests for field hockey (FIH, 1999) approved by the international and national governing bodies that rule the sport. Therein is a list of performance requirements that must be satisfied by laboratory and field test methods. It is interesting to note that there are three playing performance standards related to the standard of play, 'Global' for international competition, 'National' for top-level domestic competition and 'Starter' for general play. The test acceptability limits are wider for the lower standard play category with the intention to allow more affordable surfaces to be utilised. For example, there is the requirement for vertical ball bounce to be within the limits of 0.1m and 0.25m from a drop height of 1.5m for the Global standard and for the 'Starter' standard. The ball bounce is clearly affected by the sand fill and/or surface water, which dissipate some of the impact energy, as illustrated in Figure 2. The performance tests include uniformity of irrigation for water-based pitches, colour of the synthetic carpet in addition to engineering related mechanical properties such as friction and impact absorption. The tests are only specified for the end of installation and not necessarily monitored for continuing performance. The wide limits of acceptability are supposedly there to reflect the variations that were either expected or measured for natural turf, however this can, for example, result in a pitch construction that is at either end of the impact absorption limits (i.e. relatively hard or soft) or similarly either relatively 'grippy' or 'slippy' in its frictional behaviour. In addition, these specified playing tests do not replicate the actual game-playing scenario well (Dixon *et al.*, 1999) and source information that set these limits of acceptability is not traceable.

Player Perception Approaches

Perceptions can be defined as ‘our conscious interpretations of the external world created by the brain from a pattern of nerve impulses delivered to it from sensory receptors’ (Sherwood, 1993). However, the interpretation of sensory stimulation can differ between individuals, who may not perceive the same sensory inputs in the same way (Roberts *et al.*, 2001). Therefore, to develop a meaningful understanding of the perceptions, feelings, thoughts and knowledge of a player’s experiences on a sports surface, a suitable research method must be developed. In the field of sports psychology, qualitative techniques have been used in order to allow player perceptions to be evaluated. Such studies have been undertaken with ice skaters (Scanlan *et al.*, 1989a, b), Olympic wrestlers (Gould *et al.*, 1992), swimmers (Hanton and Jones, 1999) and golfers (Roberts *et al.*, 2001: 2002). However, none of these previous studies elicited information regarding a playing surface and all were individual sports as opposed to a team sport.

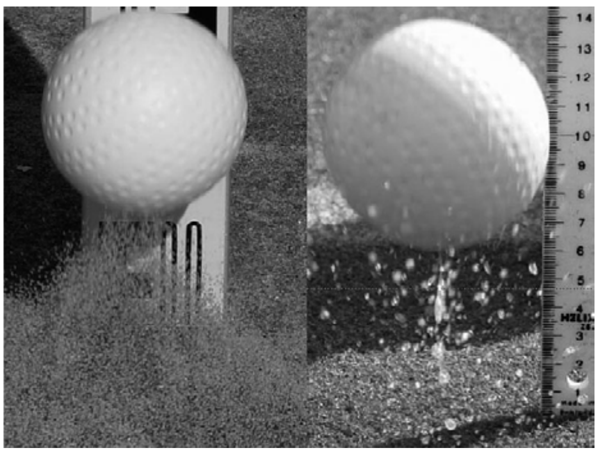

Fig 2.Vertical ball rebound on sand (left) and water (right) based pitches showing a significant source of energy loss on impact

It is important that the investigator does not attempt to manipulate the participant by imposing pre-existing ideas or expectations on their responses, consequently the research technique should be subject led. A qualitative design is inherently naturalistic (the investigator does not manipulate the participant) and oriented towards exploration, discovery, and inductive logic (Patton, 1990). An inductive analysis attempts to understand the responses without imposing pre-existing ideas or expectations on the data collected. To structure the qualitative data a process known as ‘clustering’ is often used. ‘Clustering involves comparing and contrasting each quote with all the other quotes and develop emergent themes to unite quotes with similar meaning and separate quotes with different meanings’ (Scanlan *et al*., 1989a). This process is then repeated with the emergent themes grouped together generating higher-level themes until it is not possible to locate any further underlying data uniformities (Scanlan *et al*., 1989a).

Using this process of inductive analysis, the ‘themes’ emerge from the quotes rather than being pre-determined which enables the issues of importance to the player to be identified reducing the risk of investigator bias. Thus, the use of an individual interview with open-ended questions allows the participant freedom to express their opinions and the semi-structured format gives the investigator the opportunity to probe the players’ responses. Probing involved the interviewer asking questions to enable the player to expand on their responses. For example, if a player stated that the ball bounce was ‘high’ the interviewer would ask the player ‘what do you mean by high?’ or ‘high compared to what?’ This process allowed the interviewer to elicit further information from the players’ without leading their responses. A topic was only probed once it had been introduced by the player. The themes developed from the data are then grouped together to form ‘dimensions’ which represent the highest level of this hierarchical system. Roberts *et al.*, (2001) showed that the emergent dimensions are not exclusive and that there can be a level of interactivity between dimensions. Consequently, an additional stage of analysis can be used to aid investigation of inter-dimensional relationships known as ‘structured relationship modelling’.

Data Collection and Analysis

A total of twenty-two players were interviewed, one-to-one, at most one hour after play to ensure they retained detailed memory of their experiences. Of the twenty-two players interviewed the age range was 18 to 32 years, and twelve were male. Players from six teams (three men’s) in the English hockey league (EHL), premier and 1st division were interviewed. Full consent was obtained prior to the interviews. The number of interviewees was deemed appropriate as it was concluded by the interview and analysis team that saturation point had been reached with no new information emerging from the ongoing data processing. A range of playing positions were covered including three goal keepers/minders, six defenders, seven midfield players and six forwards.

The Loughborough University (LU) water-based artificial field hockey pitch was used as a benchmark to relate the other pitches nationally in the EHL to. When the LU men’s and women’s first teams travelled away, several individuals were interviewed one-to-one about the pitch they had just played on in relation to their (LU) home pitch. When away teams travelled to Loughborough, several of their team members’ perceptions of the LU pitch were obtained in relation to their home pitch. This methodology allowed a direct comparison between two pitches, enabling the identification of preferable qualities from each pitch. In addition, it aimed to help the process of selecting pitches for engineering assessment at a later date (i.e. those pitches that presented strong views or concerns regarding playing performance). The pitches selected represented a diverse range of the carpet types, age and usage level. Team, position, shoe type, shoe age, stick manufacturer and ball preference were recorded from each player. In addition, the outcome of the game, the weather conditions, and how well the player believed they played were also recorded in order to identify how, or if, any of these extraneous factors could have influenced their perceptions. It was envisaged that elite players would give relatively high quality responses due to their high level of skill and better understanding of their playing environment relative to lower standard players.

Interview guide

To aid the interview process, a guide was produced that enabled the interviewer to optimise the amount of data obtained from the players and to provide a selection of unambiguous questions and thus ensure a consistent approach was followed by the two interviewers. One interviewer was experienced in sports psychology research and the other was trained through experience in the pilot study carried out. The interview guide was produced with the additional help of two international field hockey coaches (1 male and 1 female). It contained three sections that were consistent for all interviews. Topics within the guide were only discussed if the players themselves had introduced them into the conversation. The initial lead question, which was designed to focus the players response but allow free expression, was:

Having just finished a full match I would like you to describe your feelings/perceptions of the pitch you have just played on, drawing specific comparisons with your home pitch.

The interviewer then had complete freedom to probe the response of the field hockey player to this initial question. It was important that the interviewer did not lead the responses of the player, so, the interview guide contained several questions designed to elicit perceptions without suggesting characteristics of importance, such as:

What were the main/major differences between the pitch you have just played on and your home pitch?

Was there anything in particular that you liked/disliked about this pitch, or was different from your home pitch?

Open-ended questions were used to obtain qualitative data in the form of detailed descriptions. To ensure the suitability of the developed interview technique and consistency between the two interviewers, six pilot interviews were carried out, from which several minor modifications were made to the guide to reduce the possibility of ambiguous and leading questions.

Interview Recording

Each interview was recorded in its entirety. The recording equipment needed to be robust, portable and able to accurately reproduce each spoken word such that verbatim transcriptions could be produced. Two wireless lapel microphones were transmitted to a recordable mini-disc player. The mini-disc system enabled the player and interviewers responses to be captured on separate tracks (left and right stereo), which greatly eased transcription, particularly when both parties spoke at the same time. The recordings were transcribed verbatim into (Microsoft Word) text documents for subsequent analysis. Interviews typically lasted 25 minutes and resulted in 15 page long transcribed documents.

Quality of Data

During interviews, there were several data quality issues of concern including, the player misunderstanding what was being asked, the interviewer misinterpreting the responses and the preconceived attitudes and opinions of the interviewer influencing the player's responses (Cohen and Manion, 1980). For example, players terminology could differ from the investigators causing misunderstanding. Throughout these interviews a number of methods were employed to reduce the potential for bias. Prior to the interview phase, the pilot interviews helped define player terminology to construct a usable interview guide. The pilot study also allowed the interviewers a chance to practice their interview technique and be consistent and clear in their questioning and probing.

Data analysis

Data analysis involved the organisation of raw data (quotes) into a set of meaningful structured themes by means of inductive analysis. As previously stated, an inductive analysis involves obtaining categories and themes from the quotes rather than forcing them into pre-determined groups. The analysis followed the procedure developed by Scanlan *et al.*, (1989a, b) which began with each interview recording being listened to, transcribed and then re-read. This increased familiarity with the interview data and helped identify the emerging themes. To aid analysis the software package QSR-N6 NUD*IST (QSR International Pty Ltd, 2000) was used to identify and group each emergent theme. NUD*IST uses a sophisticated coding system to create categories and form links between them. Once emergent themes had been identified the next phase was to group them together into a hierarchical structure to develop the dimensions. Discussion of the emergent dimensions, by the two interviewers plus a third person (who aided in the research design) experienced in qualitative analysis, was conducted to remove any possible effects of misinterpretation or individual opinions. This process is known as 'triangular consensus validation' (Scanlan *et al.*, 1989a; Patton, 1990) and was done until the final emergent dimension were realised.

To validate the procedure a reversal of this process was used. The players' quotes were coded using NUD*IST into the arranged structure using a deductive approach. This procedure provided a more organised format with more subtle themes emerged which allowed the creation of refined themes (Robert *et al.*, 2001).

Findings

Players' responses covered a large range of pitches in the EHL including twelve water-based and six sand-based. The outcome of each game was recorded, interviewed players were found to have won twelve games, lost six and drawn four. Five general dimensions emerged from the inductive analysis of the elite field hockey players' responses. These were identified as: Pitch Properties, Ball-Surface Interaction, Player-Surface Interaction, Player Performance and Playing Environment. Tree-structures for each dimension were produced and are discussed below. Each tree-structure illustrates how the analysis progressed from player quotes, through levels of clustering, and into the eventual general dimension. It was found that some quotes could be placed into more than one base theme. Hence a structured relationship model was produced to illustrate these links, discussed later. Analysis of the interviews showed that ball- and player-surface interactions were the two most frequently discussed dimensions, and hence are presented in full, with the remaining three dimensions summarised.

Ball/Surface Interaction

Perceptions associated with ball interactions with the surface are grouped into three sub-themes 'ball roll', 'ball bounce' and 'ball spin'. Figure 3 shows the tree-structure for ball-surface interaction. It was found that players perceived large variation between ball interaction on different pitches. The theme 'ball roll' embodied all the players' comments about how the ball 'rolled' across the surface including speed, consistency and distance.

The roll on this pitch was much faster than my home pitch. The ball rolled across the surface much faster.

The ball roll on this pitch was very consistent and easy to predict all across the pitch.

The 'ball bounce' behaviour was similarly found to have a large difference between pitches. Players' comments described the 'height', 'angle' and 'consistency' of ball bounce.

The ball didn't come up from the surface very much, it stayed low.

The pitch was not very consistent, the bounce was very unpredictable.

Two different types of spin were identified; one produced by the player hitting the ball and the other caused by the ball's interaction with the carpet. Player generated spin was regarded by most players as unintentional and occurred only if the ball was hit incorrectly or the ball stopped suddenly from game action such as a short corner. The majority of players' believed that spin could not be imparted on the ball intentionally in order to gain a playing advantage. It was perceived that different pitch types considerably transformed the amount the ball spun. Players stated that some pitches had more tendencies to cause the ball to spin and it was suggested that this could be a result of the carpet pile type.

The ball spins more on some pitches than others due to the carpet type.

I don't know of anyone who intentionally puts spin on the ball, it's just something that happens if you miss-hit it [the ball].

Player/Surface Interaction

Player interaction with a surface has been extensively studied in human biomechanics research. It includes *any* interaction with the surface comprising running, falling and sliding. Perceptions of the players' interaction with the surface are clustered into three sub-themes: 'surface grip', 'hardness of the surface' and 'Abrasiveness of the surface'. Figure 4, shows the tree-structure for player-surface interaction.

There were large differences between the perceived abrasive qualities of pitches. There was a consensus that low-abrasive pitches allowed players to make more aggressive movements without the risk of abrasion injuries.

When a pitch begins to dry out towards the end of a game I tend to be more conservative with my movements. There is much more chance of getting an abrasion injury at the end of a game than the beginning.

Some pitches are much more abrasive than others. Today's pitch was very abrasive; my home pitch is much less abrasive.

The surface grip was identified by players' to be influential on playing performance. Three categories were created based on the their responses 'weather conditions', 'pitch age' and 'type of footwear'.

Shoe type is very important for grip. I have specific shoes for artificial pitches and don't have as many problems as my team mates who don't have the correct footwear.

Some pitches have much more grip than others but the amount of rain can alter how slippy a pitch is. When a pitch is too dry it can become very sticky.

Surface hardness is encompassed by either a soft/compliant surface or hard/stiff surface. Players' responses relating to 'surface hardness' were diverse and it appeared that many had different opinions as to their favoured 'hardness'.

The pitch we just played on was far too hard. I can feel my back; it's going to be very stiff tomorrow.

That pitch was very soft, I was exhausted at half time, and it felt like it was draining all of my energy.

Pitch Properties

This dimension comprises perceptions associated with 'pitch properties', and is shown in Figure 5. It is split into four sub-themes; pitch colour, pitch consistency, carpet properties and pitch type. The main characteristics players described were the differences between sand and water based pitches, although many quotes were related to surface consistency and carpet properties.

The pitch was inconsistent; it was different at each end. It was like playing on two different pitches.

Water based pitches are much better than sand based, the game is completely different

Player Performance

The dimension 'player performance' brings together the contrasting themes of the players' feelings towards ability, playing position and past experiences. It is illustrated in Figure 6. Comparisons were made to how different playing positions altered opinions of the pitch and how ability and past experiences transformed perceptions.

I'm a defender so this pitch suited me, our forwards had loads of problems but us defender enjoyed playing on it.

I'm used to playing on this type of pitch. I trained on a similar pitch to this for years when I was younger so I found it very easy to play on.

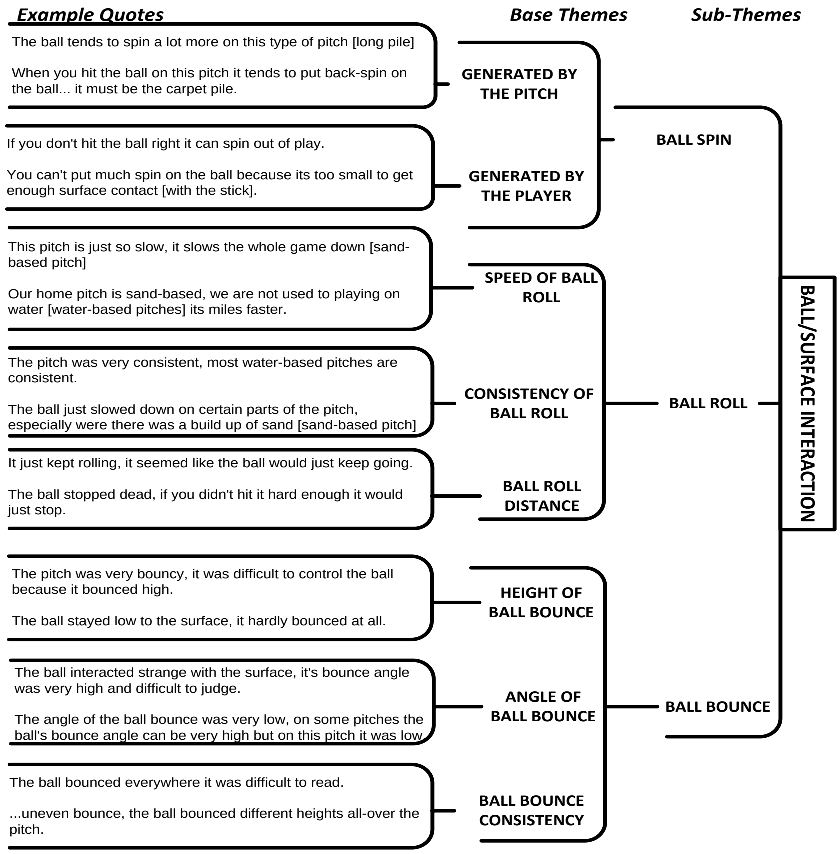

Fig 3. A tree diagram for the dimension 'ball/surface interaction'

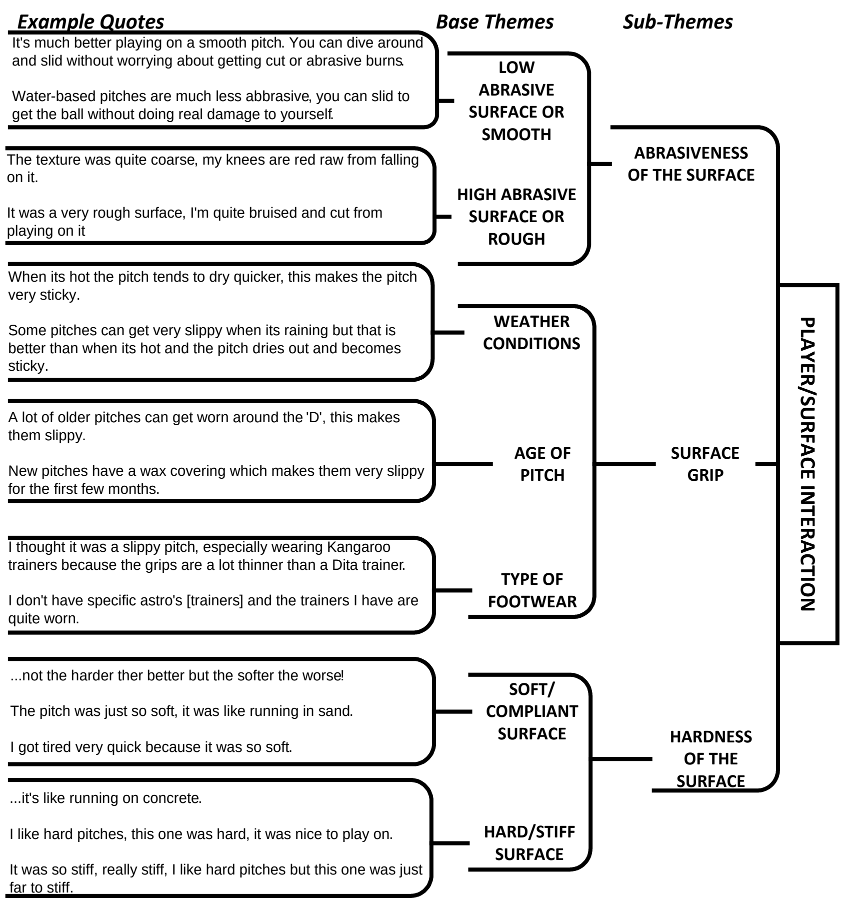

Fig4. A tree diagram for the dimension 'play/surface interaction'

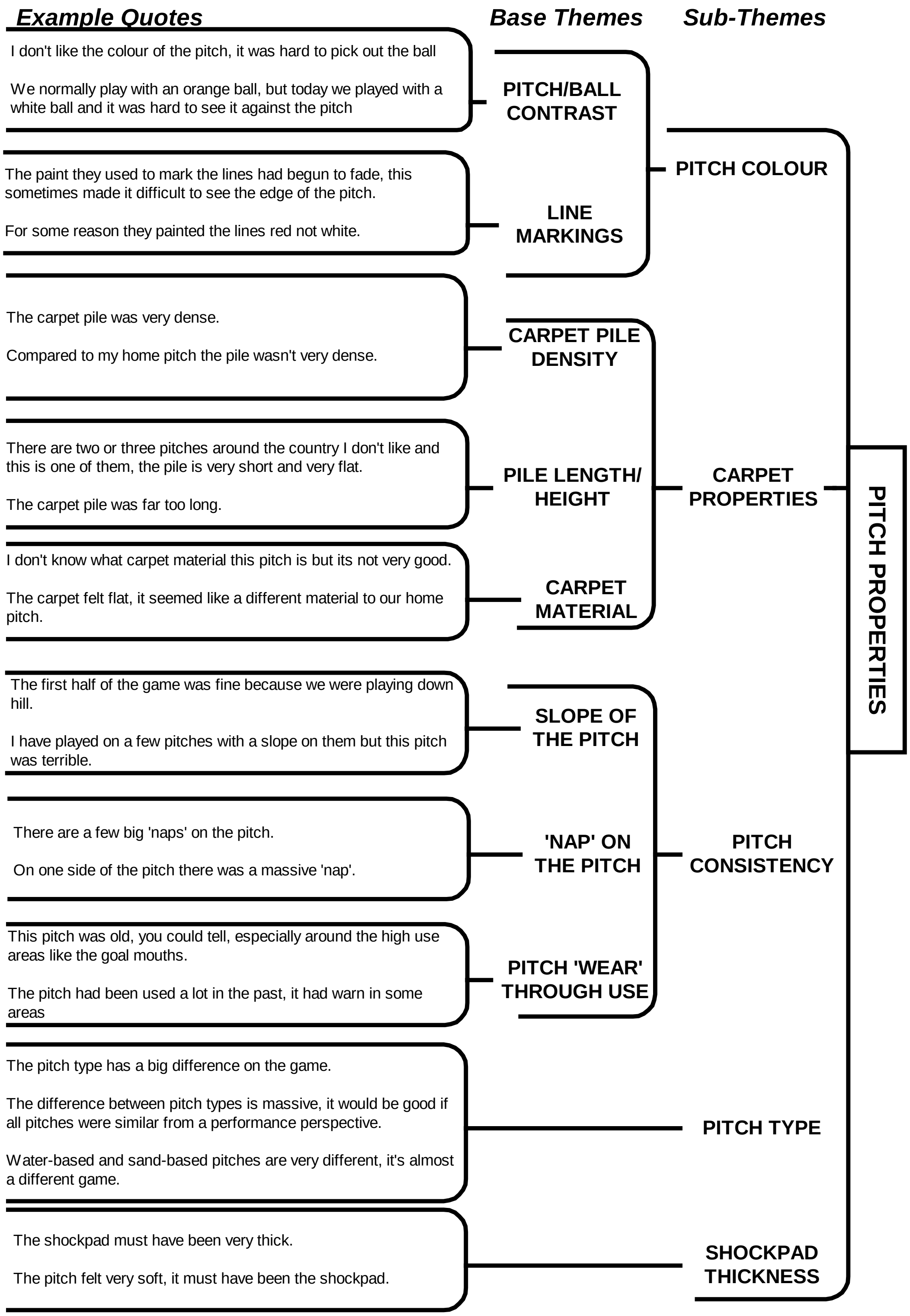

Fig 5. A tree diagram for the dimension 'pitch proper-

Player Environment

The players' descriptions of environmental issues relating to the pitch are grouped together in the general dimension 'playing environment' that is illustrated in Figure 7. Environmental issues that affected the players' included floodlights, drainage and irrigation are all contained within this theme.

The water cannons (irrigation system) didn't cover the entire pitch, places were dry. The goalmouths and the edge of the 'D's' were especially bad [dry].

It was raining when we played and the pitch became very wet, too wet. The water just sat on the carpet I don't think the drainage could handle that amount of water.

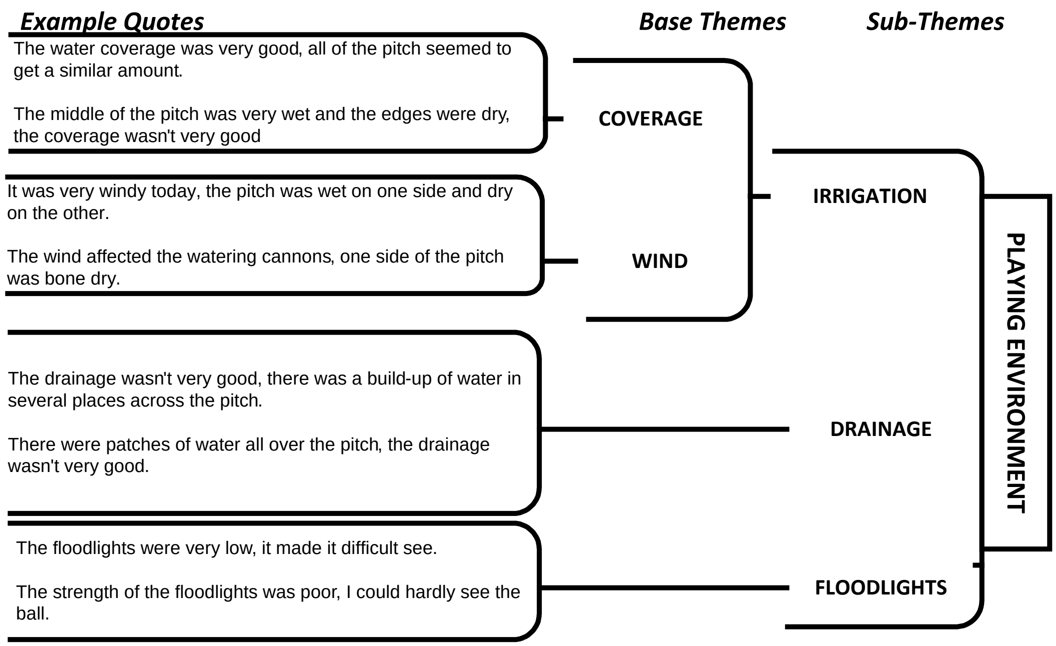

Fig 6. A tree diagram for the dimension ‘playing envi-ronment’

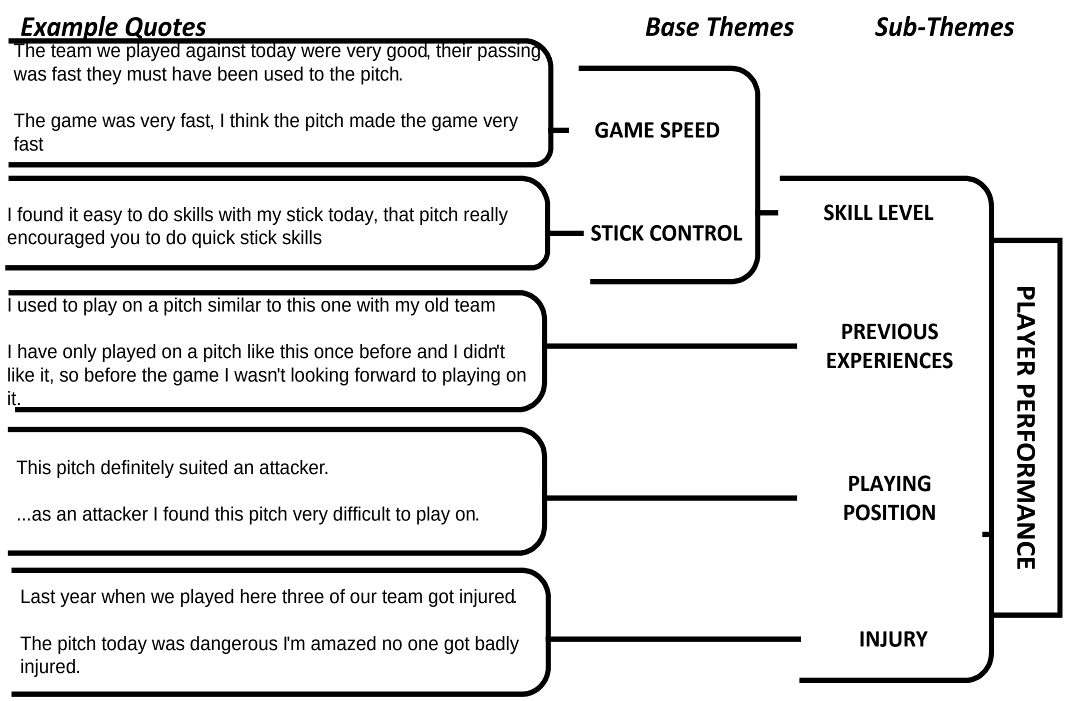

Fig 7. A tree diagram for the dimension ‘player perfor-

Structured Relationship Model

The template of semi-structured interview followed by an inductive content analysis, highlights the significant components of a players subjective perception but it does not facilitate exploration of the possible inter-dimensional relationships. The structured relationship model was produced to addresses this. The process involves finding links between dimensions via player responses. Initially, players' quotes were coded into individual themes. However, to preserve the quote's meaning they were kept whole. This often resulted in quotes with several themes, which then had to be coded into numerous categories. Take, for example, the following quotation:

The ball bounced very high, it was probably the thick shockpad, it felt very soft to run on.

The above quote describes three different perceptions; the ball bounce height, the shockpad thickness and the player/surface impact. Initially, the quote was coded into the base level themes 'bounce height', 'shockpad thickness' and 'impact'. However, the quote also suggests that there is a relationship between ball bounce height and shockpad thickness. Following further analysis of the data it became apparent that ten similar inter-dimensional relationships existed (illustrated in Figure 8) and that a complete analysis could no longer be achieved by simple tree-structures. The software NUD*IST facilitated in the formation of each relationship, it provided a search resource to identify links amongst the coded data between each dimension. Below are examples of two relationships.

The thickness of shockpad clearly affects both the bounce height of the ball and the impact feel for the player. This was particularly noticeable with a perceived high ball bounce and soft underfoot impact during running.

The pitch was very soft the ball bounced very high it must have been a thick shockpad.

It was nice to run on because it was very soft but the ball bounce was very difficult to judge because it was so high.

The type of pitch surface system was found to have a large effect on the inter-relationships, with many players clearly identifying either a sand-based or water-based pitch related to surface grip and abrasiveness.

Sand-based pitches are very abrasive, if you fall you are likely to get a friction burn whereas water-based pitches you can dive around without getting any burns.

Our home pitch is sand you get much more grip there than you do here [LU]. The water makes the pitch much more slippy, but then again, it's much less abrasive too.

This demonstrates quite markedly that players' perceptions of the surface type can significantly modify the way they play.

Discussion

Player Perception

The aim of this study was to develop an understanding of field hockey players' perceptions of the surfaces upon which they play. The interviews were structured such that players were never asked leading questions, and whilst this clearly allowed them to express what they felt was important in their own words, it did result in some difficulty identifying the *relative importance* of their perceptions. However, the inductive analysis method used ensured impartiality during the data analysis, and from the clustering of the quotes there emerged five clear general dimensions.

These dimensions were identified as:

- Pitch Properties
- Ball/Surface Interaction
- Player/Surface Interaction
- Player Performance
- Playing Environment.

It was also evident that there existed some relationships between dimensions, and the structured relationship model was developed to highlight these, and this model (see Figure 8) provides a strong indication of the aspects of the pitch characteristics that *players believe* are important to their play performance. This pictorial representation of player feedback is useful for facilitating a list of desirable pitch requirements and hence laboratory or field tests that could be utilised to evaluate play performance by objective means, e.g. mechanical testing. This is discussed later in this section after some further specific discussion of the data produced in this study.

Comparing the players' perception of their own performance and the game outcome with their opinion of the surface they had just played on, it was found that players did not necessarily blame the quality of the surface for the outcome of the game or their own performance. It was often stated that the reasons for poor performance or result were related to the player 'not being used' to playing on the surface rather than a 'poor surface'. Players often criticised a pitch they had won on and praise a pitch they had lost on.

Comments were made regarding a perceived poor quality pitch and a bad result but these were far less common than positive pitch feedback. Attribution theory suggests that the 'causes' given for losing a game are more likely to address pitch problems than the players' own personal shortcomings. However, from the acquired data it is difficult to support or reject this assumption for this study

It became evident that most players had strong opinions regarding the two generic pitch types of water-based and sand-based, and that most preferred the water-based surface system. However, players also identified large differences between the water-based pitches that they had encountered. Water-based pitches are more common at elite level and became the sole surface type for premier league games from 2004. Players commented on the difference between some aspects of the carpet such as pile height, pile density and the carpet material.

In general, they perceived that greater pile density and a longer pile caused more ball bounce but also that more watering was then required to properly wet it. Too much ball bounce was often perceived as a negative aspect, making it harder to control the ball during play. Players used the terms 'cheap' (e.g. poor build quality and colour), 'copy' (e.g. low consistency) and 'like a normal carpet' to represent dislike of how a carpet looked as well as played. There are many carpets in the market at present, and there is a current lack of available information from studies on the effects of pile height and pile density on playing performance (e.g. such as bounce or speed).

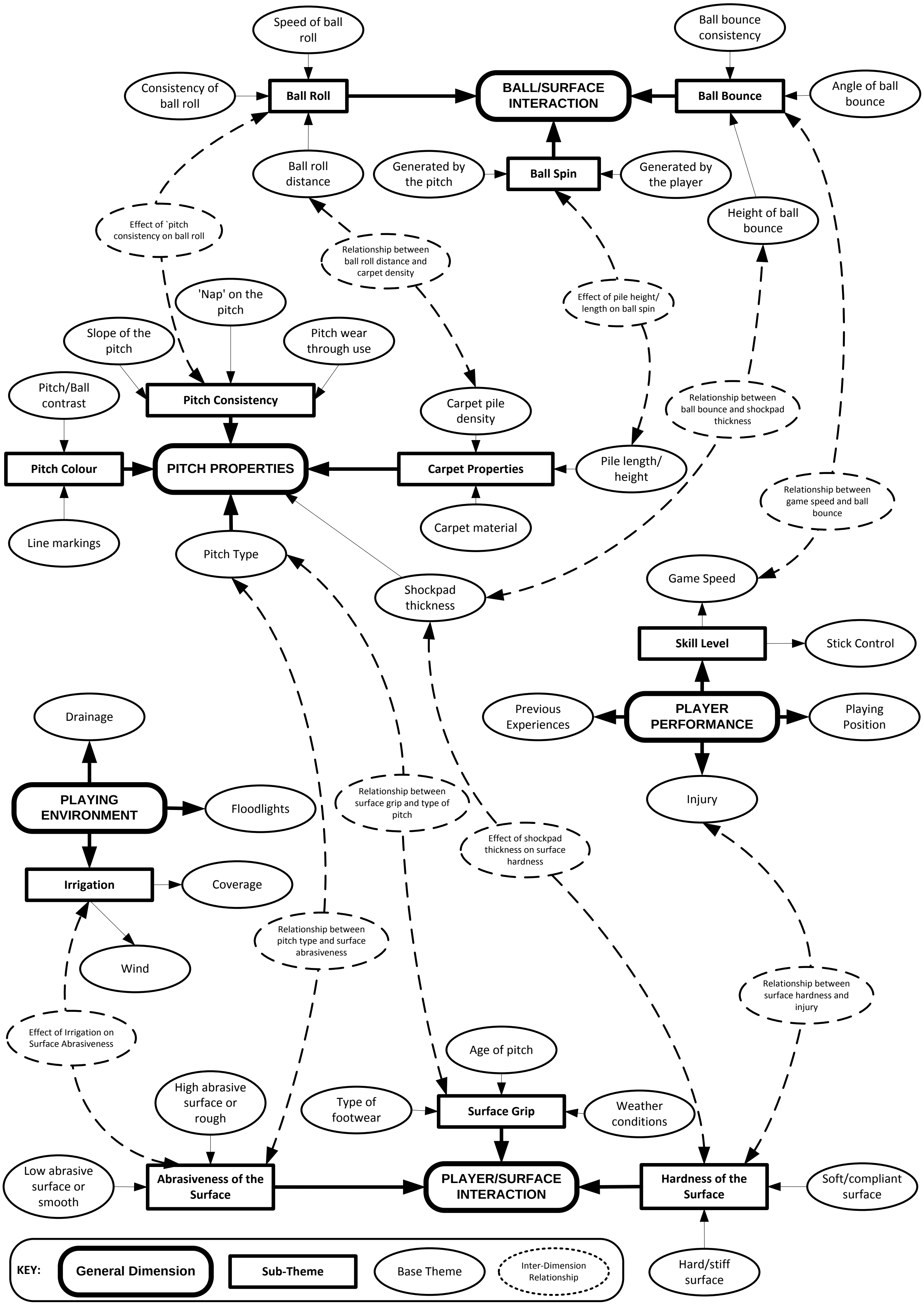

Fig 8. The structured relationship model

The shockpad is expected to affect both the ball bounce behaviour and player-surface interaction. Players appear to know that a shockpad is beneath the carpet, and do appreciate its role in general. However, whether they understand that there may be a difference in shockpad design between different pitches is harder to gauge at this stage of the research. Many players suggested that a thinner and/or harder shockpad is better for fast competitive play. However, perhaps more interestingly, many stated that for some water-based pitches 'the ball bounces all over the place' in contrast to a lower and more even bounce on a sand-based pitch. The sand dissipates energy during ball impact, and for a water-based pitch the water also dissipates impact energy, although it is also apparent that as it dries out the bounce height increases and can become less consistent due to variability in wetness. Furthermore, inconsistencies with the irrigation system coverage can lead to poor surface uniformity of wetness that may give the impression to a player of inconsistencies caused by the surface itself.

The efficiency of the irrigation and drainage of specifically water-based pitches was seen as very important, and was mentioned by most players. Inconsistency of coverage was a clear issue, especially in windier conditions, as was how well the water is retained on the surface during play (related to rate of drainage). Water based pitches often have to be fully irrigated again at half time. Differential drying across the pitch and 'becoming too dry' was mentioned by many as a potential source for injuries.

The colour contrast of the pitch, the line markings and the ball (relative to the sand) were highlighted by many players as important to them. The main concern was for visual contrast between the ball and the sand for sand-based pitches, with lighter sands causing more problems for white balls as opposed to orange balls. In addition, the white line markings were deemed harder to define against lighter coloured sand infill. Few players mentioned floodlighting as affecting the visual pitch qualities, and the comments received were restricted to floodlight height i.e. players suggested low floodlights often 'dazzled' them, making it harder to identify the ball and other players.

A relatively small number of players made reference to their preference for footwear on the different surfaces. This does not perhaps diminish the importance of choosing the proper footwear for different playing surfaces; however it does bring into question how different footwear could shape perceptions of the playing surface. Nigg and Segesser (1992) demonstrated that footwear can significantly reduce the impact to the body's lower extremities (i.e. help attenuate shock and thus affect the perception of the 'hardness' of a playing surface). A few players highlighted a link between injury and surface hardness but none related this to their choice of footwear. However, players stated that they often wore the same footwear on each pitch played on and as this factor remained constant the interview responses are thus considered more focused on the surface differences rather than the effects of footwear.

In general, players did perceive differences regarding the surface hardness and friction properties of the pitch. Some players clearly desired very fast play, and considered this to be best achieved on hard surfaces with low ball bounce characteristics, whilst some appreciated the important role of the shockpad in cushioning player-surface impact forces, and in their opinion protecting themselves from injuries related to repetitive strain. However, many stated that when the surface was 'bouncy' the ball was harder to control and may give an attacker an advantage over a defender. The game speed on water-based pitches was perceived to be faster than sand, consequently many players stated that the skill level needs to be higher to exploit the pitch to its full potential. In addition, many skills could be performed on a water based pitch, such as diving or sliding, that were not applicable to a sand-based pitch due to its higher abrasiveness. The two players who preferred sand-based pitches have one as their home pitch. It appeared that some players adapted better than others to different surfaces, a finding supported by Ferris *et al.*, 1999. The skill level aspect of play was mentioned by many, and it is possible that players with more experience of many surface types will have learned to adapt more than those with less experience. However, for the bouncier pitches more problems in ball control were described and there was a need for the use of different skills to gain an advantage over the opposing competitor.

It appears that players can adapt to different surfaces, and whilst some prefer surfaces that allow skilful play these may be less forgiving on the body and the players interviewed seem to understand that there may be possible long-term injury consequences. However, this sample interviewed was from the elite level playing population only, and it needs to be debated as to whether pitches for use by lower ability amateur players, and especially younger players, should be designed more with player protection or basic skill development in mind. It is the authors' opinion that better information should be provided to the pitch operator/user regarding its behaviour, such that judgements may be made with greater confidence regarding both playing quality and user safety. However, this requires better knowledge regarding the benchmarking of the relevant properties of the pitches in use, and also how design and construction affect the playing characteristics of a new pitch and how these change with time. It appears that pitches are rarely monitored after construction.

Whilst tests to evaluate playing performance exist (generally administered by the sport's international governing body, e.g. FIH 1999) it is useful to consider the parameters that this study has highlighted as requiring assessment, although a more detailed review is outside the scope of this paper. The player comfort aspects of surface hardness and underfoot friction were clearly identified. The hardness of a surface is considered to be associated with the carpet compliance, the infill stiffness and the shockpad stiffness. With regard to friction the requirement is for both stopping and starting and also during in-motion manoeuvres such as cutting, and thus comprises linear static and dynamic friction and also rotational friction (traction). The effect of shoes is clearly an added complexity in developing a simplified test method.

Engineering Properties of Pitches

Whilst tests to evaluate playing performance exist (generally administered by the sport's international governing body, e.g. FIH 1999) it is useful to consider the parameters that this study has highlighted as requiring assessment, although a more detailed review is outside the scope of this paper. The player comfort aspects of surface hardness and

underfoot friction were clearly identified. The hardness of a surface is considered to be associated with the carpet compliance, the infill stiffness and the shockpad stiffness. With regard to friction the requirement is related to both stopping and starting and also in-motion manoeuvres such as cutting. These requirements relate to linear static and dynamic translational friction and rotational friction. The effect of shoes, both for impact and frictional behaviour, is clearly an added complexity in developing simplified test methods to quantify these requirements.

Ball bounce and roll was also identified as key to the playing performance and skill level afforded. The ball can impact the surface at a variety of angles and velocities, and as a result of its low mass (i.e. relative to the pitch surface layer it impacts) it is considered that the near surface materials are likely to have the greatest effect (e.g. as evidenced by the effect of variable surface wetness of the water based pitch) in conjunction with a combination of both surface friction and stiffness influencing the amount it slows down and the angle of rebound. The current FIH test methods are for a relatively low-velocity roll and a vertical drop height, neither of which recreate in-play conditions but are simple to perform.

The interaction of the carpet, infill, and shockpad layers is considered important to the performance of the system under any form of loading. It is also likely that ageing and wear effects will cause the properties to change. In addition, the intrinsic material properties, such as the non-linear stiffness and visco-elastic behaviour of the rubber shockpad, requires the assessment regime to be at appropriate strain rate and strain magnitude levels, and also at appropriate stress levels and suitable environmental states (e.g. temperature and wetness). Other assessments indicated by the study include the reflectivity of the surface, visual contrast between elements, and the cross pitch consistency of all the factors identified.

It is of particular note that in general, standardised tests do currently exist that assess the performance related parameters identified although their accuracy can be questioned. The only clear exception is a test for water-based pitches that can establish the 'wetness' of the surface, which would clearly help establish the effectiveness of both irrigation and drainage systems. Most importantly, from a safety viewpoint it would help establish when further watering is required. Review of the FIH standardised tests shows that there exists a significant gap between the simple tests therein (i.e. primarily 'static' in nature such as vertical impact, vertical ball bounce and so on) and the in play parameters. The player and ball motion is very dynamic, and the pitch and material response is considered relatively complex for these and other factors (i.e. such as biomechanical effects relating to individuals).

As a result of the study it would be ideal to provide a simple answer to 'What makes a good pitch?' This study has shown that at the elite level players are more concerned with the quality of play, the skills they can achieve and winning, rather than they are with the potential for discomfort or injury during a game. In summary, players generally wanted a fast, low bounce and non-abrasive but grippy (underfoot) pitch. Different playing positions preferred different playing requirements. However, it is clear that it may not be possible for a pitch to satisfy ALL these requirements for competitive play.

Conclusions and Recommendations for Further Work

The aim of this research was to develop a suitable method for eliciting player perceptions of field hockey pitches and determine the key themes that players consider when assessing pitches. Using a qualitative approach of interviews and inductive analysis of the statements recorded, five dimensions emerged. These were; Ball/Surface interaction, Player/Surface Interaction, Pitch Properties, Player Performance and Playing Environment. A structured relationship model was then developed which graphically represents how the base level themes fit into the higher order dimensions and also illustrates the interactions between dimensions.

The player responses suggest that they can and do perceive differences between the pitches studied. The majority of players considered a 'hard' pitch with a 'low' ball bounce facilitating a 'fast' game speed was desirable. However, it is clear that a conflict between certain perceived playing properties may exist, for instance a pitch that is suitably soft underfoot will result in undesirable high ball bounce. It was identified that players tended to favour water-based pitches over the more traditional sand-based design, as they were perceived to facilitate fast skilful play. However, issues remain as to consistency of the surface during the match and between the different systems experienced.

The player perceptions are useful in assessing and setting the priorities for both measurement and design of pitches to achieve the players' desired playing performance. However, other users than solely the elite level studied here, and other playing requirements such as training, need to be taken into account

The players' comments can be used to identify the key pitch playing parameters that are of concern and that can be then considered in terms of the pitch materials engineering requirements. These were identified to primarily include, for behaviour under player loading, the stiffness of the system (primarily vertical) and the surface frictional properties (static, dynamic, linear and rotational).

The general dimensions (figure 8) are of great interest but their relative importance cannot be identified from the qualitative data presented. Thus there is a need for further research to discover the importance of these emergent themes. It is recommended that a follow-up programme of research, via questionnaire, be undertaken with a large sample to elicit the players' preferences and priorities for the themes derived here. The careful design of such a questionnaire is vital, and the perception study is extremely useful in aiding the question design such that terminology players are familiar with is used and it is focused on the key issues. A series of field measurements are then considered necessary to assess the link between players' perceptions and (mechanical) performance testing to aid future designs for artificial surfaces for field hockey.

A further step would be to integrate pitch assessment research with studies of player-surface interaction, biomechanical models and injury-related studies, to determine the real significance of the pitch on the players' health in general.

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