In many sports, referees, umpires or judges are placed under immense pressure to make accurate split-second decisions that determine or contribute to the outcome of the sporting competition. In some sports, such as figure skating or gymnastics, the judges are responsible for the entire score. In other sports the referee or umpire has the ability to make field-of-play decisions that significantly contribute to, or in some cases may determine, the outcome. In order to function effectively such decision-makers must have full knowledge of the rules of the sport and be able to apply their knowledge in split-second decisions made under often very stressful conditions. If they make the wrong decision, they are often blamed for the outcome of the game.

Given the pressure that these individuals face and the importance of ensuring accurate results, several sports governing bodies have attempted to increase the accuracy of officiating decisions through implementing new technologies in their sports (Woodward, 2013). These officiating technologies, often based on video systems, allow movements to be replayed and judgements to be confirmed or reviewed. In some cases these systems have been developed specifically for an individual sport, but in other sports the push for technological intervention has come from commentators and coaches who have access to more advanced technology than the referees themselves (Leveaux, 2010). For example, the slow-motion replay that commentators make use of on television was available to commentators before it was available to referees.

This chapter considers the actor-networks of various sports that have enrolled technological devices for assisting with umpiring or judging. The cases of cricket, tennis and artistic gymnastics are drawn upon to examine how the actor-network of each sport is affected by the new technology. Each sport is followed beyond the point at which the governing body introduces the new technology, to look at how the new assemblage affects other, often unexpected, parts of the actor-network.
The translation from movement to score

The motivation for introducing technology stems from the aim of sporting competition. In order for a sporting competition to occur, the rules of every sport must have a method for determining a winner. In some sports, such as swimming or running, this is a relatively simple matter, with the winner being the person who completes a particular distance in the fastest time. In these sports the numbers describing the time taken to finish the race translate directly into a ranking system. These sports employ devices such as stopwatches and photo-finishes in order to determine an accurate and direct translation. Such devices obtain empirical data, then convert the data into a score without human intervention. For example, in swimming competitions, the moment swimmers touch the end of the pool, which is equipped with sensors, they can look up at the scoreboard to see their times. In races that are very close it is common to see all swimmers rush to look up at the scoreboard to see who won. This can be seen as an ‘ideal’ form of evaluation for sport, as the performance translates smoothly into a number in order to rank performers and establish a winner. This allows little scope for controversy, with the times recorded generally accepted as the correct outcomes.

However, in many other sports the rules include much greater complexity so a smooth translation is difficult to achieve. Determining the winner may involve factors such as whether they adhered to the rules, or even subjective judgements from human umpires or judges. Subjective judgements are not seen as ideal in sport, as they are perceived to be unreliable, so technology is often introduced in order to assist with the provision of reliable, empirical data.

In order to arrive at the correct results, a range of sports have introduced different pieces of technology. In all cases, the assumption is that the technology will act in a more reliable or accurate manner than a human performing the same role, or that the technology will provide more information to a human making the decision. Latour (1992) asserts that technologies can often be relied upon more than humans since they generally perform a repetitive, boring function without any interruption. Latour illustrates his argument using the example of a door hinge. He describes how humans can be notoriously unreliable at remembering to close doors after they have passed through them, which can, of course, lead to wind or rain coming inside. He argues that one solution to this could be to employ a porter to close the door; however,
the porter, being human, is likely to find the job very boring and tedious and will also require lunch breaks etc. in order to function. Another solution could be to place a sign by the door, reminding people to close it; however, people who may be absorbed in their thoughts or a conversation when they enter are not likely to pay attention to such a sign. By contrast, if the porter or sign were to be replaced by a door hinge that automatically closed the door, this would be a far more reliable solution. The door will be closed every time without the door hinge becoming bored, forgetful, requiring a break or requiring pay. While this example is very simple, it illustrates one of the fundamental arguments of this chapter: that delegation to non-humans can produce a more reliable result, or is assumed to be able to do so. In sport, the accuracy of the results of a game or competition is important in order for the sport to be deemed valid, but in many cases in sport humans cannot always provide reliable results, as in the swimming example described in the previous paragraph. Here the technology capable of determining the precise point when a swimmer touches the wall to finish the race is far more effective than a human. The human eye can easily distinguish between swimmers who are several seconds apart but is not able to determine the winner when the intervals are in fractions of a second.

Latour (1991) further argues that, when an actor-network arrives at a state of relative stability, it is usually due to the presence of a non-human ensuring that the network is functioning well. This is illustrated in the above example where, without the technology that provides timing differences to fractions of a second, it would be necessary to rely on the human eye to determine winners. In such a scenario it is likely that those watching the swimmers would disagree on which swimmer won the race if the swimmers finished the race at what appears to be the same time. Such a situation would result in many arguments and could result in rule changes regarding who is allowed to make the final decision about the winner, and where they should stand etc. In contrast, with the current technology in place, swimmers can be confident that the technology will reliably tell them who won the race, and there is no need to argue for any changes to how the sport is run in this area. Therefore, swimming has obtained a desirable form of stability in possessing a piece of technology that is able to reliably determine the winner. This is quite different from a sport such as gymnastics, which instead employs large numbers of judges who must be constantly re-educated about rule changes in the sport. Gymnastics lacks the technology that swimming possesses, and so instead exists in a state of constant
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instability. The rules and regulations are formally updated every four years, with other changes also occurring on sometimes a monthly basis. But even in gymnastics, stability is possible at particular competitions owing to the presence of an inscription, a rule book known as the Code of Points that everyone at the competition agrees to follow.

Technologies utilised in team sports competitions

Thus far in this chapter, very little in the way of technologies for team sports have been referred to. Stopwatch-style technologies such as that used in swimming, and rule books as used in every sport are relatively simple types of technology that are easy to understand. But with the variety of types of sports, both individual and team, comes a variety of types of technologies that are used to ensure that the results of a competition are valid and correct. I will now discuss some of the more common types of technology utilised by different team sports.

Post-match

After a match is over, many sports employ an expert, often referred to as a ‘citing commissioner’ (Leveaux, 2010, p. 5), to review video footage of the game. Any incidents that are seen during this process can be viewed from multiple angles, and any offending player/s can be brought before the sport’s judiciary or tribunal (Leveaux, 2010). This technology is more likely to be utilised in team sports, where there are multiple players on the field. For example, in the sport of rugby union, where there are thirty players on the field at once, it is impossible for the referee to see the behaviour of all these players at all times. Here the use of the citing commissioner following the game has at times resulted in players receiving yellow or red cards, owing to the commissioner observing behaviours such as eye gouging or biting that were not observed by the referee during the game. These examples indicate that the use of the citing commissioner who reviews replayed footage is effective for identifying rule-breaking behaviour.

At the same time, from a legal standpoint, Nafziger (2004) notes the necessity of sports having clear regulations around the use of video footage. He describes a case where a rugby player had his suspension overturned by an English court because video footage had been used to determine that he
should be suspended, but the player had had no opportunity to view and comment on the footage before the decision to suspend him was made. Nafziger’s emphasis on the need for regulation acknowledges the usefulness of considering officiating technologies within the network of the sport in which they operate rather than as standalone items. The policies and regulations around how video footage is used to make decisions can be as important as the technology itself.

**During the match**

Some sports use video replay systems during the match. In several sports a system is employed where the referee may opt to use a third party to make a decision if they not feel they were in a position to make an accurate call. Some examples are a line call in tennis, the fall of a wicket in cricket and a try in rugby (Leveaux, 2010). A problem with viewing video during the match is that it requires the brief suspension of the match while the decision is made, which can be frustrating for players and spectators alike (Nafziger, 2004). The following case study discusses this issue in more detail. Typically, the third party is a referee stationed outside the field of play who has access to video footage that allows the viewing of the situation from a variety of angles. A rugby referee in Leveaux’s study (2010, p. 5) describes how he is only able to use the third umpire in certain situations, and then must be very specific in what he requests of them:

I can only call to the video ref in certain situations, for example, about a try being scored with regards to matters relating to the grounding of the ball or if I might be undecided if a breach of the rules occurred in that play, such as a forward pass – and when I do use the video ref(eree) I have to be explicit in what I ask, e.g., was so and so in an off-side position when receiving the ball or with correct grounding of the ball in a try.

This referee’s comments indicate how the rules are carefully spelt out as to the use of the video referee, and do not allow the referee to use them in a way that may hold up the game or require clarification. Sports vary in the processes for consulting the third referee or umpire and as to whether players can also request their assistance. For example, in tennis, players can consult the third umpire but are only permitted two incorrect challenges per set (Leveaux, 2010).
Other sports such as taekwondo do not use any form of third umpire or video referee during the match, as the time taken to pause and consult is too disruptive to the sport (Leveaux, 2010). This highlights how the different actor-networks of sports influence whether a piece of technology is utilised or not. In taekwondo, where two athletes physically fight each other, the necessity for the match to continue unimpeded is far greater than the need for a video referee. Similarly, the concept of allowing a player to challenge a call, as in tennis, was seen by the referees in Leveaux’s study as open to far too much exploitation by players to be considered appropriate.

However, the taekwondo referees do view the use of a video replay system to be useful during a ‘sudden death’ match. An example the referees described to illustrate this was when both fighters score a kick at what appears to be the same time (Leveaux, 2010). This scenario resembles the swimming example discussed earlier, where technology is useful for determining what the human eye has difficulty seeing. In the taekwondo example a video replay would allow pausing of a video reply at the exact point of the kick, making it possible to determine which athlete scored first.

**Behind-the-scenes technologies**

One of the central claims of ANT is the importance of following all the strands in a network. Latour (1996, p. 371) describes how society has ‘a fibrous, thread-like, wiry, stringy, ropy, capillary character’ where understanding the workings of the network involves following all the capillaries. In researching in this manner, action is revealed that is often not noted in traditional sociological analyses that focus on single issues or large-scale phenomena and miss the smaller capillaries. In sport there is a range of actions that could be argued to make up these smaller capillaries. For example, when watching a sport, the spectator sees only the actual performance by the athletes. Hidden from view are a complex array of organisational factors that make the sport run, which often include a variety of technologies. One type of technology that makes sport run is the systems put in place to schedule tournaments, including the selection of and scheduling of umpires and referees. In examining tennis, Farmer, Smith and Miller (2007, p. 187) describe how ‘Behind the scenes, an intricate system of hierarchies, experience, and qualifications dictates the proper assignment of umpires to tennis matches.’ They describe how the scheduling of tennis umpires in a large tournament can be very complex,
with up to eighteen matches being played simultaneously with up to ten umpires per match, and with the need to take into account nationality, player histories and experience. In order to facilitate such complicated scheduling, the United States Tennis Association (USTA) developed a software package. Unfortunately, this software did not prove to be a success for a range of reasons. One factor that limited the software was it was created specifically for the US Open, not taking into account that different tournaments have different scheduling practices. Additionally, the software did not consider the global commitments of the umpires. Finally, in the event of a rain delay, the software could not adapt itself to the new conditions, but rather required the schedule to be rewritten completely from scratch. With this as an example, one of the goals of this chapter is to open the black box and examine technologies that more commonly exist behind the scenes.

Anti-programmes and ‘networks’ within the study of technology and sport

In one of his landmark articles, ‘Technology is society made durable’, Latour (1991) introduces the concept of anti-programmes. These are any programmes that work counter to the desired programme. In the case of tennis, the ‘programme’ is for a tennis tournament to occur. For this many things need to be in place including umpires, who need to be specifically scheduled. In order to make this happen, software is added to the actor-network of tennis. However, as discussed above, Farmer, Smith and Miller (2007) describe how the original software that was enrolled was a failure because it was interrupted by several anti-programmes: the differing practices of other tournaments, the global commitments of tennis umpires and the rain. The remainder of the article details the creation of a new software that was written in order to overcome these difficulties. The article illustrates Latour’s (1991) argument that actor-networks can become ever more complicated and extensive as anti-programmes are identified and overcome.

With this in mind, the ANT theorist’s role is to follow and describe the actor-network. It must be remembered, however, that the ANT understanding of ‘network’ is somewhat different from the mainstream. Latour (1999a) describes how ‘network’ came into use in ANT studies prior to the invention of the worldwide web, yet with the ubiquity of the web the word has come to be understood as the creation of instantaneous ties and connections. Yet Latour
argues that this is the exact opposite of the original intention. He argues that the use of 'network' was intended to refer to a concept similar to Deleuze's 'rhizome', which refers to 'a series of transformations' (Latour, 1999a, p. 15). The word 'transformations' emphasises Latour’s argument that bringing things together produces new assemblages and forms that have different qualities from the disparate parts that combined together. Therefore, the ANT theorist’s role is to examine these transformations through following the network, with an understanding that every point in the network can connect to another point and form new associations. The following examination of Hawk-Eye technology aims to demonstrate how the actor-networks that exist in cricket and tennis have facilitated a variety of outcomes through the way that they have connected with Hawk-Eye. This case particularly emphasises the transformative nature of the network.

Case study: the use of Hawk-Eye in cricket and tennis

In terms of its history, the case of Hawk-Eye demonstrates one of the most significant connections currently in existence in sport: the sport–media connection. This connection is immediately apparent through the way that Hawk-Eye was developed almost simultaneously as both a technology for enhancing the viewing experience for spectators and for improving the accuracy of officiating decisions (Hawk-Eye Innovations, n.d.). Hawk-Eye was first used in public in 2001 by UK’s Channel 4, where it was introduced to enhance the coverage of the Ashes cricket series. While still under development it was trialled at the Davis Cup tennis tournament in 2002. Collins and Evans (2012, p. 910) provide the following description of its workings:

Hawk-Eye is an example of what we call a ‘Reconstructed Track Device’ or RTD. RTDs use visible-light television cameras to follow the path of the ball and a procedure to filter the pixels in each frame. Certain pixels are taken to represent the position of the ball and others to indicate the position of the line or other features of the playing arena. The space and time coordinates of these pixels are represented numerically and a statistical algorithm reconstructs the flight and impact point of the ball and crucial features of the playing area by combining information about the pixels in the different frames with information about the size of the ball, the physics of its distortion, the width of the line, and so forth. From these calculations, the system then determines what decision should be given – for example, should the ball be called ‘in’ or ‘out’?
This description explains how Hawk-Eye relies upon a particular actor-network of cameras, which are placed around the field or court and provide the data Hawk-Eye needs in order to reconstruct the exact movements of the ball. For the actor-network to work, and for this particular assemblage of disparate parts to transform and become useful, cameras need to be carefully placed to see the ball from different angles, and particular algorithms need to be integrated into the system. Then these separate parts to combine together to produce a device with unique capacities.

Spectators and umpires both find it desirable to be able to identify where the ball is in relation to other factors. For umpires, Hawk-Eye is useful for determining the correct call to make in cases where it can often be difficult for the umpires themselves to see to make the correct call. For spectators, Hawk-Eye allows more information to be given than may be provided by the television cameras alone. Indeed, for television viewers Hawk-Eye is particularly transformative. Viewers are provided with a ‘virtual reality graphic’ that consists of ‘either an image or a short video clip showing the path and impact point of the simulated ball’ (Collins and Evans, 2012, p. 910). With this clip, the viewing experience is transformed to become similar to the umpire experience, where viewers use the images provided by Hawk-Eye to make their own decisions on the match.

A range of sports, including cricket, tennis, football, snooker and badminton, have adopted Hawk-Eye (Singh Bal and Dureja, 2012). Hawk-Eye has become part of a very large actor-network that incorporates these sports along with the assemblages that make up the umpiring processes of each sport, and the sport–media connection. It is beyond the scope of this chapter to examine the whole breadth of this extensive actor-network, so this chapter will focus on the introduction of Hawk-Eye as part of the umpiring processes of two sports: cricket and tennis. The following chapter will then examine the actor-network of sports media.

**Hawk-Eye in cricket**

The sport of cricket incorporated Hawk-Eye into the umpiring actor-network of cricket for test matches in 2009 and for one-day matches in 2011 (Steen, 2011). Cricket took an unusually long time to adopt Hawk-Eye technology as part of its officiating process in international cricket, even though it had existed as a broadcasting tool since 2002. One of the most interesting reasons for the slow
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enrolment from an ANT point of view is the difficulty in determining how the umpire and Hawk-Eye should assemble together. Steen (2011) emphasises that, unlike technologies such as the stopwatch, which, as previously discussed, are designed to translate movement directly into a score, Hawk-Eye is not designed to work as a standalone device and it is not a substitute human. Instead, Hawk-Eye in cricket was designed to be part of a ‘system of review’ (Steen 2011, p. 1430). It is a piece of technology that was designed to ‘enhance perception’, and is quite different from technologies that ‘take decisions’ (Collins and Evans 2012, p. 907). Collins and Evans state: ‘Where these technologies are used, the replays are usually reviewed by a newly created class of “off-field” officials who then advise the on-field officials.’ This is exactly the case with Hawk-Eye in cricket, where a third umpire uses what is essentially an animated reconstructed replay of the incident in order to review the decision of the on-field umpire. Steen (2011) emphasises that Hawk-Eye’s purpose is frequently misunderstood by the media, where he explains: ‘The final decision remains with the on-field umpire – the decision is reviewed by, not referred to, the third umpire’ (ICC, 2011, cited in Steen, 2011, p. 1430). This statement confirms that Hawk-Eye is only permitted to be enrolled as a way to assist the decision-making process, not to determine any actual outcomes. McFee (2004) argues that assuming technologies can do the work of humans better than humans can be problematic, because technologies lack the capacity to explain. The set-up of Hawk-Eye prevents this problem because the work of making a decision is not delegated to Hawk-Eye itself; instead, a new assemblage of human-Hawk-Eye is produced that is used to support a decision made by a human. The assemblage is acknowledged as effective through the praise it has received for improving umpires’ decisions in cricket (see Steen, 2011).

However, as Latour (1991) notes, new forms of technology can also generate unexpected consequences. Such consequences reflect the notion of the network as transformative, where connections between parts of the network can transform the way action takes place or generate new forms of action. In the case of Hawk-Eye, Steen (2011) notes how the technology has become utilised as a method of surveillance of cricket umpires. In this example Hawk-Eye can be seen as not only a device for assisting umpiring but also as a method of transforming the practice of umpiring into a monitored act. By noting how many times the third umpire views Hawk-Eye, the ICC can evaluate various umpires’ skills. Through using Hawk-Eye in this manner, the ICC found that umpires believed to be the most skilful really do make good decisions, compared with those umpires
who are believed to have less skill. In the 2011 Cricket World Cup there were a total of 182 referrals to Hawk-Eye across forty-nine games, where 20.33 per cent led to reversals in decisions. In tracking which umpires had their decisions reversed, Steen (2011, p. 1437) described:

The vaunted emerged with heads high – Dar was challenged 14 times and not once reversed, Billy Bowden (six challenges) also defied contradiction, Taufel was proven right in 10 of 12 reviews and Steve Davis (perfect after his first 10) affirmed his growing reputation. At the opposite end of the scale, reservations about Asoka de Silva (four reversals in his first four reviews, which led to him being dropped for the final group matches) and Daryl Harper (seven in 14) had been underscored.

Steen’s argument here is that the monitoring performed through Hawk-Eye confirmed Dar, Bowden and Taufel as good umpires, and de Silva and Harper as not so skillful. The findings of the differences between umpires reveal two different aspects of Hawk-Eye. First, as discussed, these findings reveal the way that technology can affect sporting practice in unexpected ways. While the goal of utilising Hawk-Eye is to improve umpiring decisions, its deployment has revealed that it is also useful for demonstrating the ability level of different umpires. The actor-network further expands with the addition of the actant, the ICC, which can now select umpires appropriately, which may result in an improved level of umpiring in the long term.

Second, given that Hawk-Eye is a hybrid system and not a substitution for a human, the ability of a human to use it correctly becomes crucial. In this example, the actor-network extends to the umpires needing to acquire new skills. Steen (2011) discusses how cricket officials are understandably aware of the need for good umpires to work with Hawk-Eye and have therefore adopted a system where perceived ‘good’ umpires are rotated throughout a test match so that they take turns being on the on-field or third umpire. This rotation demonstrates how the introduction of a new piece of technology in sport can be very disruptive, requiring significant reworking of the actor-network. In this case the hybridised nature of Hawk-Eye resulted in the need for a third umpire, which further resulted in the anti-programme of insufficient umpires with the necessary skills. This then led to a further expansion of the network through the need for introduction of a rotation system to ensure that umpires are used equitably and effectively.

This example has implications for sports policy-makers who intend to enrol new pieces of technology. Through viewing the case as an actor-network, we
can see the way that introducing a new piece of technology may also result in the need for restructuring or further resourcing. The example highlights how, although new technologies can improve sporting practices and processes, they can require extensive networks around them in order for the technology to be used for its maximum effectiveness. In the case of cricket, significant work has been performed by the ICC over several years in order to finalise an effective structure, but this work was not foreseen prior to Hawk-Eye’s introduction.

Earlier it was argued that the actor-network of cricket acknowledges Hawk-Eye as a hybrid system rather than expecting it to be a full replacement for a human umpire. However, there are suggestions that the hybrid format can be problematic. For example, Mahmood et al. (2012) suggest that it would be more effective if the human element were eliminated and an entirely automated system produced instead. This would be akin to Latour’s (1992) example of the speed bump replacing the human policeman. Mahmood et al. provide two arguments for the effectiveness of removing the human element through identifying two anti-programmes at work: game time lost in consultation, and the problem of human error.

In terms of game time, the use of the third umpire is supposed to take only thirty seconds, but in reality it more often takes up to a minute for them to reach a decision. This is understandable, given the role of the third umpire in reviewing the footage provided by Hawk-Eye and coming to a conclusion. However, this amount of time is argued to be enough to break a player’s concentration and therefore acts as an anti-programme, disrupting the player’s performance and the flow of the match. Mahmood et al. (2012, p. 12282) describe cases where the referral to the Hawk-Eye system has resulted in altered performance:

We witnessed that several bowlers bowled brilliantly before a referral, by preventing the batsmen from scoring lots of runs. However, after the referral, the same bowlers lost their rhythm, hence leading to an increased scoring rate. Similarly, there were several batsmen who were scoring lots of runs before a referral, but after a referral, their scoring rate decreased, or they got out, due to a disruption of their rhythm.

The result here of a distinct change in performance, is a highly undesirable outcome from both the players’ perspective and for spectators. A drop in performance is obviously undesirable for players, and for spectators the potential excitement offered by high scores and continual play is disrupted. Again this is an unexpected consequence of the introduction of a new piece of technology,
with potential follow-on effects to other parts of the network: in this case, player performance and resultant spectator interest.

This argument points to the lack of perspectives that have been adopted in examining technology in sport. While theorists have examined technology as adopted by athletes and its impact on performance (see, for example, Butryn, 2003; Haake, 2009; Magdalinski, 2009; Tangen, 2004), the lack of any perspectives that utilise the idea of sport existing as an actor-network has meant that there has been very little consideration of how the integration of technologies for other purposes affects athletes. An exception is Butryn (2003), who notes the impact that the large ‘jumbo-screens’ placed around the Olympic athletics stadium have on performance. Butryn (2003) and Mahmood et al. (2012) leave little doubt that the technologies that are introduced to improve the watching of sport (by both spectators and umpires) have a significant effect on athlete performance. Yet interestingly providing ways to produce programmes to overcome these anti-programmes is viewed as part of the role of the athlete’s coaching and scientific team rather than a wider concern. This is in contrast to an issue such as doping, which is commonly understood as a problem for all parts of sport. Further research about the impact of decisions about the use of officiating and media technologies on athlete performance that acknowledges the connections between these two areas of the actor-network would be of benefit.

The second argument of Mahmood et al. (2012) against the use of technology that exists as a hybrid is that of human error. Both Steen (2011) and Mahmood et al. (2012) discuss the problem of human error as evidenced by cricket being a sport with a long history of contentious umpiring decisions. Steen (2011) and Collins and Evans (2012) describe numerous instances of questionable umpiring decisions as a way of justifying the need for a technologically assisted system. In other sports the reliability of the human umpire, referee or judge has also been raised. Nationalistic bias (Ansorge and Sheer, 1988; Dixon, 2003; Ružena, 2000), expectations of success (Findlay and Ste-Marie, 2004; O’Brien, 1991) and evidence of genuine mistakes (Ste-Marie, Valiquette and Taylor, 2001) have all been found at various studies of judging. In contrast to human fallibility, technology is assumed to be free of these sorts of mistakes, since it is not able to be persuaded. This reasoning mirrors the argument made by Latour (1992) that non-humans can be more reliable than humans. However, a counter-argument put forward by Collins and Evans (2012) opens the ‘black box’ of the Hawk-Eye system by positing that the system is seriously lacking in its reliability. In this sense, it is similar to the human judges being subject to making genuine errors.
Collins and Evans describe the immense difficulty in determining decisions regarding leg-before-wicket (lbw). In an lbw situation the umpire must make a call based on where the ball would have gone if it had continued uninterrupted, which is extremely difficult. Given the difficulty of the decision, Hawk-Eye is often used to confirm lbw decisions, but it is also unable to calculate this with complete accuracy. Collins and Evans (2012, p. 912) describe how, when reconstructing the path of the ball, Hawk-Eye includes a ‘zone of uncertainty’: if the ball is found to land in that area, the third umpire cannot overrule the on-field umpire's decision. This lack of accuracy demonstrates that despite the belief that technologies can produce more accurate and reliable results than humans, in the case of Hawk-Eye the technology is not completely reliable. The question of reliability becomes more complicated and interesting when the use of Hawk-Eye in cricket is compared with its use in tennis.

**Hawk-Eye in tennis**

Tennis adopted the Hawk-Eye system earlier than cricket. It was first used for broadcasting in 2002, and 2006 was the first time the system was used for umpiring purposes in a professional tennis match (Fischetti, 2007). Clarke and Norman (2012, p. 1765) describe how Hawk-Eye is used in tennis, which is quite different from how it is used in cricket:

In tennis, it displays a schema of the court lines along with a mark where the ball is believed to have bounced, along with a decision on whether it was in or out. (Interestingly, the path of the ball is never shown with any error bounds: the public and players appear to accept that it is exact and infallible.) The interesting development in tennis was that the players, not the umpires, under certain conditions were allowed to challenge the umpire's decision by referring to Hawk-eye. If Hawk-eye sided with the appealing player, the umpire's decision was reversed.

This quote outlines two clear differences between the actor-network of tennis and that of cricket. First, in tennis it has always been the case that the players are allowed to challenge the umpire's decisions and refer them to Hawk-Eye, which was not originally the case in cricket. The implications of this difference will be discussed later. Second, in the case of cricket, there is an awareness of the existence of the zone of uncertainty by both the officials and the spectators. During a cricket broadcast, commentators discuss the zone of uncertainty when the Hawk-Eye reconstruction is shown, leading to
spectators having a greater understanding of why decisions are made in the way that they are. However, in the case of tennis a different actor-network exists, in which the International Tennis Federation (ITF) has not seen fit to acknowledge any zone of uncertainty. It remains an unacknowledged anti-programme. The reconstructions produced by Hawk-Eye are presented as accurate, with the ball conclusively being in or out. Therefore, spectators have no sense that there may be apparent inaccuracies in tennis as there are in cricket. Collins and Evans (2012) argue that the lack of acknowledgement of a zone of uncertainty is problematic as it allows incorrect decisions to be made that are understood to be correct. They argue that the ITF should introduce similar rules to cricket that acknowledge that Hawk-Eye is not 100 per cent accurate and note that a zone of uncertainty exists. They suggest that part of the problem is identical to the one already discussed in cricket: the assumption that Hawk-Eye is a standalone device that can produce the ‘correct’ answer, rather than acknowledging that Hawk-Eye works as an assemblage with a human. They argue that if Hawk-Eye were understood as a device to assist umpires to avoid making mistakes, rather than being seen as an unarguable voice of authority, more accurate line calls, and consequently more effective operation of tennis, would occur.

Collins and Evans (2012) argue that the actor-network that makes up tennis is less effective for producing accurate results than the cricket actor-network. However, as previously described, it also points to the way that the cricket actor-network has been forced to become larger and more complicated as a result of acknowledging the existence of a zone of uncertainty. By contrast, tennis has not acknowledged the limitations of Hawk-Eye, which means it has been possible to keep the umpiring actor-network ‘black-boxed’ without seeing the need to extend the network. The anti-programme of the zone of uncertainty remains unacknowledged, and therefore the need to extend the network to overcome the anti-programme is not seen as necessary.

As briefly mentioned earlier, another difference between the cricket actor-network and the tennis actor-network is the inclusion of permission for players to challenge the umpire’s decisions and refer the decision to Hawk-Eye. A result of this ruling is that players whose actor-network includes the ability to understand how this ruling can work to their advantage can quite deliberately benefit. In tennis players have been able to challenge a call and ask for it to be referred to Hawk-Eye from the outset, whereas with cricket, allowing players to initiate a challenge has only recently been introduced. But despite this, many tennis players do not use their ability to challenge the call to their
best advantage. Players are allowed a limited number of challenges: up to three unsuccessful challenges in a set and four if it reaches a tie-break, but when they choose to use these challenges can make up to a five per cent difference in the outcome of the game (Clarke and Norman, 2012). After using dynamic programming, to analyse the effect of challenging calls at particular times during matches, Clarke and Norman (2012, p. 1771) conclude:

the optimal strategy depends on the importance of the point – the more important the point in winning the set, the more likely a player should challenge. Since importance increases in later points of close games, and in later games of close sets, this implies that players should save their challenges until needed deeper into close games and sets. However this must be balanced against the possibility that another challenge opportunity may not arise. A player well ahead will have more chances of challenge opportunities should his opponent make a comeback, and so might be sensible to save his challenge. But a player well behind may not get another opportunity, so should be more aggressive with his challenges.

Clarke and Norman (2012) suggest that tennis players should deliberately adopt a strategy for when to challenge points during a match. However, this would also mean that traditional tennis coaching and training should be altered to include education about this issue. This reflects the same idea as that already identified in the discussion about cricket, that the effects of technologies that improve the watching of the game can also have an impact on other parts of the actor-network of the sport that might not appear connected. In this case, understanding the workings of the Hawk-Eye was found to make a significant potential difference to a tennis player’s ability to win the match; and it would therefore be useful to integrate it into tennis training and coaching. Again, the Actor-Network Theory approach demonstrates how connections can exist between areas that may appear disparate. This is important for sports policy-makers when considering introducing new technologies into the sport.

Case study: IRCOS in artistic gymnastics

Just as cricket has been identified as a sport with a long history of contentious decisions, so too has the sport of artistic gymnastics. Artistic gymnastics has had judging scandals on a regular basis almost since its inception. There are numerous cases of gymnasts and coaches feeling they were judged unfairly
or incorrectly for a range of reasons. One of the most famous occurred at the Athens Olympics in 2004, when Paul Hamm was incorrectly crowned Olympic champion as a result of a judging error.¹ In a reflection of the emphasis on the human as opposed to the non-human in the study of sport, there have been several studies examining the process of judging. Judging studies examining artistic gymnastics, rhythmic gymnastics and figure skating have found examples of judging errors as a result of nationalistic bias (Ansorge and Sheer, 1988; Dixon, 2003; Ružena, 2000), expectations of success (Findlay and Ste-Marie, 2004; O’Brien, 1991) and genuine mistakes (Ste-Marie, Valiquette and Taylor 2001).

Improvements in technology and the close sponsorship of the Swiss company Longines led to an attempted solution to the problem of judging inaccuracies or bias. At the 2005 World Championships, a video replay system developed by Longines, known as IRCOS (Instant Reply and Control System), was used for judging men’s and women’s artistic gymnastics. It simply allowed some of the judges to replay the routine, or parts of the routine, to confirm exactly which movements the gymnast made. Alyssa, a New Zealand gymnastics judge who has used the system while judging at several international competitions, explained:

It’s quite a big screen, obviously. You have two screens; over here you get a list of the competitors, so you can click on the competitor to bring up the screen. And then you get, well, it’s like a DVD player, you can go forwards, backwards, slow motion, whatever you want to do, it will do first six second session, second six session, etc. Especially in bar, you don’t want to watch the whole minute routine so you hit the last six seconds or the first six seconds because you want to obviously see a turn. So you can choose whereabouts. It’s quite easy to use. Then you obviously get the replay here. Then here you get the judges scores.

Unlike in cricket and tennis, where all umpires have similar roles, in artistic gymnastics there are two roles that a judge can hold. First, a judge may be responsible for judging what is termed ‘difficulty’, which means they determine how many movements a gymnast performed during their routine and decide whether the gymnasts should receive the marks for demonstrating these skills. Second, a judge may judge what is termed ‘execution’. Execution judges deduct marks from a score of ten for any errors in performance. A gymnast’s final score is then calculated by adding the difficulty and execution scores together.
When it was implemented, the IRCOS system was designed to be used only by the difficulty judges and not by the execution judges. Difficulty is the area of gymnastics where objective evaluation is a possibility. When judging difficulty, the judge is determining whether the gymnast performed a skill or not. As in ice skating, it is 'a matter of verifiable empirical fact whether skaters performed the required jumps and do so without falling or stumbling' (Dixon, 2003, p. 105). In gymnastics each skill has very particular guidelines describing whether it has been performed correctly. For example, on rings any holds must be held for between one and three seconds to be counted. Thus, whether a gymnast performed this is easily confirmable through watching a video and timing the hold. Yet, as described in the previous section, human judges can make mistakes.

In contrast, as discussed in relation to cricket, it is often argued that technology is more accurate than a human (see, for example, Mahmood et al., 2012). This assumed reliability of technology led to the International Gymnastics Federation (FIG) greeting IRCOS with enormous enthusiasm. IRCOS was expected to have the ability to avoid mistakes of the sort that occurred in the Olympic Games in 2004 where the wrong gymnast received the gold medal owing to a judging error. It allows the difficulty judges the chance to check that they have made correct judgements, and it allows coaches to protest and use the video footage as evidence of perceived incorrect judgements. After each routine the difficulty judges are immediately able to view either parts or the whole of the routine again on a laptop to confirm they have made the correct judgement. If a coach or gymnast disagrees with their difficulty score, they can issue a protest and the routine will be reviewed by other judges to ensure the mark is ‘correct’.

As with Hawk-Eye, part of the reason that IRCOS is effective is because it is a hybrid system that utilises both a human and technology in order to make a
decision. Its hybrid nature allows accountability because there is an inscription created in the form of a video that allows the routine to be circulated among other judges. As a result, the score can be checked and confirmed, yet explanations can still be provided. However, in order for this to occur, the judge must enrol the technology; the video must become an assemblage with the judge. Interviews with judges revealed that there were variations in how often judges made use of the replay system. Stuart, a judge of men's gymnastics, described his experience of using the system at international competitions:

**Roslyn:** So how often did they use it at Worlds (World Championships)?

**Stuart:** Quite a bit, I suppose.

**Roslyn:** Every routine, every tenth routine?

**Stuart:** In rings, if you don't hold a skill for a second it doesn't count, if you hold it for a second it does count. So, if it's not going to be counted, they'd probably look at it then. If it's between one and two seconds, they won't look at it because they can see it's counted, that's their job. And generally if you say it's '1001' (counting) they'll give it credit without looking at the video. But if it's really short, that's where they'll look at the video to get the proof … And probably looked it 20–30 per cent at the time. At a guess.

Stuart’s description suggests the men's judges perceived the system to be a useful tool and enrolled it regularly. Stuart believed it assisted with ensuring accurate judgements. Alyssa's comments, from women's gymnastics, were quite different:

**Alyssa:** I didn't use it to make any judgements at all. But we used it on vault to confirm a decision we'd made … both times we were right.

**Roslyn:** So it wasn't used that often?

**Alyssa:** No. They used it a few times on bars just to check the completion of something … And I don't know if they used it at all on beam … But on floor we used it later to confirm what we thought.

Alyssa described how the system was only enrolled occasionally to confirm a judgement they had already made. However, she was clear in saying that she did not require the system and that she was capable of doing her job without the system. Unlike Stuart, Alyssa did not suggest the assemblage was particularly worthwhile.

The quotes from the judges reveal that, even when international sporting bodies enrol technologies with the intention of improving judging performance, it is a mistake to assume that the judges or referees will enrol the device. Both Stuart and Alyssa emphasised that, in their view, their own knowledge meant that they did not need to enrol IRCOS. This reflects the argument that was raised
earlier in the book with the French kayakers: that it is a mistake for sporting bodies to assume that a piece of technology will be utilised purely because their own empirical evidence suggests it will be an improvement. Just as the athletes trusted their own knowledge of kayaking, which made them suspicious of the newly designed kayak, the judges here similarly trusted their own training, which meant that IRCOS was not utilised fully.

Conclusion

Through examining officiating technologies in cricket, tennis and gymnastics this chapter has demonstrated how acknowledging that sport exists as an actor-network can be significant for sporting bodies. The officiating technologies examined in this chapter were introduced into their respective sports with the goal of improving umpiring and judging standards. In all three cases the particular technologies included an aspect of video replay that meant the performances of the athletes could be repeatedly seen and examined in detail by suitably qualified umpires or judges. All three sports also chose to implement hybrid systems, which exist as a technology and human working together in order to produce the most effective outcome, with literature arguing that both technology or humans on their own can be problematic.

In all three cases, following the network revealed unexpected consequences that were not foreseen by the respective sporting bodies. In cricket the use of Hawk-Eye revealed the respective skill-sets of various umpires, which in turn necessitated the inclusion of rotating systems for umpires within matches. Perhaps more significantly, Hawk-Eye was argued to affect player performance strongly. This last point is particularly interesting, with performance enhancement being touted as one of the primary reasons for adopting technology in sport. This chapter, along with Butryn’s (2003) work, demonstrates how officiating technologies can have a negative effect on sporting performance. In cricket, the delay in waiting for the outcome from Hawk-Eye can have a detrimental effect on performance, while in tennis, players who do not use their permission to challenge calls are not maximising their performance. But the potential negative effects do not seem to be considered by sporting bodies when considering adopting new officiating technologies. The effect on the audience in taking time away from the match is considered, but not player performance. Instead, this is generally considered the realm of the sports scientist or coaching team rather than the responsibility of an international sporting body. This separation could
be viewed as logical if player performance is seen as a ‘micro’ factor while officiating systems are considered as ‘macro’. Yet as the ANT perspective argues and as this chapter demonstrates, the micro and macro levels cannot be considered in isolation, and it is problematic for international sporting bodies to do so. The role of international sporting bodies is to regulate their sports and provide the best competitive opportunities for their athletes, so any new initiative should be considered in the light of the effect it could have on all aspects of the sport, and particularly on athlete performance. More extensive research examining the effects of new officiating and media technologies on athlete performance would be helpful in addressing this issue.

Note

1 Paul Hamm received the individual all-around gold medal, which should have gone to Yang Tae-Young from Korea. The FIG and IOC investigated the situation and discovered that three judges had accepted bribe money and consequently marked Yang down. These three judges were banned for life from judging at any further gymnastics competitions. Paul Hamm was asked by the FIG to return his gold medal in the spirit of fairness but declined to do so (Grandi, 2004).