QUANTIFYING AND EXPLAINING HOME ADVANTAGE IN SPORT

N. J. BALMER

PhD.

2001

LIVERPOOL JOHN MOORES

DXN 052019

QUANTIFYING AND EXPLAINING HOME ADVANTAGE IN SPORT

NIGEL JOHN BALMER

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy following work carried out at The Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, School of Health and Human Sciences.

September 2001

Quantifying and Explaining Home Advantage in Sport

Nigel John Balmer

Abstract

Previous research has identified four factors thought to account for home advantage in sport. These fall under the headings of crowd factors, familiarity with local conditions, travel factors and rule factors. A growing body of research suggests that crowd factors are the most dominant cause of home advantage. The present thesis aimed to extend current knowledge by examining the contribution of crowd noise and officiating to home advantage in sport.

Chapter 3 quantified home advantage in multi-event winter Olympic competition, while considering the influence of officiating, travel and familiarity factors. Events employing subjective officiating were shown to enjoy enhanced home advantage, and it was proposed that this could result from partisan home crowds influencing judges to favour home competitors. Chapter 4 tested this proposal experimentally using association football. Participants were asked to judge challenges recorded on videotape either in the presence of crowd noise, or in silence. Crowd noise was shown to result in more fouls against away and less against home players than adjudicating in silence. Chapter 5 replicated the findings of Chapter 4, with the crowd noise causing referees to under penalise the home side rather than over penalise the away side. Two possible mechanisms were proposed to explain the crowd noise effect. Firstly, participants may be focusing upon cue saliency, regardless of its relative diagnostic value. For contentious decisions, this would result in over emphasis on crowd noise. Secondly, participants may be adopting an avoidance coping strategy, avoiding the anxiety of making what the home crowd feel is a 'bad call'.

Having identified the influence of crowd noise upon officials in football, Chapter 6 expanded upon the methods employed in Chapter 3 by measuring home advantage for five groups of summer Olympic events. Quantifying home advantage for team games demonstrated that the influence of crowd noise resulted in significant home advantage, comparable to that of the subjectively judged events. The lack of home advantage in objectively judged events (controlling for athlete participation) also suggested that the crowds' influence upon officials is the major element of 'crowd factors', and not its influence upon players. Finally, Chapter 7 examined the mechanisms underlying the influence of crowd noise upon officials. In addition to a large crowd noise effect, comparable to that of Chapter 5, the effect size was related to an increase in anxiety and mental effort in the noise over the silent condition. The suggestion is that the crowd noise effect was at least partly due to the adoption of an avoidance coping strategy. Participants addressed increased anxiety with both increased mental effort and bias in favour of the home side, avoiding further negative consequences of making a 'bad call'.

In summary, the thesis provided support for crowd factors as the dominant cause of home advantage, and demonstrated that the crowd is able to influence referees to make an imbalance of decisions in favour of the home side. This crowd noise effect was shown to result in enhanced home advantage, which was present whenever officials had a large input (judging outcome or enforcing rules). The influence of crowd noise was partly explained by participants adopting an avoidance coping strategy.

Acknowledgements

The past three years have been a great pleasure, mainly due to the people I have been lucky enough to work alongside. Many people have encouraged me along the way, all of whom are greatly appreciated, though I make particular note of the following:

To those who got me here in the first place, particularly Steve Hamilton, Ben Craven, Rachel Norman, Victoria Bateman and Craig Walter Walker.

To all those who participated in my experiments, particularly David Davies and his colleagues at the North Staffordshire Referees' Club. Also thanks to those who provided technical assistance, specifically George Savage.

Thanks to Tom Reilly, Greg Atkinson and Mark Scott for sound advice whenever needed. To my fellow postgraduates who have provided friendship and advice. Particularly Ben Edwards, Andy Franks, Andy Grant, Rob Horn and Paul Ward for intellectual (though mostly recreational) support.

My supervisors Alan Nevill and Mark Williams for support and advice throughout the past three years. Mark, many thanks for your consistent support and attention to detail (and for stepping in when my director of studies abandoned ship). Alan, it has been an honour to work with a great statistician and a true gentleman. Before embarking on a PhD, I was advised of the importance of finding an appropriate supervisor. I can safely say I fell on my feet in this respect.

Special thanks to Julia for everything over the last three years and giving me a reason to push on and finish.

Finally, I would like to thank my family for their love, support and tolerance of my full seven years of university. To my mum and dad for all your love and encouragement and to my big brother Al for always being there.

LIST OF CONTENTS

List of Tables

List of Figures

Chapter 1. Introduction

1.1 Statement of the problem

This thesis is concerned in the first instance with assessing the contribution of officiating to variation in the home advantage. Secondly, the specific influence of the crowd upon officiating will be assessed, and any systematic error observed put into context in archival analysis of multi-event Olympic competition. Finally, the thesis will consider mechanisms underlying the influence of crowd noise upon officiating.

The specific aims are:

(i) To examine the contribution of factors thought to influence home advantage, while controlling for confounding variables associated with unbalanced competition. This aim is addressed in Chapters 3 and 6.

(ii) To assess the influence of crowd noise upon refereeing decisions, and the subsequent creation of home advantage. This aim is experimentally examined in Chapters 4, 5 and 7.

(iii) To put any observed imbalance in context for unbalanced competition, and compare home advantage observed for differing officiating styles. This is investigated through archival summer Olympic research in chapter 6.

(iv) To investigate the mechanisms behind the influence of crowd noise upon officiating, specifically regarding mental effort and stress. Underlying mechanisms are addressed in chapter 7.

Fulfilment of these aims will highlight methods with which archival home advantage may be fairly measured and how specific factors may be isolated experimentally. Moreover the influence of the crowd upon officiating in football, in increasing home advantage will be measured experimentally and put into context using archival data. Investigation of underlying mechanisms will complete an overview of the contribution of officiating to the home advantage.

1.2 Introduction to the programme of work

1.2.1 Archival assessment of home advantage

Home advantage for team games has been defined as "the consistent finding that home teams in sports competitions win over 50% of the games played under a balanced home and away schedule" (Courneya & Carron, 1992, p. 13). For major team games, this phenomenon has been both well researched, and well proven (Nevill & Holder, 1999). Couneya and Carron (1992) went on to propose four possible factors thought to account for home advantage; travel factors, learning/familiarity, rule factors and crowd factors. Evidence of a travel effect has been conflicting (e.g. Snyder & Purdy, 1985 vs. Pollard, 1986), and familiarity largely unsubstantiated possibly due to difficultly in its assessment (e.g. Clarke & Norman, 1995; Moore & Brylinsky, 1995). Rule factors apply to only a very small number of sports and as a result are of little interest. Crowd factors, meanwhile, have been shown to have a major influence upon home advantage (Nevill & Holder, 1999). This influence has been demonstrated both archivally (Nevill, Newell & Gale, 1996; Pollard, 1986) and more recently experimentally (see Chapters 4, 5 and 7). Much of the present body of work will focus on the identification of, and mechanisms underlying crowd factors.

In individual sports, findings are far less conclusive. Some evidence of home advantage has been identified in cross-country running (McCutcheon, 1984), high school wrestling (Gayton & Langevin, 1992) and World Cup alpine skiing (Bray &

Carron, 1993). In contrast, once quality of athlete had been accounted for, home advantage was not found to be a major influence on performance in individual 'grand slam' tennis and 'major' golf tournaments (Nevill, Holder, Bardsley, Calvert & Jones, 1997). Holder and Nevill (1997) confirm these findings, suggesting that any apparent home advantage is a result of exaggerated numbers of home competitors. Having accounted for this imbalance, the authors suggested that lack of home advantage may stem from objective scoring and relatively little subjective input from officials.

In Chapter 3 these suggestions are examined by assessing home advantage in multi event Winter Olympic competition. Controlling for confounding factors (notably nation quality), indices of home advantage are obtained for all events held at more than one Olympic, and for all Olympics. Analysis then compares indices between subjectively judged and objectively judged individual events, measuring the contribution of officiating to the home advantage. Familiarity with local conditions is considered by assessing fluctuations in home advantage where conditions are at there most variable. Finally, an additional analysis gauges whether performance is influenced by number of time zones traversed in attending competition.

1.2.2 Quantifying of the influence of crowd noise upon officiating

A number of sports have demonstrated the crowd to provide a powerful contribution to the home advantage. For example, the advent of domed stadia (and increased crowd noise) in American football (Zeller & Jurkovac, 1989a) and baseball (Zeller & Jurkovac, 1989b) has resulted in enhanced home advantage, though artificial playing surfaces had little effect. Typically, two mechanisms have been proposed to explain the crowd noise effect. Either, the crowd might influence players to alter their performance, or the officials to alter their decisions (Pollard, 1986). These suggestions were supported by Nevill et al. (1996), identifying frequencies of penalties and sendings-off in association football to favour the home side. Importantly, imbalances in favour of the home side increased with crowd size. Having investigated the contribution of subjective officiating to home advantage in Chapter 3, Chapters 4 and 5 examine the mechanisms underlying an officiating bias. Moreover, the chapters aim to provide the first experimental evidence that crowd noise is able to influence officials to make an imbalance of decisions in favour of the home side. Chapter 4 presents two preliminary studies, the first (Study 4.1) with a small sample of eleven experienced observers (Nevill, Balmer & Williams, 1999). The second (Study 4.2) employs a larger sample of 41 students, also focusing upon differences in judging difficulty between specific incidents. Chapter 5 expands upon Chapter 4 with improved methodology and a sample of 40 qualified referees. With participants ranging from newly qualified to 43 years refereeing experience, this allowed inclusion of a continuous experience covariate, to assess whether experience may dilute any crowd noise effect.

1.2.3 Further archival home advantage: putting team games in context

Officiating bias has frequently been demonstrated in sports where officials directly judge outcome, with the suggestion that the potential for bias is at its greatest in such events (Ansorge & Scheer, 1988). Previous research, however, has predominantly focused upon political and nationalistic bias (Park & Werthner, 1977; Seltzer & Glass, 1991; Ste-Marie 1996; Whissell, Lyons, Wilkinson & Whissell, 1993), while disregarding the possibility of exaggerated home advantage. Given the enhanced home advantage observed in subjectively judged Winter Olympic events (Balmer, Nevill & Williams, 2001b), it should follow that similar summer Olympic events should also yield the greatest home advantage. As has been stated, home advantage is well established in major team games and inconclusive for many objectively judged individual sports (Nevill & Holder, 1999). Previous research has also highlighted the crowd's influence upon officials as the probable dominant cause of home advantage in team games (Nevill et al., 1999; Balmer, Nevill and Williams, 2001a) (Chapters 4 and 5). Despite these experimental findings, no attempt has been made to measure their significance in terms of home advantage. Chapter 6 aims to improve upon the methodology of Chapter 3 in measuring home advantage in Summer Olympic competition. Improvements include consideration of accurate athlete participation figures and more advanced analysis to deal with confounding factors during rather than prior to analysis. Most significantly, Chapter 6 aims to put home advantage in team games into context alongside two subjectively judged and two objectively assessed event groups, approximating the crowd noise effect to a measure of home advantage. If the crowd noise effect is relatively insignificant in terms of home advantage, team games should be greater than but close to objectively judged event groups. However, if as hypothesised, the crowd noise effect is influential in creating home advantage, the observed home advantage in team games should be comparable to events where officials directly judge outcome.

1.2.4 Mechanisms underlying the crowd noise effect

A number of theories have been proposed to explain systematic errors in decision-making. Many of these are particularly applicable to the refereeing task, where incidents are often ambiguous and subject to time constraints. Participants have been shown to focus on the most salient cue regardless of diagnostic value (Payne, 1980) and when placed under time constraints (Wallsten & Barton, 1982). For increasingly ambiguous decisions, participants would focus more on increasingly salient (though partisan) crowd noise. This would create an imbalance of decisions in favour of the home side, which would be at its greatest for the most contentious decisions. Similarly, avoidance behaviour has been previously observed in referees, in response to sources of stress they felt were difficult to control (Anshel & Weinberg, 1999; Kaissidis-Rodafinos, Anshel & Porter, 1997). Avoidance is characterised by withdrawal from a potentially stressful situation to avoid the negative effects of anxiety (Eysenck & Calvo, 1992). In the present task avoidance would be displayed as an imbalance of decisions in favour of the home side, as participants attempt to avoid anxiety as a result of disagreeing with a partisan home crowd. Having investigated the existence of a crowd noise effect in Chapters 4 and 5, Chapter 7 aims to examine mechanisms underlying such an imbalance, in a more sensitive repeated measures experimental design. The 'cue saliency' proposal is addressed by asking participants to express their certainty following each decision, with these values correlated with the influence of crowd noise for each incident. The 'avoidance' proposal will be investigated through collection of anxiety measures (State Trait Anxiety Inventory (STAI, Spielberger, Gorusch & Lushene, 1970); Competitive Sport Anxiety Inventory ((CSAI-2, Martens et al., 1990) incorporating Jones and Swain's (1992) directional scale), heart rate, and mental effort measures (ECG spectral analysis, Rating Scale Mental Effort (RSME, Zijstra, 1993)). Support for avoidance behaviour would be demonstrated by participants who are most influenced by crowd noise also showing the largest levels of anxiety and mental effort.

1.3 Summary of thesis structure

Through assessing home advantage in Winter Olympics and Summer Olympics competition (Chapters 3 and 6), the relative degree of home advantage can be determined for individual sport and unbalanced competition and contrasted between types of event in an unbiased manner. The proposition that subjectively judged events have the greatest potential for bias will also be tested, with home advantage assessed for such events and compared with other sports. Additionally, such multi event competition allows and requires development of methods to remove the influence of a number of confounding variables, which may be generalised to future quasi-experimental designs.

Evidently for team sports, crowd factors are influential, and there is some evidence that the crowd may be able to influence the decisions of match officials. Chapters 4,5 and 7 attempt to examine experimentally the influence of crowd noise in producing a imbalance of decisions in favour of the home side. Complexity of the officiating task has also been suggested to reduce objectivity. Chapter 4 (Study 4.1) and Chapter 7 address whether home advantage (bias) is enhanced by increasing complexity or contentiousness of decision.

Having developed suitable methodology to account for confounding variables in home advantage (Chapter 3), Chapter 6 will allow the home advantage observed in Chapters 4 and 5 to be quantified alongside other types of sport/officiating styles. By measuring the subsequent home advantage in team games alongside that of other types of sport, an overall assessment can be made of the overall influence of the crowd upon officials in creating home advantage.

Finally, through experimental measurement of mental effort, anxiety and certainty of decision, Chapter 7 will attempt to determine the mechanisms underlying the crowds influence upon officials, and discuss implications for both officiating and future research.

Chapter 2. Literature Review

2.1 Home advantage in team sports

2.1.1 Defining home advantage

In their influential review, Courneya and Carron (1992) defined home advantage in team games as "the consistent finding that home teams in sports competitions win over 50% of the games played under a balanced home and away schedule" (p. 13). While this definition is appropriate for balanced home away schedules, it cannot be applied to unbalanced tournaments or to the majority of individual sports. The more global definition of home advantage as '***the consistent finding that teams or competitors perform disproportionately better at home than** away*' is equally applicable to such instances. The evidence supporting such a home advantage in team sports is now overwhelming (for a review see Nevill & Holder, 1999). Examples include college basketball (Moore & Brylinsky, 1995; Snyder & Purdy, 1985), with home winning percentages of 66% and 64% respectively, association football (Pollard, 1986) where home teams were shown to win some 64% of all points gained, and basketball (Varca, 1980), where home advantage approximated to 4.8 points a game for a balanced round robin schedule. The home advantage observed, although variable in magnitude between sports, is consistently significant across all major team sports, ranging from home winning percentages (excluding draws) of 54% in major league baseball (Adams & Kupper, 1994) to almost 70% for basketball and ice hockey (Schwartz & Barsky, 1977). Home advantage has also been shown to be independent of gender, with Gayton, Mutrie and Hearns (1987) providing some evidence of home advantage in women's team sports (basketball, field hockey, softball). Whilst avoiding team quality considerations by studying a single team and simply comparing winning percentages home and away, significant home advantage was demonstrated for both basketball and hockey, though interestingly not for softball. This could simply be a reflection of a small sample size (141 games) as a large home vs. away discrepancy was evident (58% vs. 46%). Similarly, Kozub and Corlett (1990) (cited in Courneya and Carron (1992)), reported a huge winning percentage of 72% for female college basketball, though again with a small sample size of 30 games. Home advantage has been observed both at college level as well as for professional sport (e.g. Edwards, 1979; Schwartz & Barsky, 1977; Varca, 1980), though at lower, high school levels, home advantage is somewhat weaker in both basketball and American football (Gayton & Coombs, 1995; McCutcheon, 1984). Gayton and Coombs (1995) reported significant home advantage for high school basketball (overall 62% vs. 49%). However, considering the mean winning percentages (home and away) for the four teams (55%), suggests the schools selected were of better than average quality overall. The authors failed to consider the possibility that such superior teams may accrue greater home advantage (e.g. Schwartz & Barsky, 1977). The possibility of a team quality effect, and other confounding factors are further discussed in section 2.3.

Based on their comprehensive review, Courneya and Carron (1992) argued that further verification of the existence of home advantage (i.e., the 'what' of home advantage) is no longer a sufficient rationale to justify game location research. They recommended that future research needs to explore the reasons 'when' and 'why' home advantage occurs. For major team games this would seem a fair conclusion, though as will be shown, findings regarding home advantage are far less conclusive in both individual sport and unbalanced competition (Nevill & Holder, 1999), and in the case of subjectively judged, or artistic disciplines.

2.2 Game location factors thought to influence home advantage

Courneya and Carron (1992) identified four major game location factors thought to account for, or affect, the degree of home advantage. These fall under the headings of travel factors, learning/familiarity, rule factors and crowd factors.

Travel factors - distance travelled or time zones traversed may impede the performance of the away team. Considering changes in away performance with distance travelled and preferably time of arrival and preparation time could assess the influence of travel.

Learning/Familiarity factors - familiarity with local conditions may lead to home advantage. This may be addressed by assessing the varying size of the advantage with changes in conditions (e.g. pitch size, domed vs. open stadia, artificial vs. grass surface).

Rule factors - thought to be influential for sports where rules may favour the home side (notably last line change in hockey or batting last in baseball).

Crowd factors - a partisan home crowd may be able to alter players' performances, or officials' decisions. This can be addressed by observing changes in home advantage with crowd size, density, volume or support.

2.2.1 Travel

Travel has been proposed as a possible influence, though evidence has been conflicting. For basketball, Snyder and Purdy (1985) found a significantly greater home advantage when away teams travelled further than 200 miles. In contrast, for football, Pollard (1986) found no discrepancy, using a larger sample of games and a similar 200-mile cut-off. Similarly, Pace and Carron (1992) proposed that "only a small portion of the variance in the home advantage/visitor disadvantage can be explained by travel related factors" (p. 60). The study focused on America's National Hockey League, which though involving larger distances than British football, still only allows time-zone traversal of between 0 and 3 hours. Jehue, Street and Huizenga (1993) dealt with a similar number of time-zones for the American National Football League. They did, nevertheless, find direction of travel to be important, as well as time of day, and stated the possibility of 'jet-lag' effects.

The time of arrival relative to the match may also be an important influence in any travel effect. For example, Pace and Carron (1992) showed that away team success was negatively associated with the interaction between time zones traversed and preparation time, although reservations have since been made regarding the validity of their regression analysis (Nevill & Holder, 1999). Studies reporting impaired performance with time-zones traversed generally consider athletes who do not arrive in good time (e.g. Jehue et al., 1993; Waterhouse, Reilly & Atkinson, 1997). For multi-event competitions such as the winter Olympics, the fact that athletes generally arrive well in advance of competition may account for the lack of variance in the home advantage explained by time zones traversed (R^2 = 0.4%) (see Chapter 3) despite distances travelled being substantial.

Pollard (1986) also uses the negligible decline in home advantage observed for association football over time as further evidence against travel providing a major contribution. Although travel for away teams has become both quicker and more comfortable, little or no changes in home advantage were observed, this also being the case for the somewhat larger distances in baseball (Thorn & Palmer, 1984; cited in

Pollard, 1986). For studies with far greater distances covered as in Olympic competition or World championships, such an argument would be further confounded by the need to consider jet-lag. It was not until the advent of four engine transports and jet airliners in approximately 1958, when rail and ocean liners were replaced as the primary mode of long distance travel, that jet-lag became a reality. If jet-lag has an influence then it should be seen after 1958. Evidently, fair assessment of a travel effect must consider not only distance travelled, but also time of arrival and preparation time, as well as possibly consideration of journey time and comfort.

2.2.2 Familiarity

Familiarity with local conditions remains a largely unsubstantiated contributor to home advantage (Dowie, 1982; Pollard, 1986; Schwartz & Barsky, 1977), as well as being perhaps the most difficult factor to assess. However, many of the sports examined (ice-hockey, basketball, baseball, American football and association football) have relatively little potential for variation in local conditions in contrast to the vast variation possible in say alpine skiing or motor sports. Sociological research demonstrated that the uniqueness of the home arena has some impact upon home advantage in basketball (Mizruchi, 1985), while Clark and Norman (1995) found limited evidence of increased home advantage in association football for teams with unusual pitch size or surface. This observation was supported by Barnett and Hilditch (1993) who found increased home advantage for teams with artificial playing surfaces, perhaps contributing to such surfaces being outlawed in English and Scottish leagues. This incidence of increased home advantage due to local conditions occurred when the difference was at its greatest (grass vs. artificial surface). It should follow that if familiarity has a significant influence upon home advantage, it should be most evident in sports or settings where the potential for variation is at its greatest. This was confirmed by Bray and Carron (1993) who acknowledged that the "beneficial effects of familiarity with the venue could contribute generally and specifically to the home advantage in World Cup alpine skiing" (p. 80), a sport where sizeable variations in piste exist between competitions. Somewhat surprisingly in view of this the home advantage reported was found only to be 'moderate'. Problems in assessing familiarity also stem from difficulty in partitioning out the effects of other factors thought to influence home advantage, which has been identified as a shortcoming of quasi-experimental designs (Nevill & Holder, 1999). Notable examples are provided by research concerning the influence of domed stadia upon home advantage in baseball and American football (Acker, 1997; Zeller & Jurkovac, 1989a; Zeller & Jurkovac, 1989b), where findings may be the result of familiarity with local conditions or crowd factors. Similarly, team quality and crowd support may also be mediating factors in the case of the single basketball team studied by Moore and Brylinsky (1995). The single team studied was forced to play in a range of local venues during the construction of a new home stadium. Not playing in familiar venues may negate the use of visual cues, or familiarity with surfaces, but presumably as the distances travelled to stadia were small (60 miles maximum), an element of familiarity may have been maintained.

Clarke and Norman (1995) highlighted a number of shortcomings of quasi-experimental designs, when reassessing the findings of both Pollard (1986) and Barnett and Hilditch (1993). The authors acknowledge the importance of including team quality in measuring home advantage, as well as the possibility of changes over time, primarily as team quality may vary with time. In contrast to Pollard (1986), using simple rank sum tests inferred from their measure of home advantage, some evidence of enhanced home advantage is found both for a subset of football clubs with unusual pitch sizes or surfaced, and depleted home advantage for a subset of London clubs. These suggestions are still far from conclusive though, as despite a large quantity of data (1981-82 to 1990-91) neither suggestion proved significant (P = 0.076 and 0.072 respectively), the latter of these also requiring the exclusion of London club Queens Park Rangers to reach this level. Clarke and Norman (1995) contested that team or year effect may have been influential in assessing the impact of artificial surfaces in football (Barnett & Hilditch, 1993), and including these effects in analysis of variance did confirm the importance of pitch type.

2.2.3 Rule factors

Although proposed as a factor by Courneya and Carron (1992), rule factors seemed primarily a demonstration of how a single factor can be isolated in quasi-experimental designs (Courneya & Carron, 1990). It applies only to a small subset of sports, such as the home side having the final line change in ice hockey, and has little relevance to the vast majority of sports.

2.2.4 Crowd factors

Crowd factors have been shown to create home advantage, and more recently to have a direct influence upon officiating, providing much of the focus for the present thesis. Pollard (1986) suggested that the crowd might stimulate and reinforce good play in home players, as well as intimidate away players. The possibility of referee bias as a result of home support was also expressed, with the pressure to remain uninfluenced being considerable. Nevill et al. (1996) tested these suggestions and identified frequencies of penalties and sendings-off in association football to favour the home side. In addition, imbalances in favour of the home side increased with crowd size. This led to the conclusion that the crowd may either be influencing away players to play more recklessly, or affecting the match officials' decisions to favour the home side. The latter of these suggestions has since been supported experimentally by Nevill et al., (1999) (Chapter 4). Crowd factors and the impact of officiating will be discussed at greater length in section 5 onwards.

2.3 Confounding factors in home advantage

2.3.1 Team/competitor quality

In assessing home advantage for archival data, a number of additional factors must be considered in order to establish an unbiased measure, particularly for unbalanced competition. Firstly, team or competitor quality must be considered, as will be highlighted by the differing conclusions reported for individual sports. At least some indication of home advantage is found when team/competitor quality is not considered in analyses (e.g., Bray & Carron, 1993; Gayton & Langevin, 1992; McCutcheon, 1984), while accounting for athlete quality has resulted in little home advantage (e.g., Holder & Nevill, 1997; Nevill et al., 1997).

Previous research has highlighted team quality as having a likely influence upon home advantage, with 'superior' teams tending to exhibit greater home advantage (Schwartz & Barsky, 1977). Likewise, Madrigal and James (1999) also identified team quality as an influence, though they made reservations regarding the classification of quality. They suggested that previous assessments (Schwartz & Barsky, 1977; Snyder & Purdy, 1985) failed to truly assess quality, as success in a given year may not be representative of performance (highs and lows) within a season. Their proposed solution of assessing high or low quality teams for a ten-year period, though, leaves the same criticism that quality may vary both within and across seasons. These studies do, however, agree that team quality should be a consideration, and significantly, for sports with league structure and relatively little scope for quality differences. Despite its importance, however, team/competitor quality is generally viewed as a complication/confounding factor in assessing home advantage (e.g. Clarke & Norman, 1995) rather than a formal cause.

As with familiarity with local conditions, the influence of quality should be at its greatest when variation in quality is large. For Olympic competition, as for tennis and golf tournaments (Nevill et al., 1997), team/competitor quality is also a major consideration, given the highly variable medal winning potential of host nations. In football's World Cup, for example, previous host nation France have a world ranking of 1, while the next hosts Japan and Korea have rankings of 33 and 37, respectively (http://www.fifa.com, 20/6/2001). Evidently, direct comparison of the performance of these hosts would be unfair. Assessing home advantage must, therefore, involve only intra-nation comparison, and consider winning nation, as stronger host nations should enjoy greater home advantage.

Madrigal and James (1999) proposed that a proportion of the team quality effect might be due to superior teams enjoying larger/denser and more supportive audiences. However, this is generally not the case for the majority of multi-nation tournaments, which consistently attract large crowds (e.g. world championships, football, rugby or cricket world cups). For such competition the stronger nations dominance in a given event would severely reduce weaker host nations' opportunity for home advantage. Similarly, stronger nations, with more athletes capable of winning medals/point should be able to produce more consistent home advantage. Evidently again, team quality must be considered to correctly measure home advantage. Previous research in unbalanced summer Olympic competition has considered nation quality in a simplistic way, by comparing descriptive statistics by nation, thus avoiding unreasonable inter-nation comparison (Leonard, 1989), though other factors, notably participation of athletes were not accounted for. Unbalanced multi-event competition such as summer and winter Olympics or athletics world championships present a number of additional factors, which must be addressed in order to successfully assess home advantage. Among these are non-hosting nation performance, medals available, event, changes in competition over time as well as team quality. Clearly, archival assessment of home advantage allows careful control of all confounding factors relevant to each case.

2.4 Individual sports and unbalanced competition

2.4.1 Redefining home advantage

The definition of home advantage proposed by Courneya and Carron (1992) cannot apply to individual competition, unbalanced competition or indeed individual teams or competitors. Firstly, individual sports and unbalanced competitions use a variety of measures of outcome or success, and not simply the win/loss or win/loss/draw observed in many team games. Secondly, home advantage could also be indicated by a home competitor performing disproportionately well, but not winning a given tennis tournament or athletics medal. Whereas Courneya and Carron's (1992) original definition can be applied fairly to complete league tables, when considering individual teams, a weaker team could quite possibly display substantial home advantage without winning more than 50% of their home fixtures. For example, a home winning percentage of 20% and an away winning percentage of 0% undoubtedly demonstrates sizeable home advantage for a weaker team. This was highlighted by Gayton et al.,

(1987) who found that a single field hockey team enjoyed significant home advantage despite obtaining a home winning percentage of only 36.8%. For this reason, a fair definition needs to express the requirement of intra-nation comparison to avoid comparison of teams of very differing abilities.

Home advantage can be defined as ***'the consistent finding that teams or competitors perform disproportionately better at home than away'***

2.4.2 Home advantage in individual sports

The prevalence of home advantage in both individual sport and unbalanced competition is less clear. Some limited evidence of home advantage has been identified in cross-country running (McCutcheon, 1984) and high school wrestling (Gayton & Langevin, 1992). For world cup alpine skiing, Bray and Carron (1993) found home advantage to be "moderate". A number of their performance measures though, relied on comparing home and away competitors, disregarding relative ability. Significantly, when this was addressed (seed vs. actual position), they found far stronger evidence for home advantage. Nevill and Holder (1999) also identified these methodological shortcomings, suggesting that Bray and Carron's (1993) home advantage may simply be a result of home competitors being superior athletes. Two approaches have been proposed to overcome such limitations. Firstly, comparing within each nation eliminates unfavourable comparisons of poorly matched competitors (e.g. Bray, 1999; Leonard, 1989). In Olympic competition this is simply comparison of the medal success of each nation when either hosting or not hosting the Olympics (home vs. away). Secondly, tournament results may be adjusted using a measure of competitors' standards prior to competition, as was demonstrated for 'major' golf tournaments (Nevill et al., 1997). For the majority of tournaments, this may be achieved by simply including world ranking (or other quality measure) prior to competition as a covariate in analysis, thus accounting for the influence of differing quality between home and away competitors.

Once quality of athlete had been accounted for, home advantage was not found to be a major influence on performance in 'grand slam' tennis and 'major' golf tournaments (Nevill et al., 1997).. Holder and Nevill (1997) confirmed these findings, suggesting that any apparent home advantage is mainly an artefact of selection procedures that favour increased entry of lower ranked home competitors. The authors suggested that lack of home advantage could be due to both objective scoring systems and relatively little subjective input from officials. Home advantage in individual sports has also been generally assessed for modern Olympic competition (Leonard, 1989), though all events were considered simultaneously, so a number of team games were included in the analysis. The study involved intra-nation comparison, though analysis involved only examination of descriptive statistics, with little in the way of formal tests of hypotheses. This simple approach also failed to address factors such as event type, travel and importantly for the case of the Summer Olympics, number of athletes/teams participating. The study did, however, efficiently reduce problems associated with changing performance over time, by comparing only previous and subsequent Olympics for each host nation.

Finally, McCutcheon (1984) examined home advantage in three high school sports, two of which were team sports, and two individual (American football, basketball, track and field, cross-country running). Magnitude of home advantage was found to be relatively small compared to senior/professional sport, and interestingly, the weakest effect was observed in an individual sport, cross-country running. The author suggests that this could be due to the lack of crowd support in cross-country running and the negligible input from officials. Evidently, stating that individual sports either do or do not have home advantage would be an over simplification. Both crowd support and officiating input are important considerations. It seems significant that home advantage is negligible where officiating input is small (e.g. Holder & Nevill, 1997; Nevill et al., 1997) or when crowd support is minor (McCutcheon, 1984). Significantly in this respect, wrestling provides a significant home advantage for an individual sport (Gayton & Langevin, 1992). Although the authors made no attempt to identify the source of the home advantage, in addition to probable crowd support, many wrestling bouts outcomes are directly judged by officials. Home advantage and officiating bias in subjectively judged disciplines are further examined in section 2.7.

2.5 The influence of crowd factors

2.5.1 Domed stadia and increased home advantage

Crowd factors have been identified as a dominant cause of home advantage (Nevill and Holder, 1999). The influence of crowd noise has been observed in a number of sports, notably with the introduction of the domed stadium in American football (Zeller & Jurkovac, 1989a) and baseball (Zeller & Jurkovac, 1989b). Although artificial surfaces were shown to have a negligible impact, teams with domed stadiums were shown to enjoy significantly greater home advantage than their open-air competitors. Acker (1997) confirmed this finding observing that domed stadia amplify the effects of home advantage, though some reservations were made regarding an inability to differentiate between factors of team quality and location. Likewise, difficulties emerge when attempting to separate familiarity factors (domed stadia having different conditions) from crowd factors (domed stadia having louder home support). While findings would seem to suggest that familiarity is most influential when variations in conditions are greatest, domed stadia will dramatically enhance crowd noise. For American football the authors suggest that a supportive home audience is the crucial element in explaining home advantage (Zeller & Jurkovac, 1989a), though difficulties in isolating factors remain. In support of a crowd influence it should be noted that the discrepancy in home advantage observed for domed stadia is both greater and more consistent than familiarity studies where crowd volume is not an issue between conditions (e.g. Barnett & Hilditch, 1993; Clarke & Norman, 1995; Pollard, 1986). Perhaps of greater concern is a possible relationship between the ability to afford a domed stadium and team quality (i.e. those teams able to afford a domed stadium are typically wealthier teams), as there is some evidence of home advantage increasing with team quality (e.g. Schwartz & Barsky, 1977). For association football, roofed stadia are rare, though crowd noise could well be enhanced in stadia with filled corners, or particularly tall stands. Any increased home advantage observed could, though, simply be a result of these teams with larger stadia having an increased potential to accrue home advantage as a result of their superiority.

2.5.2 Mechanisms behind the crowd effect

The specific influence of crowd noise in enhancing (or indeed diminishing home advantage) has been open to speculation. Thirer and Rampey (1979) and Greer (1983) recognised the influence that crowds might have on home advantage, and specifically upon players. When studying home advantage in college basketball, Thirer and Rampey (1979) found that during typical crowd behaviour the visiting teams committed more infractions, (i.e., fouls) and lost possession more frequently. During antisocial crowd behaviour (swearing, chanting obscenities), however, home teams committed more infractions. The authors concluded that "anti-social behaviour from the crowd had a detrimental effect on the home team" (p. 1051). Presumably, though, a home team committing infractions could also have a negative effect upon spectators, and it is unclear how the authors determined the direction of this relationship. Greer (1983) also assessed the effect of crowd behaviour (spectator booing) on home and away teams' performance (points scored, turnovers, violations, and a composite score comprising of points scored minus turnovers and violations). Greer observed that during typical crowd behaviour, home teams were better on all four performance measures. During those instances when the crowd was booing (for longer than 15 seconds), the home teams' superiority increased on all four performance measures, two being significant increases. Greer speculated that the observed improvement in home teams' performance was due either to a decrement in the visiting teams' performance or to referee bias resulting from intimidation by the home crowd (since most of the booing was directed at the officials).

Both studies used quasi-experimental designs to identify the effect of various aspects of crowd behaviour (cheering, booing), and the degree (intensity), on performance outcomes (e.g., fouls). However, by adopting such quasi-experimental designs, researchers recognize that it is almost impossible to untangle other associations that might confound the observed performance outcomes. For example, differences in the number of observed fouls in favour of the home side could be due to a number of other home advantage factors, such as frustration or aggression on the part of the away side or the use of more defensive tactics by the away team's coach.

Several authors have observed that officials consistently make more subjective decisions in favour of the home team (Glamser, 1990; Greer, 1983; Lefebrve & Passer, 1974; Sumner & Mobley, 1981; Varca, 1980). Sumner and Mobley (1981), for instance, found an imbalance of test cricket LBW decisions in favour of the home side, with Pollard

(1986) suggesting that this may be a result of subconscious officiating bias stemming from a partisan home crowd. Indeed, there is growing evidence that crowd influence plays a part in many such imbalances. For major league baseball, Schwartz and Barsky (1977) identified increasing home advantage with crowd density. Nevill et al. (1996) were able to confirm that not only do officials in English and Scottish football make more subjective decisions (penalties and sendings-off) in favour of the home side, but also the observed imbalance appears to increase in league divisions with larger crowd sizes. The authors concluded that the crowd might either influence away players to play more recklessly or affect the match officials' decisions in favour of the home side. Interestingly, for professional football, Duffy and Hinwood (1997) reported no home/away differences in players' (n = 30) anxiety when administering the Illinois self-evaluation questionnaire prior to competition. The latter of these suggestions has since been supported experimentally (see Chapters 4, 5 and 7), showing the presence of crowd noise to result in an imbalance of decisions in favour of the home side.

When officials are required to make subjective decisions (i.e. team sports), home advantage is consistently observed. Examples include major league baseball (home winning percentage excluding draws = 54%) (Adams & Kupper, 1994), major junior-A ice hockey (62%) (Agnew & Carron, 1994), College basketball (64%) (Moore & Brylinsky, 1995) and football (60%) (Nevill at al., 1996). In contrast to many individual sports with little officiating input (e.g. track and field), referees in the majority of team sports are expected to make numerous subjective decisions. Crowd noise seems to influence officials to give more of these subjective decisions in favour of the home side, with this imbalance increasing with larger more vocal crowds (Nevill at al., 1996). Investigation of this crowd noise influence upon officials provides much of the focus of the present thesis, and is tested experimentally in Chapters 4,5 and 7.

2.6 The demands of officiating in team sports

2.6.1 Stress and officiating

A considerable amount of research has highlighted the effects of competitive stress on performance (Gould & Krane, 1992). Researchers have used tasks involving memory recall (Davids & Gill, 1995), time estimation (Parfitt & Hardy, 1987), reaction time (Jones & Cale, 1989), anticipation skill (Williams & Elliott, 1999), and target aiming (Weinberg, 1978) to determine if, and how, stress affects performance. Moreover, an equally impressive body of literature documents the effects of social evaluative anxiety, stemming from the presence of significant others, on performance (Watson & Friend, 1969; Trower, Gilbert, & Sherling, 1990), a factor that may be particularly applicable to officiating in sport. To date, however, few studies have examined the effects of stress, presented in the form of noise from a partisan crowd, on officials' decision making in sport. This would appear to be an important area for research given the high dropout rates and evidence of psychological burnout amongst officials (e.g. Kassidis & Anshel, 1993).

Considerable physiological, psychological and perceptual demands are made of sports officials. Despite being, on average, older than players, distances travelled by association football referees during a match, are comparable to work rates of midfielders and may be greater than some players (Catterall, Reilly, Atkinson & Coldwells, 1993). Using 14 class 1 referees from a spread of English leagues, Catterall et al., (1993) found referees to cover a mean of 9488m (± 707m), comparable to the 9408m (± 838m) found by Johnston and McNaughton (1994). Both authors recognise the sizeable physiological demands placed on referees. Equally, assaults on officials in sport are common. In basketball for example, Rainey and Duggan (1998) found that

13.6%, of a sample of 721 Basketball officials, had reported being assaulted whilst officiating. In addition, 51% of these assaults were considered 'serious' acts (choking, throwing objects or punching), though punishment for offenders has been shown to be both inconsistent and lenient.

Interestingly, however, mean ratings of officials stress were shown to range from 'very little' to 'moderate' in groups of 723 basketball, (Rainey & Winterich, 1995) and 682 rugby officials (Rainey & Hardy, 1997). With only 4% reporting high stress for basketball, this led to the conclusion that "in general officials experience low occupational stress" (Rainey & Winterich, 1995 p1241). These studies, however, asked participants to rate stress some time after the relevant matches. This could explain why findings were at odds with the higher drop-out and burn-out rates observed in referees over other sports participants (Kaissidis & Anshel, 1993). Stewart and Ellery (1998) employed principal component analysis to identify four factors as being the most potent stressors in volleyball officiating. Interestingly, the most highly rated individual stressor was "making a bad call", which was also ranked highly in basketball (Kaissidis & Anshel, 1993) and association football (Taylor, 1990).

2.6.2 Random and systematic error in officiating

Despite the overriding pressure on officials to avoid "making bad calls", errors are optically inevitable due to limitations in perceptual function (Sanabria, Cenjor, Márquez, Gutierrez, Martinez, & Prados-Garcia, 1998). Examples include assessing first base calls in baseball (Rainey, Larsen, & Willard, 1987; Larsen & Rainey, 1991) 'leg before wicket' decisions in cricket (Craven, 1998) and 'offside' decisions in football (Oudejans, Verheijen, Bakker, Gerrits, Steinbrückner, & Beek, 2000; Sanabria et al., 1998). For example, Larsen and Rainey (1991) applied Wundt's theory of prior entry (that auditory stimuli appear to occur prior to the time of actual occurrence) to demonstrate bias in baseball's first base calls. Subsequently, using a computer simulation of the leg before wicket decision in cricket, Craven (1998) identified changing error as a result of varying swing, point of release and side of the wicket toward which deliveries were aimed. In association football, Sanabria et al. (1999) calculated theoretical inaccuracies associated with four simple offside decisions. They suggested that latency and duration of saccadic eye movements leads to an erroneous image of the players' positions, resulting in bias. Oudejans et al. (2000) expanded upon this experimentally, placing head-mounted cameras on assistant referees. In addition to specific bias detected in conjunction with the relative positions of the attacker and defender, 9.3% of trials were found to be "Flag Errors", what might be termed 'false alarms', though a limited number of situations/variables were considered and simple chi-squared tests were employed when traditional psychophysical methodology seemed appropriate. Unlike the above examples, on field refereeing decisions cannot be objectively measured as being 'correct' or 'incorrect'. Although some research has tried (Van Meerbeek, Van Gool, & Bollens, 1988), the legitimacy of three observers deciding that 17.4% of world-class referees decisions were wrong must be questioned. Further instances have shown general bias as a result of pitcher reputation in baseball (Rainey, Larsen, & Stephenson, 1989), ingroup (same state) favouritism (Mohr and Larsen, 1998) and nationalistic and political bias in Olympic skating (Seltzer & Glass, 1991; Whissell et al., 1993) and gymnastics (Ansorge & Scheer, 1988).

Fans have increasingly high expectations for officials to make correct decisions in judgement and interpretation of the rules. That some officials reported a fear of failure may reflect the high expectations of coaches, players and fans (Stewart & Ellery, 1998). Therefore, if officials do subconsciously favour the home side, they will naturally receive more positive reinforcement or less negative reactions from the home crowd (as an imbalance in favour of the home side would be viewed as the 'correct' decision). Equally, if the home crowd feels that the official favours the away side, calls will be treated with derision, presumably activating the potent stressor of 'making a bad call'. Investigating stress and the corresponding coping strategies amongst basketball referees, Kaissidis-Rodafinos, Anshel, and Porter (1997) suggested that referees exhibit consistent avoidance when exposed to stressful situations (i.e., a strategy of avoiding confrontation and directing activity away from the threat). In addition, avoidance was a particularly frequent coping style when facing stressors rated as difficult to control, notably verbal abuse from spectators. Consciously discounting or avoiding a potential stressor would be a legitimate response were the crowd impossible to control. However, it is possible that spectator abuse could be controlled to some extent by subconsciously favouring the home side, thus reducing their potency as a stressor, and producing enhanced home advantage.

2.7 Subjective judged disciplines

Sports requiring subjective decisions from officials can be divided into those where officials' enforce game rules, and those where officials' scores constitute a measure of outcome. Naturally, if officiating were particularly influential in increasing home advantage, then the largest discrepancy should occur when officials not only have subjective input, but also directly judge outcome. Ansorge and Scheer (1988) suggested that the "effects of biased officiating are potentially most dramatic in sports in which the officials actually score the points through judging the performances of athletes with some combination of objective and subjective criteria." Undoubtedly, some aspects of artistic performance can be fairly objectively judged. For example, Takei (1992) identified horizontal distance travelled from takeoff to peak of flight to explain some 42% of the variation in judges scoring of the compulsory vault at the 1988 Olympics. In contrast, experienced Olympic officials readily acknowledge their subjectivity, "There simply are no perfect routines. I have given a 'ten', but it is an emotional thing...a 'ten' is pure emotion, not brains" (Sasvary, cited in Hansen, Ansorge, & Scheer, 1984, p. 30). Such subjectivity would be particularly relevant to summer Olympic sports such as gymnastics and diving, or with reference to the winter Olympics, figure skating and freestyle skiing. The majority of research based on the subjectively judged disciplines has, however, focused on officiating influence on political and nationalistic bias, disregarding it as a possible source of home advantage. Anecdotal examples exist; for instance, in Olympic boxing where outcome is generally subjectively judged (in approximately 85% of bouts overall), home advantage has been observed with neutral judges. At the Seoul Olympics, American boxer Roy Jones supposedly 'outclassed' South Korea's Park Si Hun, only to have three judges, from Uganda, Uruguay and Morocco, score the fight against him (Gammon, 1988). Rather than nationalistic bias, the bout demonstrated a general home advantage from three non-Korean judges. Ironically, Jones went on to win the Val Barker Cup as the outstanding boxer of the Olympics to complement his silver medal.

2.7.1 International and political bias

Previous research has yielded consistently significant demonstrations of biased officiating. Park and Werthner (1977) highlight both the existence of nationalistic bias for two of four Olympic diving events, and the potential for politicised bias. Seltzer and Glass (1991) analysed the judging of 417 skaters (and 3753 rankings) in Olympic skating events from 1968-1988. They found that judges awarded significantly higher scores to skaters from their own countries, and that scoring was guided by 'cold war' politics. The Soviet Union directly penalised American skaters, while the United States of America accrued advantage not by penalising the Soviet Union directly, but by awarding its own skaters inflated scores. These findings suggest that specific scoring strategies were being employed to gain an advantage. Use of such strategies though, is not restricted to subjectively judged disciplines, and has also been reported for team games. For Australian Rules football, Mohr and Larsen (1998), demonstrated bias similar to that of the Soviet judges, with outgroup teams' scoring opportunities being obstructed, what the authors termed 'low-salience' bias. Whissell et al. (1993) confirmed such findings for the 1984 and 1988 Olympic skating contests, using a number of performance outcome criteria outcomes to infer bias. National bias was exhibited for both men and women, in awarding significantly more points, maximum scores, higher ranks and more maximum placements to fellow countrymen and women. Such bias was exhibited by all countries' judges with three or more skaters, was fairly consistent across nations, and exhibited by all countries' judges with three or more skaters. Interestingly, fewer incidents were reported for presumably weaker nations with fewer competitors. Although it is unclear whether such bias is conscious or subconscious, Ste-Marie (1996) suggested that international bias might be both conscious and intentional. Having previously demonstrated previous exposure to a gymnastic routine to result in judging bias (Ste-Marie & Lee, 1991), Ste-Marie (1996) directly addressed the source of the nationalistic bias observed by Ansorge and Scheer (1988). It was proposed that repeated exposure to a routine would result in increased appreciation, citing research regarding Chinese characters (Zajonc, 1968) and appreciation of music (Wilson, 1979) as examples. No such effect was observed for gymnastics judging, suggesting that international bias is conscious and intentional. It is significant, though, that the study did not directly prove conscious influences, but rather disproved a theory relating to subconscious influences (proof by contradiction), and as such should perhaps be treated with some caution.

2.7.2 Further reduction of objectivity

A subtle bias has also been identified for artistic disciplines, as a result of within team order (Ansorge, Scheer, Laub & Howard, 1978; Scheer & Ansorge, 1975) and expectations based on prior knowledge (Ste-Marie & Lee, 1991; Ste-Marie & Valiquette, 1996). Anecdotal evidence supported such an expectation effect at the Calgary winter Olympics, after three days of competition, in three figure skating categories, only two of the 20 couples changed places in the overall placement (Wallechinsky, cited in Hanley, 2000). Similarly, at the 1993 ice dancing world championships in Lillehammer, six of the nine judges were accused of basing their scores on reputation, not performance, while lack of objectivity was controversially exhibited when the gold medal winning Russian couple were not penalised for a 13-second separation, when the rules state that separations of over five seconds are illegal (Hanley, 2000).

As with artistic sports a number of elements are able to reduce the objectivity of officials in team sports (e.g. Craven, 1998; Larsen & Rainey, 1991; Nevill et al., 1999; Sanabria et al., 1998), though unlike team games, a crowd noise influence has not yet been proven, and bias in the form of home advantage has only been touched upon (see Chapter 3). As in team games, though, crowd noise cannot be discounted as an important distracter, and possible source of bias in already complex tasks (O'Brien, 1991). The complexity of the officiating task may also explain differences in bias and home advantage between tennis and golf tournaments with little officiating input (e.g. Holder & Nevill; 1997; Nevill et al, 1997), team sports with some subjective input (see Nevill & Holder, 1999), and events where officials judge outcome (e.g. Ansorge & Scheer, 1988). Research examining the home advantage in football has suggested that the crowd's influence upon officiating is more potent (in creating an imbalance of decisions in favour of the home side), for increasingly complex or contentious decisions (e.g. Balmer et al., 2001a) (see Chapter 4). Judging artistic events such as gymnastics is perhaps one of the most complex forms of officiating. Women's gymnastics judging, for example, requires the ability to identify over 900 skills or movements, recognising both deviations, and magnitude of deviations from the ideal in routines of up to 90 seconds (O'Brien, 1991). Additionally, rapid development of competitors has not matched considerations regarding the capacity of judges to assess routines (Plessner, 1999). This increased task complexity may be accompanied by a more potent crowd influence upon officials, and subsequent increased home advantage.

2.8 Error reduction, crowd noise and home advantage

2.8.1 Team sports

Research concerning LBW decisions in cricket has found sizeable random error in judgements, though practice and feedback was shown to reduce this error (Craven, 1998). Such errors have led to the suggestion that video replay technology should aid umpires in such decisions. Similar suggestions have been made regarding offside decisions in football (Ouedejans et al., 2000; Sanabria et al., 1999), and indeed steps have been taken to electronically measure whether the ball crosses the goal line. Such technology has already been introduced in Rugby League to assess the legality of tries (interestingly from soundproof booths) as well as in a number of American sports. Although video replay has been shown to reduce variability in gymnastics judging (Puhl, 1980), it is unclear whether use of such technology, or indeed feedback/training to reduce random error, would reduce bias, particularly as a result of crowd noise.

2.8.2 Subjectively judged disciplines

In recent years, the end of the 'cold war' has reduced political bias to some extent. Nationalistic bias has received vast exposure over the years, notably in figure skating at the 1978 World Championships where the USSR judging delegation was suspended by the International Skating Union due to a flagrant display of bias. In view of this, today, as Swift (1998) explained, "Any judge who places a skater from his own country two spots higher than the panel's average must write a letter of explanation to the referee" (p. 60). Corrective methods may also reduce nationalistic bias. Carefully constructed strategies such as the 'generalised efficient skating rule' (Frederiksen & Machol, 1988) have been shown to control for specific paradoxes associated with subjective judging. Figure skating, meanwhile, uses a median mark calculated following deletion of the highest and lowest marks. In addition, judges are privately informed of the median mark, and given the option to change their scoring (International Skating Union, 2000). This is followed by a procedure of comparing competitors or pairs on a one-to-one basis assigning 'points in favour' and 'comparative points' to produce ranks, which are weighted for each part of competition to determine outcome.

However, such techniques, and specifically use of median scores, do not address and may even enhance general home advantage. They may control for outliers or specific paradoxes, but not a more consistent systematic error that could lead to home advantage. Indeed, if the majority of judges were scoring home competitors disproportionately highly, neither elimination of scores, nor use of median would affect this, as both techniques simply attempt to reduce the influence of outliers. For instance, if all judges scored home skaters marginally higher than their performance merited when not at home, deletion of marks and median use will have no impact. Home advantage may even be enhanced, as the trimming procedure designed to combat other forms of bias would eliminate a judge or minority of judges not scoring a home competitor highly.

2.9 Overview

Home advantage is well established in team sports, though a number of quasi-experimental studies using archival data have failed to properly control for confounding factors (for a review see Nevill & Holder, 1999). Further reservations have been made about how to correctly quantify such factors (Madrigal & James, 1999), and how their influence should be negated (Clarke & Norman, 1995; Nevill & Holder, 1997). Clearly, such considerations are vital to obtaining an unbiased measure of home advantage. The existence of home advantage in individual sport and unbalanced competition remains unclear, perhaps again largely due to problems associated with confounding factors distorting measurements of home advantage.

Four game location factors have been proposed as significant in the creation of home advantage (Courneya & Carron, 1992), with the suggestion that each may be considered by isolating the influence of the other in quasi-experimental designs. Of these factors, support for two (familiarity with local conditions and travel) has been conflicting, a third (rule factors) is thought to be insignificant (Courneya & Carron,

1990) while the fourth (crowd factors) has received stronger support and is thought to be a 'dominant source of home advantage' (Nevill & Holder, 1999).

Two possible mechanisms have been proposed to explain the influence of the crowd upon home advantage; either the crowd is able to manipulate away players to play more recklessly or affect the match officials' decisions in favour of the home side (Nevill et al., 1996). The first experimental evidence confirming the latter of these hypotheses has been conducted and can be found in Chapter 4. Although demands made of officials are high, no formal mechanism explaining how crowd noise is able to influence officials has been proven.

Subjectively judged disciplines have been consistently shown to demonstrate officiating bias (e.g. Ansorge & Scheer, 1988), and are acknowledged to have the greatest potential for bias as a result of officiating input/style. A number of methods have been developed to reduce both random and systematic errors made by sports officials, though the majority have failed to acknowledge or address home advantage Indeed, little research has addressed whether such events enjoy home advantage, or whether such an advantage is disproportionately larger than other sports. Likewise very few studies have addressed home advantage for multi-event competitions, which would allow both fair comparison of home advantage between sports/sport types and comparison of sports with differing officiating style/input. Additionally, such studies would allow isolation of factors thought to influence home advantage, and an estimation of the crowds influence upon officials in terms of home advantage. Previous Olympic studies, although addressing aspects of nation quality and changes over time, have simply considered all events simultaneously (Leonard, 1989).

Chapter 3. Home advantage in the Winter Olympics (1908-1998)

3.1 Introduction

Courneya and Carron (1992) identified four major game location factors thought to account for, or affect the degree of home advantage. These fall under the headings of crowd factors, learning/familiarity factors, travel factors and rule factors. Of these three are directly applicable to Winter Olympic sports, with rule factors again being of marginal interest.

Crowd factors have been shown to create home advantage, and more recently to have a direct influence upon officiating. Nevill et al., (1996) identified frequencies of penalties and sendings-off in association football to favour the home side. In addition, the imbalances in favour of the home side increased with crowd size. This led to the conclusion that the crowd may either be influencing away players to play more recklessly, or affecting the match officials' decisions to favour the home side. If crowd noise were to influence officiating in the Winter Olympics, this effect should be most significant in events relying entirely on judges for scoring, and such an influence could be most potent. In figure skating or freestyle skiing, for example, the influence of a crowd upon judges would have a direct bearing upon the scores of competitors.

Familiarity with local conditions remains a largely unsubstantiated contributor to home advantage (Dowie, 1982; Pollard, 1986; Schwartz & Barsky, 1977). However, the sports examined (ice hockey, basketball, baseball, American football and association football) have relatively little potential for variation in local conditions, in contrast to, say alpine skiing. Clark and Norman (1995) did find some evidence (although non-significant) of increased home advantage in association football, using teams with unusual pitch size or surface. This observation was supported by Barnett and Hilditch (1993), again in association football, who found increased home advantage for teams with artificial playing surfaces. It seems little coincidence that the increased incidence of home advantage due to local conditions occurred when the difference was at its greatest (grass vs. artificial surfaces). It should follow that if familiarity is significant in the Winter Olympics, it should be most evident in alpine skiing, where the potential for variation is at its greatest. This was confirmed by Bray and Carron (1993) who acknowledged that the "beneficial effects of familiarity with the venue could contribute generally and specifically to the home advantage in world cup alpine skiing" (p. 80). As with classifying team quality (Madrigal and James, 1999), quantifying potential for familiarity with local conditions between sports is problematic. For Winter Olympic competition, this potential is assessed by consideration of differences in conditions between Olympics and the probable impact of such differences.

The potential for travel to affect performance has not been thoroughly investigated in the context of the Winter Olympics, and research regarding its influence elsewhere in sport has been far from conclusive. Pace and Carron (1992) proposed that "only a small portion of the variance in the home advantage/visitor disadvantage can be explained by travel related factors" (p. 60). They were, however, dealing with the National Hockey League, where time-zone traversal may only vary between 0 and 3 hours. Jehue et al. (1993) dealt with the NFL's relatively small potential magnitude of time-zones to traverse. They did, nevertheless, find direction of travel to be important, as well as time of day, and stated the possibility for a 'jet-lag' effect. With regard to the Winter Olympics, the range of time-zones traversed is far greater (-17 to +16 hours), though information as to the time of day when each event took place was not available. With regard to jet-lag, with results stretching as far back as 1908, rapid traversal of time-zones was evidently not possible. It was not until the advent of four-engine transports and jet airliners in 1958, when rail and ocean liners were replaced as the primary mode of long distance travel, that jet-lag became a reality. If jet-lag is influential, then, its influence should be seen after 1958, and possibly vary with magnitude and direction of travel. Given the likelihood that time would be available to overcome such adverse effects, the influence of such travel factors should be marginal.

The outcome of many Olympic events is determined using an objective and quantitative scale (e.g., time, distance), whilst others rely on less clear cut and more subjective judgements. As stated in Chapter 2, sports where officials directly judge performance have the greatest potential for biased officiating (Ansorge & Scheer, 1988). Examples include gymnastics and diving, or with reference to the Winter Olympics, figure skating and freestyle skiing. Previous research based on the Olympic games has, however, focused on officiating's influence on political and nationalistic bias (e.g. Ansorge & Scheer, 1988) disregarding officials as a possible source of home advantage.

The present study focuses on factors thought to account for home advantage and which apply to specific Winter Olympic events. In assessing home advantage, the study also aims to account for confounding factors such as team quality. A number of studies, notably those addressing individual sports (e.g. Bray & Carron, 1993) have failed to control for team quality (Chapter 2, section 2.3.1). The present study addresses the problem by using an intra-nation analysis, comparing the medal success of each nation when either hosting or not hosting the Olympics (home vs. away), thereby avoiding imbalances due to the relative strength of specific nations. Moreover, Winter Olympic competition presents a number of additional factors which must be considered, notably 'non-hosting' nation strength, changes in number of medals over time and number of opportunities nations had to win medals. The methods section provides a full explanation of how such factors were controlled.

Of the 12 disciplines considered (see Table 3.1), for two (figure skating and freestyle skiing) the outcome is determined entirely by the subjective scores of judges. Ski jumping also features an element of judging (style marks) as does Nordic combined, albeit to a lesser extent. Regarding familiarity with conditions, this should be most influential in alpine skiing, where variable pistes must be traversed at high velocity. In events such as biathlon and Nordic skiing, conditions may be variable but the lower speeds involved would theoretically marginalise such home advantage. Travel factors meanwhile are relevant in all Olympic events, as for any given Olympics, away teams must travel between -17 and +16 hours.

Table 3.1. Events used in the analysis (excluding the discontinued skeleton event and events held at only one Olympic)

Event No.	No. of hosting nations	Times held	Years	No. of medals (points) won for each event by	
				All Nations	Hosting Nations
1 Figure Skating	12	20	1908-1998	204(408)	103(192)
2 Freestyle Skiing	3	3	1992-1998	30(60)	9(17)
3 Ice Hockey	11	19	1920-1998	60(120)	27(56)
4 Ski Jumping	10	18	1924-1998	96(193)	60(116)
5 Nordic Combined	10	18	1924-1998	66(132)	43(92)
6 Alpine Skiing	10	15	1936-1998	307(616)	277(565)
7 Nordic Skiing	10	18	1924-1998	327(654)	100(200)
8 Short Track Skating	3	3	1992-1998	48(96)	3(5)
9 Bobsled	10	17	1924-1998	97(194)	74(150)
10 Luge (no skeleton)	7	10	1964-1998	96(193)	19(35)
11 Biathlon	7	11	1960-1998	105(210)	19(40)
12 Speed Skating	10	18	1924-1998	391(787)	189(383)
Total	103			1827 (3663)	923 (1851)

The aims of the present study were to assess the overall degree of home advantage in the Winter Olympics, and more importantly, to determine the influence of factors thought to have a bearing on home advantage. Three such factors are considered, subjective officiating, distance travelled and familiarity with local conditions. Subjective judging is addressed as a possible cause of greater home advantage than events relying on objectively measurable performance. Investigation of travel factors is well suited to the changing venues and multi-national nature of the Winter Olympics, as is familiarity with conditions, given the vast variations in say, piste as opposed to the far less variable rink size or stadia. Olympic games from 1908 to 1998 were used to investigate these three factors, a list of which can be found in Table 3.2. Firstly, it is hypothesised, that subjectively judged events display significantly greater home advantage than the remaining events. Secondly, it is hypothesised that familiarity with local conditions show increased home advantage, for events where there is most variation in terrain between Olympics (alpine skiing, luge and bobsled). Finally, travel is proposed to have a negligible effect, especially since time of arrival/preparation times were not available.

Table 3.2. Olympic games listed with location and host

Olympic Number	Year	Location	Host-occasion as host
1	1908	London	United Kingdom-1
2	1920	Antwerp	Belgium-1
3	1924	Chamonix	France-1
4	1928	St. Moritz	Switzerland-1
5	1932	Lake Placid	United States-1
6	1936	Garmisch Partenkirchen	Germany-1
7	1948	St. Moritz	Switzerland-2
8	1952	Oslo	Norway-1
9	1956	Cortina D'Ampezzo	Italy-1
10	1960	Squaw Valley	United States-2
11	1964	Innsbruck	Austria-1
12	1968	Grenoble	France-2
13	1972	Sapporo	Japan-1
14	1976	Innsbruck	Austria-2
15	1980	Lake Placid	United States-3
16	1984	Sarajevo	Yugoslavia-1
17	1988	Calgary	Canada-1
18	1992	Albertville	France-3
19	1994	Lillehammer	Norway-2
20	1998	Nagano	Japan-2

3.1 Methods

All the results of the Winter Olympics 1908 to 1998 were obtained from the Internet (http://www.chu-rouen.fr/jo/johome.html).

3.2.1 Determination of Home Advantage

Calculating home advantage in unbalanced competitions has been criticised for not accounting for the relative abilities of home and away competitors (Nevill & Holder, 1999). This imbalance may influence the observed home advantage. The following procedure aimed to address this problem by comparing, for a particular event, the medals/points won by a hosting nation (home) with the medals/points won by the same nation whilst visiting other Olympics games (away).

Home advantage for both medals and points were calculated by the following 4-step procedure. It aims to control for nation strength, 'non-hosting' nation performance and number of medals on offer, resulting in unbiased measures of home advantage. Freestyle skiing is used as an example throughout.

(i) Step 1-Elegibility

To allow a fair assessment, a nation's home performance(s) was compared to an aggregate measure of all their performances away from home. This ensures that a comparatively less successful country, for instance Yugoslavia, is not unfavourably compared to the more successful say, Norway. Clearly, nations who had never hosted the Winter Olympics were eliminated from the analysis, as they had no home performances to compare to their away performances.

For each event, the number of medals and points scored for each hosting country was entered into a table (e.g., see the medals and points scored for freestyle skiing in Table 3.3).

Table 3.3 (*Step 1*). Medal/points winning of 'hosting nations' for freestyle skiing, with non-hosting nations removed

	Medals(*Points) won by;			
Olympic (host nation)	France	Norway	Japan	Total
1992 (France)	2(5)	1(1)	-	3(6)
1994 (Norway)	1(1)	2(4)	-	3(5)
1998 (Japan)	1(2)	1(1)	1(3)	3(6)

*Gold=3 points, silver=2 points, bronze=1 point.

Note that the countries involved varied for each event since not all events began at the same Olympics. For example, luge began in 1964. This eliminated Switzerland, who hosted in 1928 and 1948, as it has never hosted luge in its modern form (despite being the home of the 'sliding' sports), and therefore had no home performances to compare to their away performances. Similarly, UK, Belgium, Germany, and Italy were be eliminated for the same reason, leaving only 7 eligible nations of the full set of 12 countries. Similarly, only 10 hosting nations of the full set of 20 Olympics were eligible when investigating Figure Skating. Correspondingly, medals/points won by hosting nations varied, firstly, with the relative strength of the hosting nations compared to non-hosting nations at each Olympics, and secondly, with the total number of medals/points available to all eligible nations (which generally increased over time).

(ii) Step 2-Medals on offer and non-hosting nation performance

Using a simple tally of medals or points as a measure of success would not control either for number of medals on offer or for non-hosting nation performance. Each tally and score was therefore divided by the total number of medals and total score attained by eligible nations at each Olympic. This gave the proportion of medals/points won by each nation of the total sum of medals/points won by all eligible nations at that Olympics (see Table 3.4).

Table 3.4. (*Step 2*). Medals/points won divided by total number available, for each 'hosting nation'

	Medals (Points) won by divided by totals			
Olympic (host nation)	France	Norway	Japan	Total s
1992 (France)	2/3=**0.67**, (5/6=**0.83**)	1/3=**0.33**, (1/6=**0.17**)	-	**3(6)**
1994 (Norway)	1/3=**0.33**, (1/5=**0.2**)	2/3=**0.67**, (4/5=**0.8**)	-	**3(5)**
1998 (Japan)	1/3=**0.33**, (2/6=**0.33**)	1/3=**0.33**, (1/6=**0.17**)	1/3=**0.33**, (3/6=**0.5**)	**3(6)**

This gave a balanced measure of performance for both medal tally and points, for each event, for each country and at each Olympic, which accounts for both total medals available (to all eligible competitors) and for non-hosting nations performances.

(iii) Step 3-Summation of performances home and away

The proportions from the above were summed for each country for home and away Olympics independently. The result was, for a particular event, one sum of proportions of medals won at home and one sum of proportions of medals won away, for each eligible nation in each given event, and for all Olympics at which each event was held (see Table 3.5).

Table 3.5. (*Step 3*). Proportions of medals/points won by each nation, summed for all home and away Olympics

	Medals (Points) won divided by totals						
Olympic (host nation)	France Home	France Away	Norway Home	Norway Away	Japan Home	Japan Away	Total
1992 (France)	**0.67 (0.83)**			0.33 (0.17)		0 (0)	1(1)
1994 (Norway)		0.33 (0.2)	**0.67 (0.8)**			0 (0)	1(1)
1998 (Japan)		0.33 (0.33)		0.33 (0.17)	**0.33 (0.5)**		1(1)
Sums	0.67 (0.83)	0.67 (0.53)	0.67 (0.8)	0.67 (0.34)	0.33 (0.5)	0 (0)	

Number of home and away Olympics varied across countries events. In Nordic skiing, for instance, which began in 1924 (18 Olympics), the United States has been at home 3 times (away 15 times), Switzerland twice (away 16 times) and Canada once (away 17 times). In luge, however, which began in 1964 (10 Olympics, excluding the now defunct skeleton event), the United States has been at home once (away 9 times), Switzerland none (always away and therefore excluded) and Canada once (away 9 times).

(iv) Step 4-Final calculation of home advantage

To obtain fair measures of performance, the home and away sums of proportions for each event, were divided by the number of opportunities each hosting country had to score points home and away (each of which is a subset of the Olympics at which each event was held). For Biathlon, the home sum of proportions for the United States was divided by 3, its away sum of proportions by 15, while Switzerland's home sum of proportions was divided by 2, and its away by 16 and so on. This took into account nations' failure to win medals at a given Olympic, which would not be the case if simple means were used.

This procedure yielded a mean proportion of medals/points won at home, and a mean proportion of medals/points won away for each of the set of hosting countries for a given event, and for all events. Each of these mean proportions may vary between 0 and 1. For a home mean proportion, 1 would indicate the given country winning all medals/points on offer for that event's set of eligible countries when at home. A score of 0.5 meanwhile, would show the country winning a mean of 50% of the medals/points available to the hosting nations over the set of home Olympics for the given event. Similar logic applies to the away mean proportions.

To obtain a measure of home advantage, the mean away proportion of medals/points was subtracted from the corresponding home proportion of medals/points for each hosting country involved in each event (for all events). This value, home advantage, can vary between -1 (total away advantage) and +1 (total home advantage) with 0 indicating that no advantage was accrued as a result of location. Home advantage, therefore, is equal to the mean proportion of medals/points won at home minus the mean proportion of medals/points won away for each nation that had hosted a given event, for all events. For the purpose of analysis, it would be equally legitimate to compare home and away scores as to use differences (see Table 3.6).

Table 3.6. (*Step 4*). Consideration of opportunities available to win medals/points, and final calculation of home advantage

	France		Norway		Japan	
	Home	Away	Home	Away	Home	Away
Sums of proportions of medals (points) won.	0.67 (0.83)	0.67 (0.53)	0.67 (0.8)	0.67 (0.34)	0.33 (0.5)	0 (0)
Number of occasions as host.	1		1		1	
Number of occasions away.		2		2		2
Mean sums of proportions of medals (points) won.	0.67 (0.83)	0.33 (0.27)	0.67 (0.8)	0.33 (0.17)	0.33 (0.5)	0 (0)
Away mean sums subtracted from home mean sums.	0.67-0.33 (0.83-0.27)		0.67-0.33 (0.8-0.17)		0.33-0 (0.5-0)	
Home Advantage.	0.33 (0.57)		0.33 (0.63)		0.33 (0.5)	

Table 3.6 shows that for Freestyle skiing, each event yielded as many pairs of home advantage scores (one for medal tally, one for points scored) as there are hosting countries who have competed in that event.

3.2.2 Determination of Travel Effects

As with the determination of home advantage, number of medals/points won by 'hosting' nations are converted to proportions by dividing total medals/points won by all hosting nations for the given Olympic (see steps 1 and 2 in 'Determination of Home Advantage'). Rather than summing home and away performances, each away performance must be considered as a separate observation in the analysis (due to the varying degree of travel involved). Degree of travel is expressed in terms of hours of time change (positive-eastward or negative-westward) and determined by time zones traversed from the hosting nation concerned to the relevant Olympic host.

To achieve a fair measure of performance to assess travel factors, the following technique was employed. The procedure is identical to that of 'Determination of Home Advantage' for steps 1 and 2; however, each specific away performance must be considered, due to the variation in travel between them. Distance travelled is expressed as number of time-zones crossed (hours), either positively (east), or negatively (west), for each away performance (i.e., the distance from each 'hosting' nation to each Olympic Games). Freestyle skiing is used for illustration (see Tables 3.7 and 3.8).

Table 3.7. Proportion of medals/points won in Freestyle skiing

Nation Competing	Olympic	Proportion of hosting medals (points) won.
France	Albertville 1992	0.67(0.83)
France	Lillehammer 1994	0.33(0.2)
France	Japan 1998	0.33(0.33)
Norway	Albertville 1992	0.33(0.17)
Norway	Lillehammer 1994	0.67(0.8)
Norway	Japan 1998	0.33(0.17)
Japan	Albertville 1992	-
Japan	Lillehammer 1994	-
Japan	Japan 1998	0.33(0.5)

Table 3.8. Difference in proportions of medals/points won and time-zones traversed (Freestyle skiing)

Competing Nation.	Proportion of hosting medals(points) won at home.	Proportion of hosting medals(points) won at each away Olympic.		Differences in proportions. (Response variable)	Time-zone change (hours)
France	0.67(0.83)	0.33 (0.2)	Norway 1994	0.34(0.63)	0
France	0.67(0.83)	0.33 (0.33)	Japan 1998	0.34(0.5)	+8
Norway	0.67(0.8)	0.33 (0.17)	France 1992	0.33(0.63)	0
Norway	0.67(0.8)	0.33 (0.17)	Japan 1998	0.33(0.63)	+8
Japan	0.33(0.5)	0 (0)	France 1992	0.33(0.5)	-8
Japan	0.33(0.5)	0 (0)	Norway 1994	0.33(0.5)	-8

So, for each hosting country at each away Olympics, a measure of performance is recorded comparing each away score with each hosting country's mean home score, for each specific event. This will yield a pair of difference scores (for medals and points), for each country's set of away performances, for all countries, and for all events. Each pair of scores will also have an accompanying distance measure, expressing the number of time-zones traversed, and the direction of travel for each of the hosting nations to attend each of their away Olympics.

By comparing each away performance against mean home performance, weaker hosting nations are not compared unfairly against stronger nations and vice versa, as each performance is set against that country's unique standard measure, home performance. These differences can then be analysed against time zones traversed. It should be noted though, that this technique excludes comparison of home and away columns of scores, as repetition would create an artificial number of home observations.

3.2.3 Classification of Events

Two separate groupings were employed;

i) Subjectively judged (group 1) and objectively measured (group 2).

Group 1=figure skating and freestyle skiing, Group 2=all other events.

ii) Subjectively judged (group 1), familiarity (group 2) and other events (group 3).

Group 2=alpine skiing, luge and bobsled.

The subjectively judged group comprised of events where the outcome measure was entirely made up of judges' scores. For the familiarity group, events falling under alpine skiing, luge and bobsled are included, since it is felt they have the greatest variation in conditions. Given this reasoning, sports using ice rinks were removed, as only minimal differences in the ice condition of stadia are possible compared to vast variation in mountains between Olympics. Similarly, ski jump and Nordic combined are excluded due to lack of sufficient variation, as are Nordic skiing and biathlon due to the low velocities involved allowing adaptation to terrain. Regarding luge and bobsled, it is acknowledged that tracks may only be constructed over a relatively short time-scale before the competition. Lacking information as to precise times of track construction, however, the two are included in the familiarity group due to both their highly variable terrain and high velocities.

3.2.4 Statistical Methods

Preliminary analysis of the home advantage response variables indicated that the residuals were not normally distributed, and for this reason, non-parametric statistics were employed throughout. This involved, in the first instance, a Wilcoxon signed-rank test to determine overall home advantage. Secondly, a series of Kruskal-Wallis tests were employed to examine the factors of subjective officiating and familiarity with local conditions. Finally, regression analysis was used to assess the influence of travel upon performance, fitting linear, quadratic and exponential terms. The number of observations used for figures and analyses (excluding travel) can be determined by the addition of relevant events in the 'no. of hosting nations column' of Table 3.1. All error bars on figures denote standard error.

3.2 Results

3.3.1 Overall Home Advantage

Measures of performance for medals and points were calculated home and away as illustrated in Table 3.6. The difference between home and away scores was calculated for each hosting nation and for all events to give an overall measure of home advantage. Using a simple Wilcoxon signed-rank test on two sets of 103 observations, home advantage was found to be significantly greater than zero for both medals (P = 0.029) and points (P = 0.023).

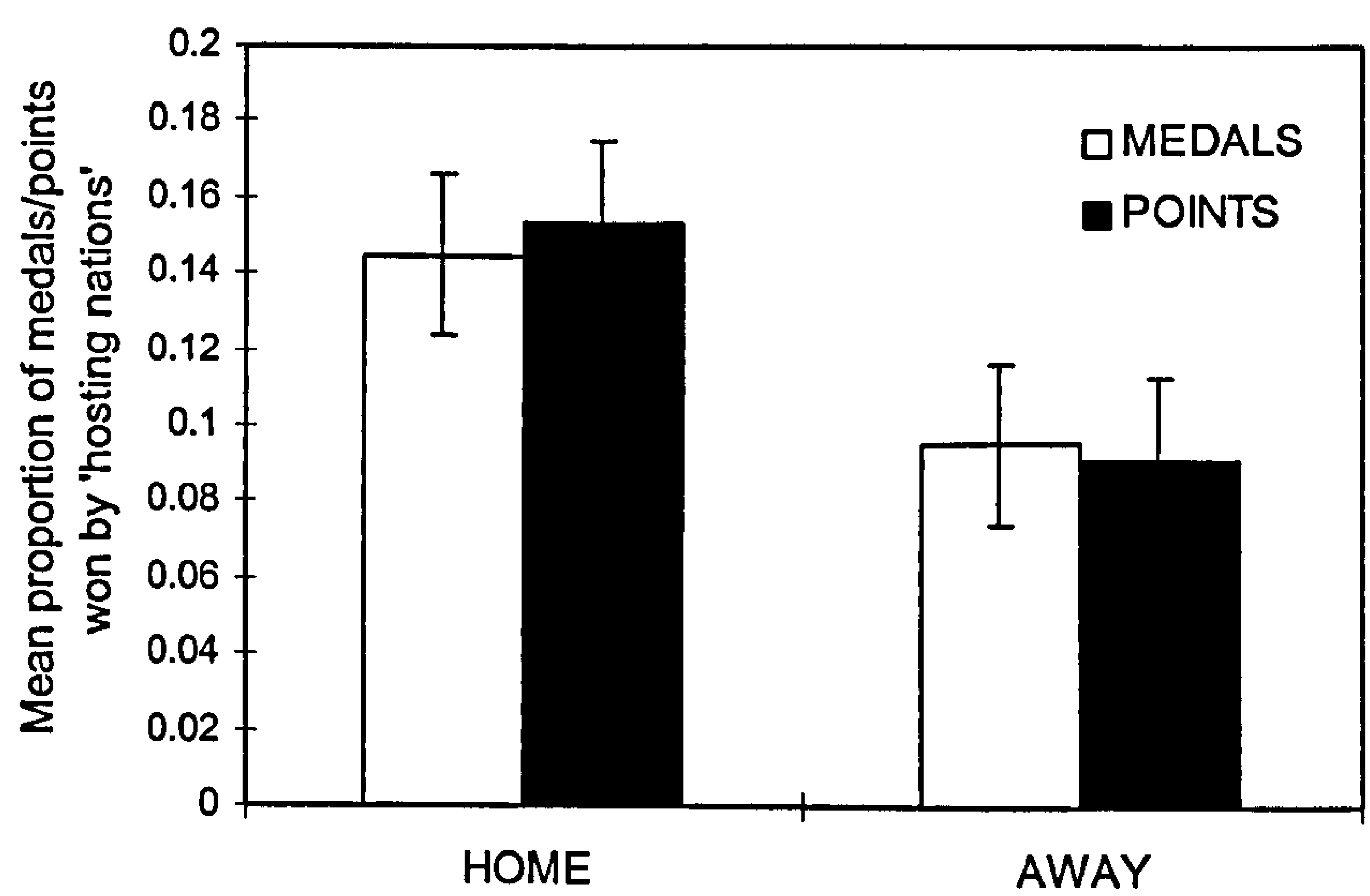

Figure 3.1. Proportion of medals/points won home and away by 'hosting nations', for all nations, Olympics and events.

3.3.2 Subjective Judgements and Variable Local Conditions

Initially, two Kruskal-Wallis tests were employed to determine differences in home advantage between events (see Figure 3.2). No significant differences were found either for points, H_{11} = 17, (P = 0.093), or medals, H_{11} = 15.17, (P = 0.177).

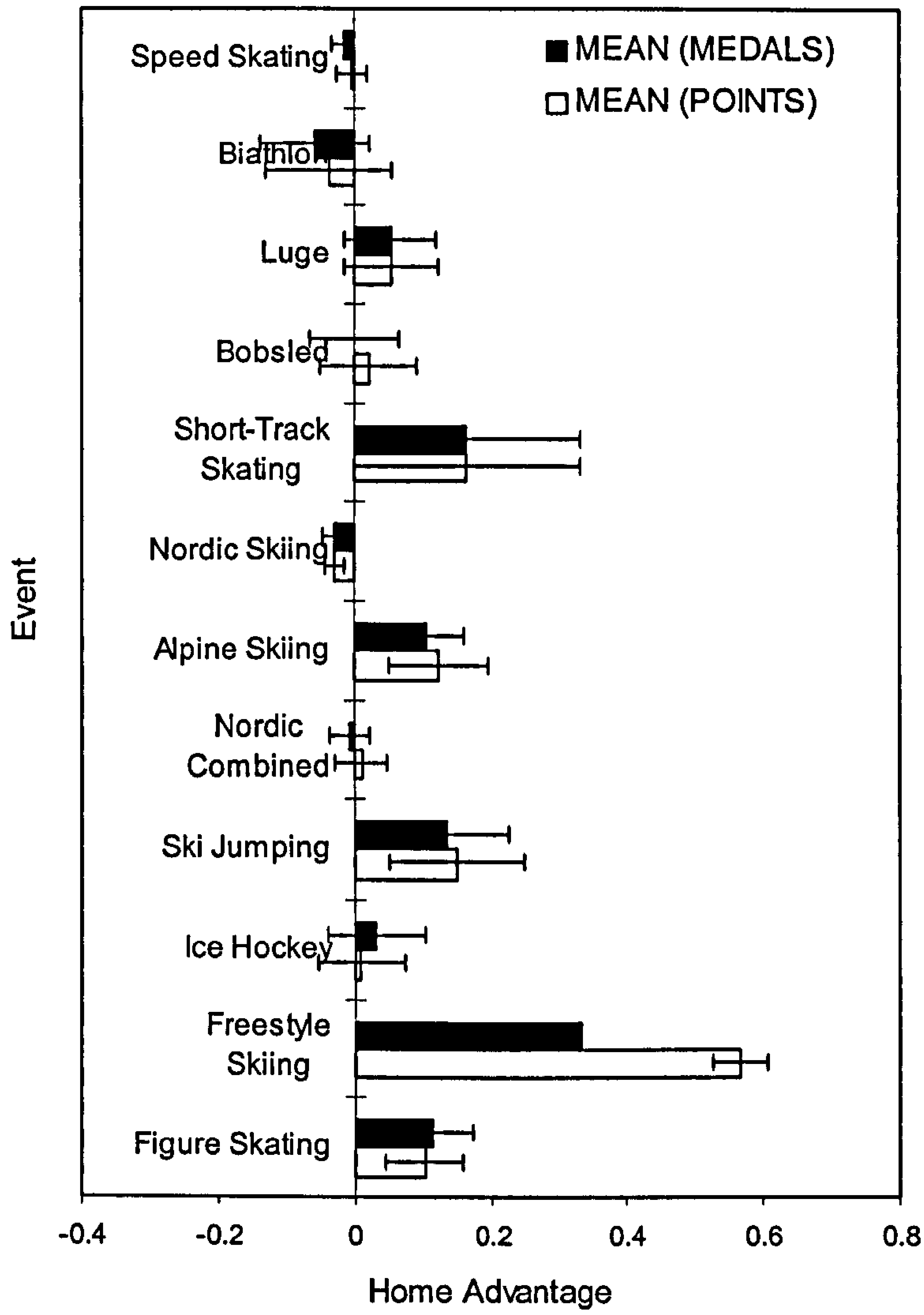

Figure 3.2. Home advantage measures for all events by both medals and points.

Kruskal-Wallis tests were used to investigate whether home advantage differed in events where subjective judging was employed. Significantly greater home advantage was found for group 1 versus group 2 (grouping i) for both medals, $H_1 = 4.35$, ($P = 0.037$), and points, $H_1 = 4.13$, ($P = 0.042$) (see Figure 3.3).

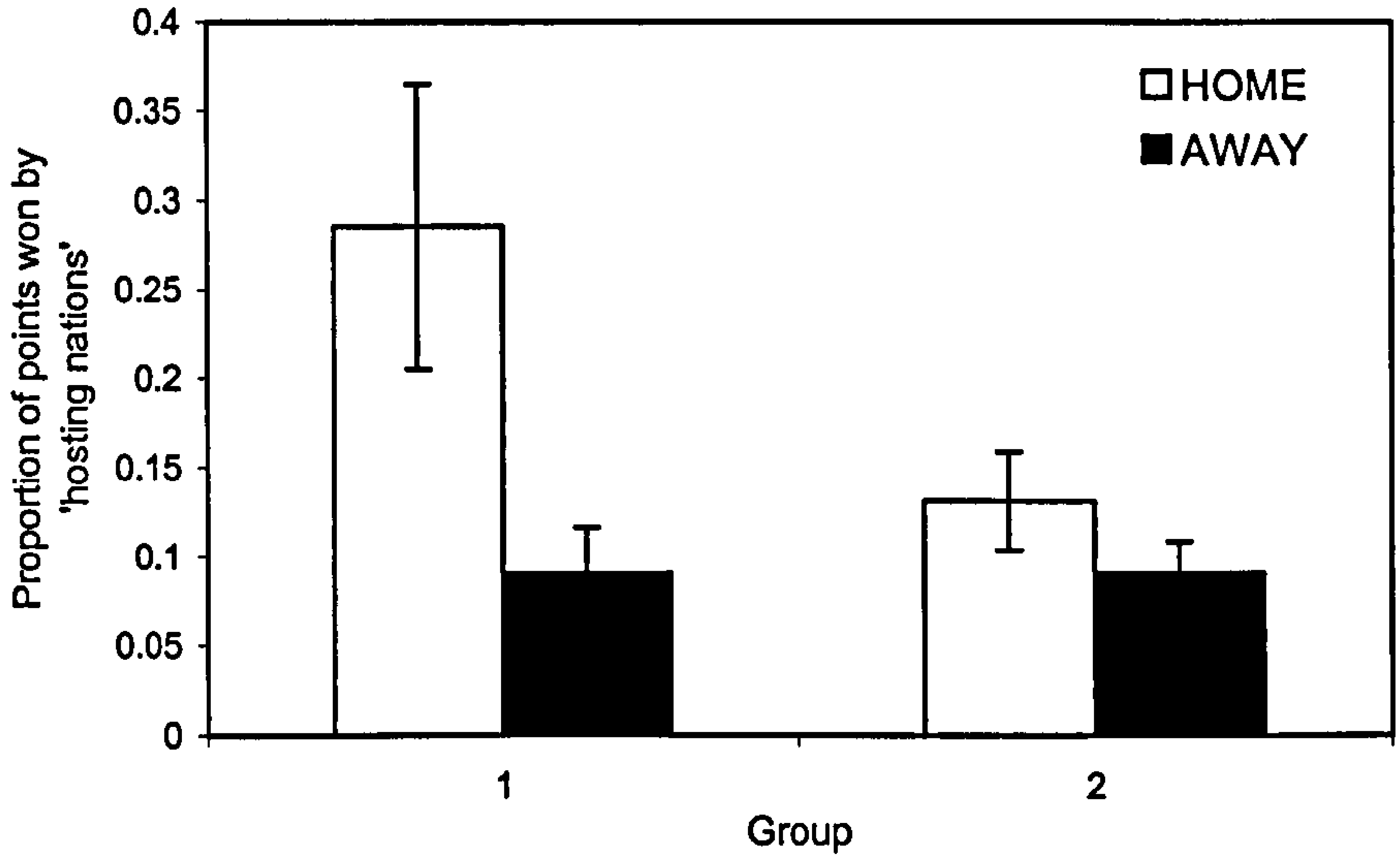

Figure 3.3. Home and away point winning performances for 2 groups (subjectively (1) and non-subjectively judged (2)).

The triple group case (grouping ii) also showed significant differences in home advantage between groups for medals, $H_2 = 6.19$, ($P = 0.046$), and points, $H_2 = 6.25$, ($P = 0.044$) (see Figure 3.4). Subsequent post-hoc tests (though not strictly legitimate given the lack of normality) demonstrated that the significant findings observed were as a result of differences between groups 1 (subjectively judged) and 3 (other events).

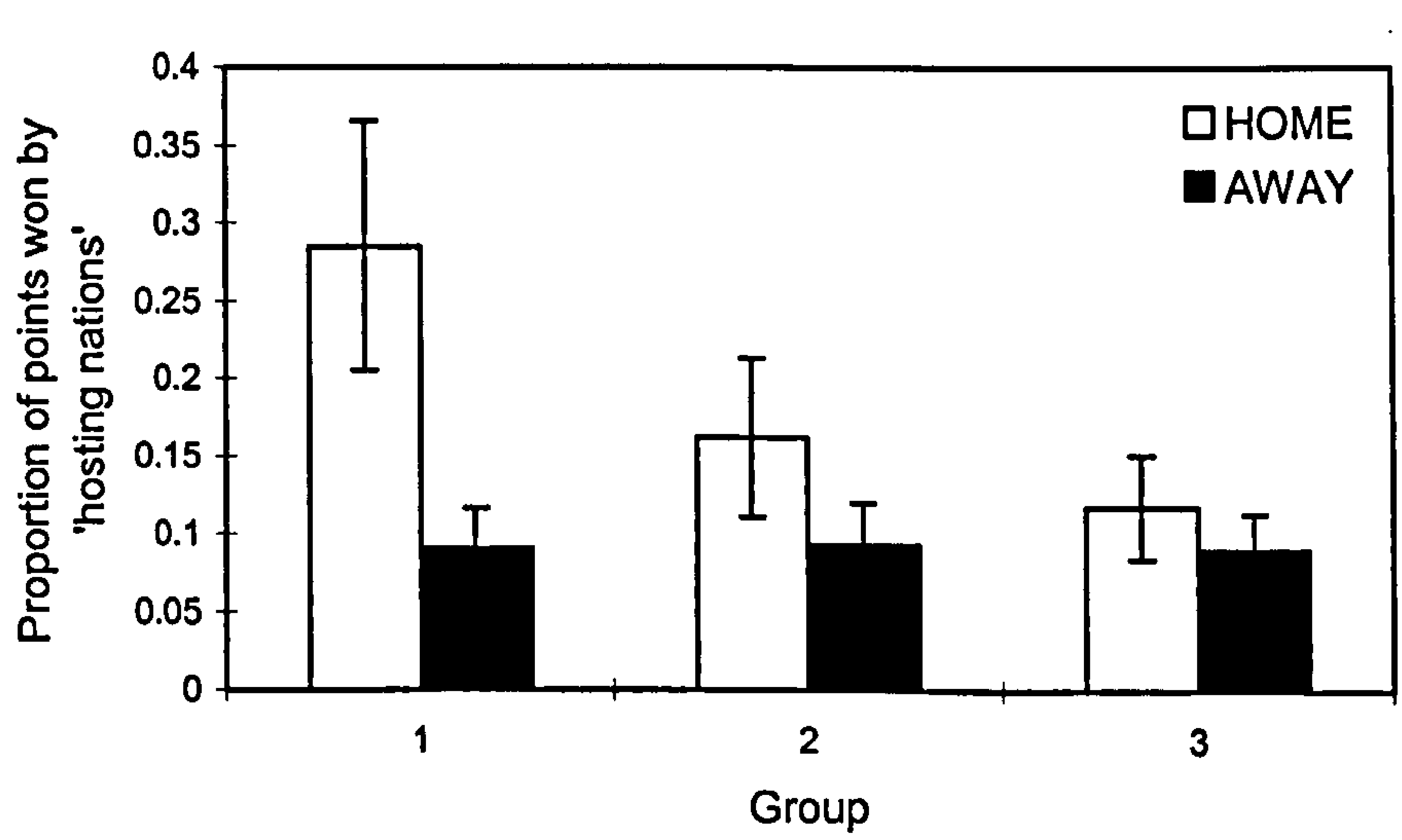

Figure 3.4. Home and away point winning performances for 3 groups (subjectively judged, variable local conditions, non-subjectively judged).

Incidentally, further Kruskal-Wallis tests revealed no significant differences between all nations home advantage, for medals, $H_{11} = 10.96$, ($P = 0.448$), or points, $H_{11} = 11.06$, ($P = 0.439$). Likewise, there were no significant fluctuations in home advantage over time, for medals, $H_{19} = 13.94$, ($P = 0.786$), or points, $H_{19} = 12.23$, ($P = 0.874$).

3.3.3 Travel Factors

In order to determine travel effects, distance travelled for away performances was recorded for each hosting nation, event, and Olympic involved. These were subtracted from each hosting nation's mean home score for each given event, for both medals and points. This process is comprehensively described below; for simplicity, however, these units of observation will be collectively referred to as either medal winning or point winning performances.

Initially, differences between medal and point winning performances were determined with time-zones traversed as a factor (20 levels, between -17 and +16 hours). Two Kruskal-Wallis tests were performed, showing highly significant differences between time-zones crossed for both medals $H_{19} = 83.50$, ($P < 0.001$), and points, $H_{19} = 76.80$, ($P < 0.001$). This result could, however, simply be a reflection of specific countries performing particularly well or badly at a given location or Olympics, and does not necessarily indicate trends in performance over hours travelled. To this end, regression analysis was employed using both medal and point winning performances (see Figure 3.5), fitting linear 'time-zones crossed', quadratic '(time-zones crossed)^2' and exponential 'exp(time-zones crossed)' terms as predictors. This examined the possibility that performance increased or decreased from -17 to +16 hours crossed (linear), and that performance became worse with increasing hours crossed, east and west (quadratic). Alternatively, east or west travel had an influence on performance alone (exponential).

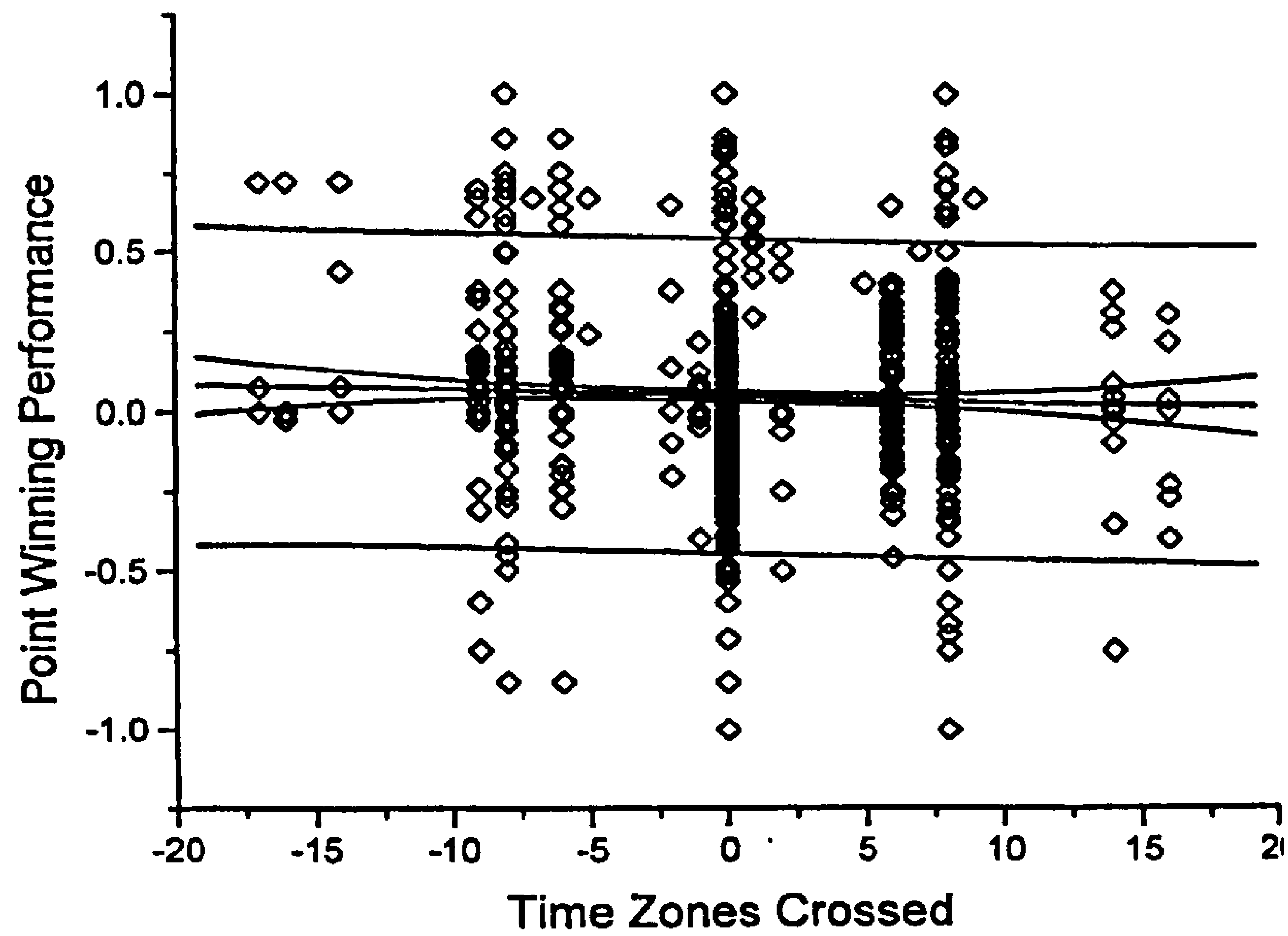

Figure 3.5. Point winning performance plotted against distance travelled for all events, nations and Olympics, with 95% confidence and prediction intervals.

None of these predictors was found to be significant either with medal or point winning performance, ($P > 0.05$) and fitting all terms simultaneously was only able to explain a negligible amount of the variance ($R^2 = 0.3\%$). Only the constant term was found to be significant (constant ≈ 0.045, $P < 0.001$ in all cases), identifying a consistent home advantage throughout. There were no significant changes in the travel effect either over time. Grouping Olympics by date (1908-1924, 1928-1936, 1948-1956, 1960-1968, 1972-1980, 1984-1992, 1994-1998) and again fitting all three terms simultaneously for each period, explained at maximum only a very small portion of the variance ($R^2 = 0.4\%$). This demonstrated that time period had little influence upon the travel effect.

3.3 Discussion

Based on data from all Winter Olympics, significant evidence of home advantage was identified. This finding was expected, given the wealth of support for the home advantage phenomenon. Of greater interest was whether specific differences in home advantage between groups of events would emerge. Although no significant differences were found across all events (Figure 3.2), when the two separate groupings of events were employed, some interesting differences in home advantage emerged. Grouping events on the basis of whether they were subjectively judged or not, demonstrated that using subjective judgements as a form of assessment, produced significantly greater home advantage than events with objectively measurable performance or outcome (e.g., time, goals or distance). This finding may reflect superior performances by athletes competing in front of a supportive partisan audience. However, this explanation would result in consistently elevated home advantage over all events, whenever crowds were present. An alternative explanation for the observed group is that the judges responded more positively to crowd noise, when judging home competitors' performances. This conclusion is speculative since the use of such archival data does not permit examination of the make-up of specific crowds. Nevertheless, this rationale seems entirely plausible considering previous research reporting that officials consistently make more subjective decisions in favour of the home team (Glamser, 1990; Greer, 1983; Lefebrve & Passer, 1974; Lehman & Reifman, 1987; Sumner & Mobley, 1981; Varca, 1980). Significantly, subsequent research has gone on to highlight the role of the crowd in this process (Nevill et al., 1996; Nevill et al., 1999).

Whatever the cause, this finding suggests that subjective assessment by officials would appear to explain a large proportion of the variation in observed home advantage in Winter Olympic events, especially given that these events appear to have no other discernible and exclusive factors influencing home advantage. Figures 3.3 and 3.4 show that the variation in home advantage found between groups of events was a reflection of differences in home rather than away performances. Away performance remains fairly constant throughout, suggesting the imbalance is a direct result of enhanced home, and not deteriorating away performance.

Familiarity with local conditions, grouping (ii), was shown to have an intermediate influence on home advantage, between the subjectively judged group and the remaining events. The significant differences between the three groups, however, were a reflection of differences between the 'subjectively judged' group and 'other events', though familiarity is shown to have some influence. This finding should, however, be treated with some caution given the difficulty in assessing when familiarity with local conditions should be most influential (in order to assemble a familiarity group). Although events where most variation was possible were chosen, it is recognised that no discrete grouping would be perfect when dealing with a variable which is difficult to assess objectively. Familiarity with local conditions remains as Courneya and Carron (1992) suggested, both an under-investigated and elusive possible source of home advantage. This present study adds to a growing list of inconclusive and/or contradictory findings concerning such a familiarity concept (e.g. Barnett & Hilditch, 1993; Clarke & Norman, 1995; Dowie, 1982; Pollard, 1986)

With regard to travel, no appreciable trends were present, regardless of the regression model fitted. The only significant term in the regression analysis (the constant) simply identified consistent home advantage, regardless of time-zones traversed in any given away performance. This suggests that absolute degree or direction of travel had negligible influence, with a maximum of 0.3% of the variance able to be explained. Perhaps of greater importance is the fact that travel had taken place, as shown by the general home advantage found for all events, and the significant constant in all regressions. This should not give the impression that jet-lag is illusory however, as it is likely that Olympic athletes arrive in good time to allow adjustment of the body clock. In contrast, athletes in studies reporting impaired performance with time zones crossed (e.g. Jehue et al., 1993; Waterhouse at al., 1997) generally did not arrive in good time. In future competition, precise data concerning time of arrival and competition would allow a more thorough assessment of the influence of travel.

Volume of data, number of hosts and number of events falling into particular categorisations limited the Winter Olympic data. Considering these limitations, future research could apply similar methodology to the far more substantial set of data provided for the Summer Olympics. Without mountainous terrain as a requirement for a host, this gives a larger set of 17 hosting nations, over 24 Olympics (including Sydney 2000). Also, the larger range of events would allow more thorough investigation into each specific factor influencing home advantage. A subjectively judged group for instance could contain aquatics, gymnastics and diving, as well as possibly judo and wrestling. Gymnastics alone has awarded 775 medals, excluding Sydney 2000, 541 more than the subjectively judged group for the Winter Olympics, giving some measure of the increased size of the data set. Despite these limitations, the study does provide simple methods by which confounding variables may be controlled (see 'determination of home advantage'). These techniques do, however, lead to a large reduction in the data set (two sets of 103 observations). Future Summer Olympic analysis could develop an analysis that controls for confounding factors, without such a large reduction.

In summary, events in the Winter Olympics relying on subjective assessment by judges yielded significantly greater home advantage than in other events, an imbalance that appeared independent of corrective methods designed to eliminate nationalistic and political bias. These findings may reflect the way judges respond to crowds' reactions when judging home competitors' performances, which seems reasonable based on previous research. Familiarity with local conditions was shown to have some limited effect, while degree and direction of travel in this context, were shown to produce no discernible trends or difference in performance.

Chapter 4. Crowd noise and the home advantage: preliminary experimental work

4.1 Crowd influence on refereeing decisions in association football

4.1.1 Introduction

Chapter 3 identified the role played by officiating in enhancing home advantage. Having identified enhanced home advantage for subjectively judged events, it was speculated that the home crowd influences judges to favour the home side. Given that home advantage in football is well established, Chapter 4 aims to examine mechanisms underlying home advantage, testing proposals made in Chapter 3. Again focusing upon the role of officiating, Studies 4.1 and 4.2 aim to determine experimentally whether the crowd is able to influence refereeing decisions. This expands upon the findings of Chapter 3, by addressing why sports with a major officiating input enjoy enhanced home advantage.

As referred to in the general introduction, Nevill et al., (1996) were able to confirm that not only do officials in English and Scottish football make more subjective decisions (penalties and sendings-off) in favour of the home side, but that the observed imbalance appears to increase in divisions with larger crowds. To explore this observation, the present study attempted to provide experimental evidence of how the crowd or more specifically, how crowd noise might be effecting officials' adjudications.

In order to help explain why officials consistently make more subjective decisions in favour of the home team, Study 4.1 investigated whether knowledgeable observers' opinions of 52 tackles/challenges in football matches, recorded on videotape, could be influenced by a partisan crowd's reactions. By isolating the tackles/challenges from their 'real life' setting, it is recognised that the present study may lose some external validity but, on the other hand, gains the ability to control all the confounding effects associated with the various alternative quasi-experimental designs discussed earlier. It was hypothesised that the presence of partisan crowd noise leads to some tendency to penalise the home team less, and the away team more.

4.1.2 Methods

(i) Participants and procedure

Eleven participants, made up of experienced footballers, qualified coaches and referees, were asked to assess the legality of 52 incidents from the 1998 Champion's League match between Lens (home) and Panathinaikos (away). This single match was used in order to control the effect of variable crowd sizes between matches, whilst taking advantage of a partisan home crowd of approximately 40,000.

The eleven participants were randomly assigned to either a noise group, receiving background noise (n = 5), or a 'no noise' group, who received only visual stimuli (n = 6). Each participant then judged the legality of the 52 edited incidents, which were presented chronologically, on a 21-inch (53 cm) monitor screen, the experimenter recording the adjudications. A home player initiated 26 of the incidents with the remaining 26 initiated by an away player.

(ii) First analysis (all challenges)

Firstly, the observers' responses (foul vs. no foul) were collapsed into two mean proportions of fouls awarded to the 26 home and 26 away players' challenges. These binomial proportions were analysed using a two-way analysis of variance (ANOVA) with repeated measures, one factor between-subjects (the noise condition; noise vs. no noise) and one factor within-subjects (team representation; home vs. away player). In recognising the limitations of using traditional ANOVA to compare binomial proportions, the analysis was repeated using an arcsine transformation of the data to stabilise the variances, as recommended by Winer (1962).

$$p' = \arcsin\sqrt{p}$$

The proportions used as a response variable form a binomial distribution (varying between 0 and 1). Particularly large or small proportions have been shown to result in large deviations from normality (Zar, 1999). In stabilising the variances, the arcsine transformation should result in a nearly normal distribution.

(iii) Second analysis (subset of incidents)

Secondly, it was noted that the eleven observers reached 100% agreement on 27 occasions. Clearly, for such 'non-contentious' challenges (either a definite foul or definite legal challenge), the crowd is unlikely to influence officials' decisions, and as such, these challenges were not included in the subsequent analysis. Of the remaining subset of 25 'contentious' incidents, 15 were challenges initiated by a home player and 10 by the away player. Groups' responses to each challenge were analysed as a binomial proportion (e.g., 4 out of 6 observers judged the challenge to be a foul) using Generalised Linear Interactive Modelling (GLIM) software. A 2 × 2 factorial design was used to assess the effect of the two noise groups (noise vs. no noise group), and team representation (home vs. away player) on the proportion of fouls. The referee's judgements are illustrated graphically for comparative purposes only.

4.1.3 Results

(i) All challenges

In the first case, Table 4.1 shows the percentages of fouls (± standard deviation) awarded by the two groups of participants, and the referee in response to challenges initiated by either home or away players. This relationship is illustrated graphically in Figure 4.1. Applying ANOVA to the mean proportions for the two experimental groups, excluding the match referee, revealed a significant two-way interaction between 'noise group' and 'team representation' ($F_{1,9} = 8.20$, $P = 0.019$). Analysis incorporating the arcsine transformation yielded similar values ($F_{1,9} = 8.03$, $P = 0.020$), though reassuringly, the residuals were more acceptably normal than with the initial analysis.

Table 4.1. Percentage (±SD) of fouls awarded by the observers and the referee, for challenges by the home and away players.

	Home	Away
No Noise (N=6)	57.6 (±9.8)	48.3 (±1.9)
Crowd Noise (N=5)	50.0 (±4.7)	56.9 (±5.0)
Referee (N=1)	50.0	65.4

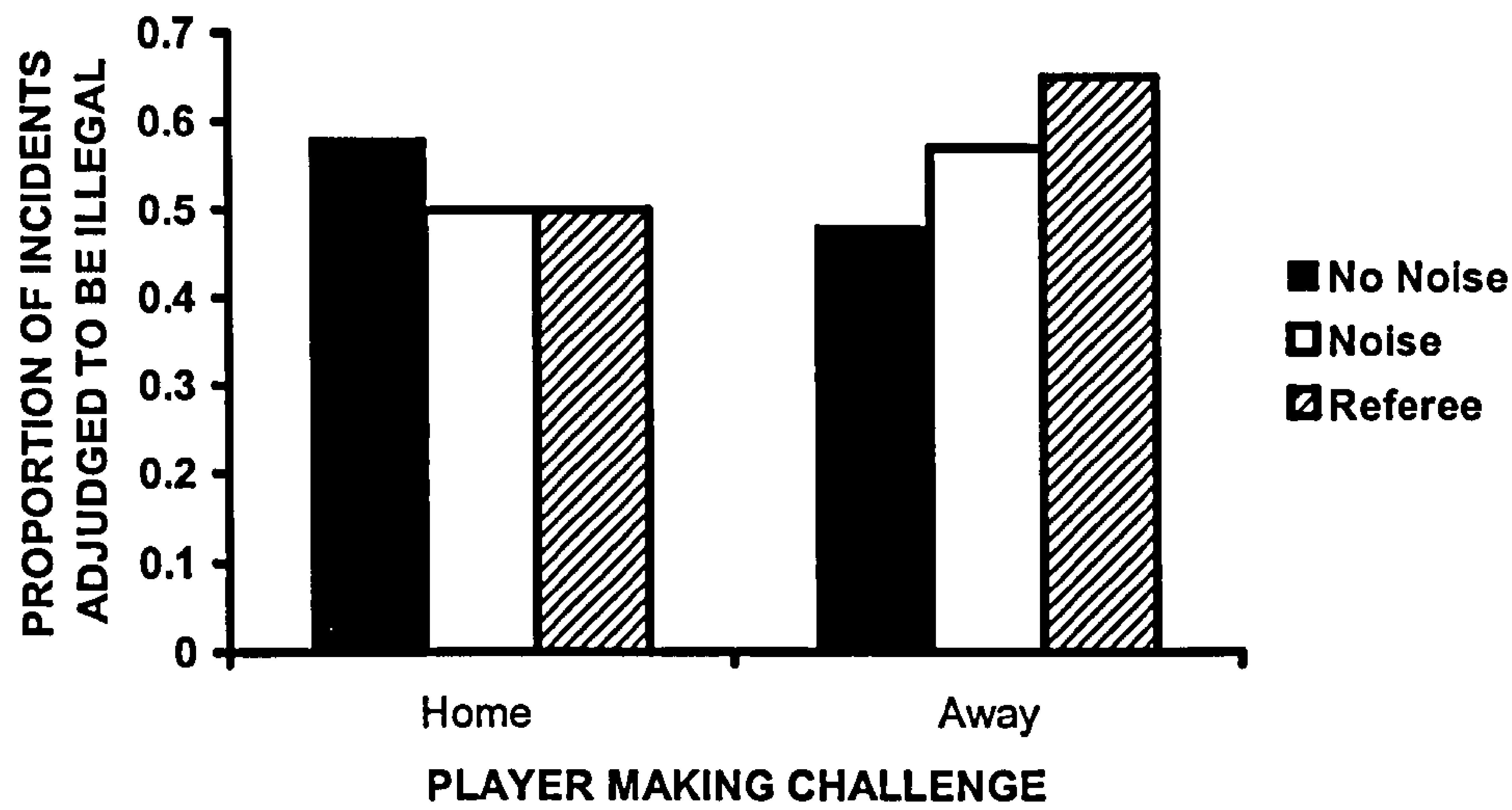

Figure 4.1. Proportion of fouls awarded by the observers and the referee, for challenges by the home and away players.

The participants demonstrated a tendency to penalise the away team significantly more, and the home team significantly less often when exposed to crowd noise alone. Given that the direction of the referee's decisions follow closely that of the 'noise group' (Figure 4.1) it would be fair to assume that the official could be expected to behave in a manner comparable to the 'noise group'. Moreover, from the referee's perspective, crowd noise would be both louder and more invasive (i.e., directed specifically toward the official), and therefore, if anything their adjudications should demonstrate an increased imbalance. This increased imbalance is suggested in Figure 4.1, as the referee penalised the away team players to a slightly greater extent than the 'noise group'.

(ii) Subset of challenges; GLIM analysis

In the second case, fitting both the main effects and the interaction term explained a loss in deviance of -10.59 with 3 degrees of freedom (df) ($P < 0.05$). When the interaction term was removed, the increase in deviance was large, +8.81 on 1 df ($P < 0.01$). Clearly, the contribution of the interaction term is important in explaining the proportion of fouls awarded by the observers under the two conditions. Figure 4.2 describes the proportion of fouls awarded by the observers and the referee. The observers demonstrated a greater tendency to award a foul when viewing challenges by away players in the presence of the crowd noise, a tendency that disappears when crowd noise was absent. Similarly, observers were inclined to penalise challenges by the home player less frequently when exposed to crowd noise.

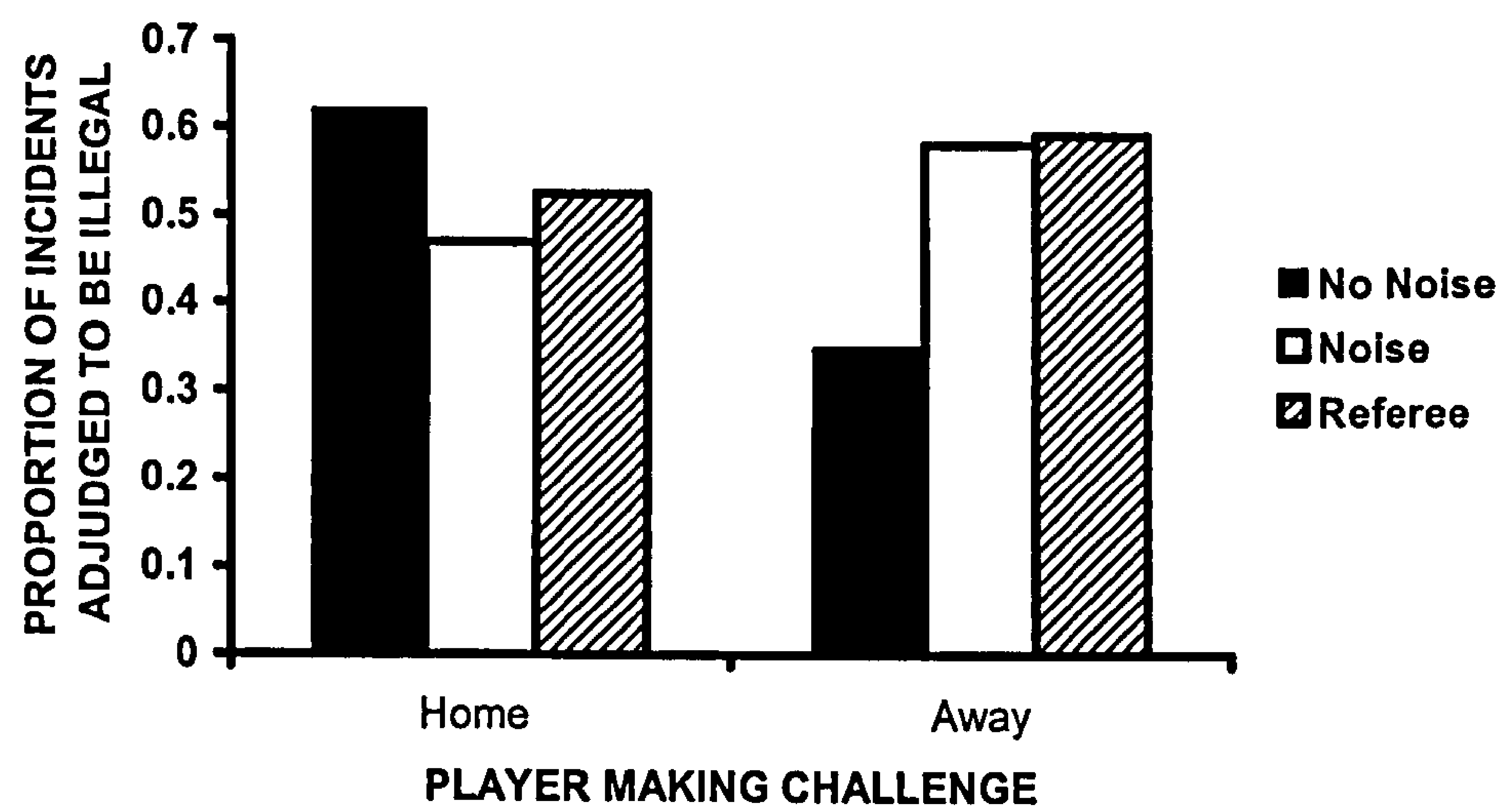

Figure 4.2. Proportion of fouls awarded by the observers and the referee for the 25 challenges by the home and away players.

4.1.4 Discussion

In the absence of crowd noise, the observers adjudged 57.6% of the home players' challenges to be illegal, compared with 48.3% for the away players. The imbalance in these figures should be attributed to the specific incidents used, as opposed to a trend to favour the home side. In contrast, when exposed to crowd noise, observers awarded 50% of the incidents as fouls by home players and 56.9% by away players. This marked tendency to penalise the away and favour the home players, therefore confirms the hypothesis. These data suggest that decision-making is significantly affected by partisan crowd noise, and the direction of the resultant imbalance corresponds with the idea of home advantage. These findings provide a possible explanation for the increased home advantage observed with greater crowd density (Agnew & Carron, 1994; Nevill et al., 1996; Schwartz & Barsky, 1977). Nevill and Holder (1999) proposed that the crowd subconsciously influence officials to favour the home team as a possible explanation for a crowd density effect. The present findings, albeit in a controlled laboratory setting, provide experimental support for this proposal.

Various reports have provided anecdotal evidence to suggest that referees' decisions can be influenced by the crowds' reactions to favour the home side. For example, Askins (1978) stated,

"During the course of any contest there are many incidents which appear ambiguous, even to the most veteran officials. When this occurs, officials do basically what all humans do in such a situation, they seek clarification through any means available at the time. Crowd reaction may sometimes provide the cue which prompts the decision." (p. 18).

The results from the present study have demonstrated how this may occur. Clearly, crowds' reactions to challenges/tackles are capable of influencing observers to be more or aggressive or severe when judging challenges by the away players, and more lenient when considering challenges by the home players.

Addressing the issue of ambiguity, the second case involving incident removal showed crowd noise had no effect on the observers' decisions when assessing 27 'non-contentious' challenges. However, when judging the remaining 25 (48%) 'contentious' incidents, the observers exposed to crowd noise had a tendency to be more aggressive towards challenges by the away player and more lenient to challenges by the home player. For these 'contentious' incidents, the observers appeared to demonstrate an inability to adjudicate objectively, referring to the crowd for guidance. This suggests that participant uncertainty, as a result of increasingly contentious incidents produces larger imbalance in favour of the home side, as shown by the highly significant interaction term. Assuming that officials' decisions may be effected in a similar way, as seems to be the case, these results provide the first experimental/empirical evidence of the influence of crowd noise. Given the direction of the imbalance (to favour the home side), these findings provide a valuable contribution to explaining the home advantage phenomenon.

4.2 Are crowds more able to influence 'contentious' decisions?

4.2.1 Introduction

Study 4.2 aims to reproduce the findings of Study 4.1 (Nevill et al., 1999) with a larger number of subjects. A greater number of participants will also allow systematic assessment of whether increasingly complex or contentious incidents enhance the influence of crowd noise. Particularly complex officiating tasks in sport are often accompanied by increased systematic error (e.g. Ansorge & Scheer, 1988; Whissell et al., 1993). A suggestion is that the potential for such bias is at its greatest, when officials judge competitors with a combination of objective and subjective scoring (Ansorge & Scheer, 1988). Errors may well be partly a function of complexity of the task. In artistic sports, such as Women's gymnastics, officials must identify and judge deviations from the standard in over 900 movements (O'Brien, 1991), with progression in athletes' skills not matched by similar progressions from judges (Plessner, 1999). While football referees do not directly judge outcome, they are expected to make a number of subjective decisions in the course of a match, which vary in complexity or contentiousness.

Study 4.2 aims to investigate whether increased complexity or contentiousness may increase the influence of crowd noise in creating home advantage. It is hypothesised that as less contentious challenges are removed, the remaining sets of incidents, being progressively more difficult to judge, are increasingly susceptible to the influence of crowd noise.

4.2.2 Methods

(i) Participants and Procedure

A class of 41 sports science students was asked to assess the legality of 52 incidents from a 1998 Champions' League match. The students were randomly allocated to either a noise, or a no noise group, with the match projected onto a lecture theatre screen. Participants were given four options for each incident, labelled as: no foul (certain), no foul (uncertain), foul (uncertain) and foul (certain). This replaced the simple option of foul or no foul, thus allowing some assessment of certainty on an individual, as well as a group level. Following each incident, a numbered screen was presented, corresponding to each given incident, during which time participants recorded their decisions. For the purpose of analysis, these categories were graded 0, 0.25, 0.75, and 1. Given a larger number of participants, total agreement was never reached for any incident as in Study 4.1. Rather than analysing the full set of challenges, and a subset of contentious challenges, challenges with higher or lower mean scores were systematically removed. This began with challenges whose mean was furthest away from the total mean for all challenges. High or low mean indicated both greater agreement between participants and greater certainty in general, this indicating a less contentious incident. This process is referred to as elimination by mean. Elimination by mean was chosen over elimination by standard deviation, as increasing standard deviation would not only indicate less agreement on an individual level, but also greater certainty on a group level. Elimination of challenges with increasingly divergent means, therefore, yielded an increasingly contentious subset of incidents.

(ii) Analysis

For each of the 52 incidents, 3 columns of mean proportions were calculated; mean of the noise group, mean of the no noise group and total mean calculated from all participants' scores. Differences between mean proportions of fouls awarded for each incident for the two group means (no noise-noise) formed the response variable. This variable had the potential to vary between -1 and +1, with scores tending toward -1 or +1 showing disagreement between groups. Scores closer to 0 therefore, show greater agreement. Home advantage as a result of noise would be indicated by team representation having an influence upon this variable. For an incident initiated by a home player then, if noise were influential, it would be shown by an inflated positive score (noise group penalising the home team less), or for an away player, by a comparatively smaller or negative score (noise group penalising away players more). Data were examined using normalised standard score t-values, for each incident used, from a series of two-sample t-tests upon the differences in mean proportion of fouls awarded between noise and no-noise groups. These standard score t-values gave a measure of noise effect size, whilst accounting for sample size (number of challenges used). Home advantage as a result of noise would be indicated by fluctuations in the response variable in correspondence with team represented by each given incident's initiator. T-values were examined each time an incident was removed, with team representation of the player initiating the challenge as a factor. It is hypothesised that the whole set of 52 incidents shows evidence of increased home advantage in the presence of noise, and that the size of the noise effect is enhanced as less contentious incidents are removed.

4.2.2 Results

Using team representation as a factor, t-values for differences in mean proportions of fouls awarded by noise and no noise group, each time an incident was removed, showed the significance of noise in creating home advantage for n incidents (Figure 4.3).

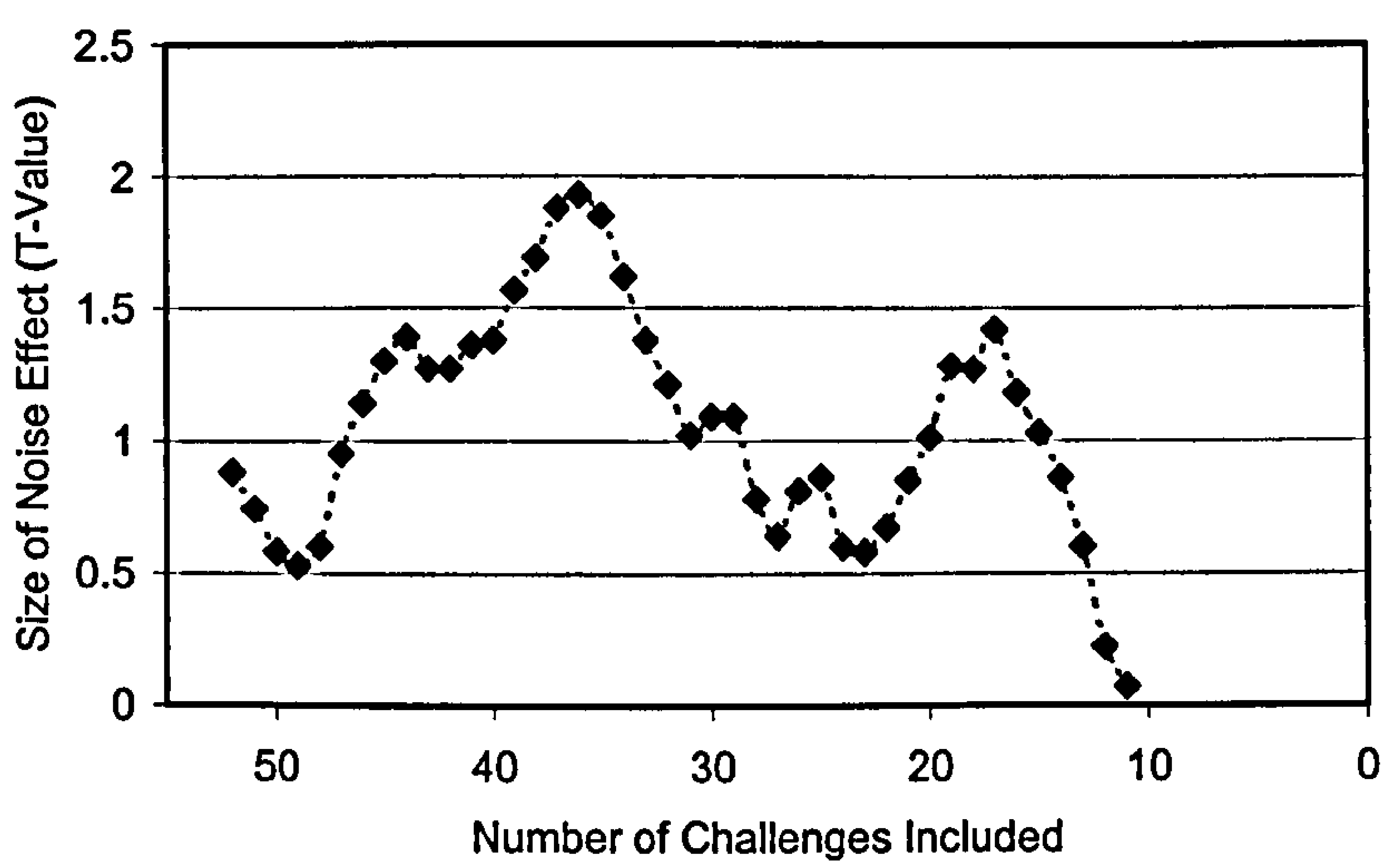

Figure 4.3. Size of imbalance with crowd noise as incidents are eliminated.

Examination of t-values showed the noise group to demonstrate greater home advantage, with the imbalance increasing as less contentious incidents were removed. This discrepancy reached a peak using 36 of the 52 incidents, yielding significantly greater home advantage for noise group participants, $t_{34} = 1.93$, ($P = 0.031$). Following this peak, effect size generally decreased as number of incidents used grew small.

4.2.3 Discussion

The results support the findings of Study 4.1 (Nevill et al., 1999) as presentation with crowd noise resulted in an imbalance of decisions in favour of the home side. Although this effect was not initially as strong as previous research, elimination of non-contentious incidents did identify a significantly greater home advantage with crowd noise. It should also be noted that when significance was reached, 20 of the significant subset of incidents corresponded to the contentious group of 25 used in Study 4.1. These results give some support to the hypothesis that the influence of crowd noise increases in tandem with contentiousness of decision, though this effect was diminished as number of incidents used grew small. In summary, the findings continue to contribute to the explanation of home advantage as crowd noise was again shown to influence officiating in association football. Future research using a similar number of qualified participants (referees) or a more rigorous repeated measures protocol, could more accurately measure both the general crowd effect and the influence of contentiousness of decision.

Chapter 5. Crowd noise and the home advantage in association football

5.1 Introduction

Chapter 5 aims to replicate the findings of preliminary research in Chapter 4, using a sample of 40 qualified football referees. Referees ranging from newly qualified to 43 years of experience also allow consideration of the influence of experience. Fluctuations in the crowd noise effect with experience are examined by entering linear and quadratic 'years of experience' as covariates. This allows examination of whether experience may diminish the crowd noise effect, and attempts to identify optimum years of refereeing experience. Experimental protocol is also improved, as participants are asked to identify the direction of fouls, removing the need to identify each incident's initiator. This also permits assessment of the influence of crowd noise upon each of the response options independently, and whether bias is a result of under penalising the home team, over penalising the away team, or both. In addition to simply identifying the influence of crowd noise, Chapter 5 also aims to present possible mechanisms that could explain the influence of crowd noise upon officiating.

Schwartz and Barsky (1977) found that the home advantage in Major League baseball increased with crowd density. The trend in the home advantage increased from 48% in relatively empty stadia (less than 20% capacity), to 55% when the stadia were between 20% to 40% capacity and to 57% when crowd density was greater than 40% capacity. Similarly, using multiple regression, Agnew and Carron (1994) showed crowd density to be significantly related to the home advantage in major junior-A ice hockey ($R^2 = 0.011$, $P < 0.001$). Depleted home advantage in matches involving English football's 13 London clubs (Clarke & Norman, 1995), and in local derbies in general (Pollard, 1986), provides further support of a possible crowd influence. Local matches generally attract an increased number of away supporters, given the decreased distances involved. Similarly, given their number, the London clubs play a far greater number of derbies, possibly accounting for the discrepancy observed by Clarke and Norman (1995). Such research has led to the suggestion that the crowd is able to either raise the performance of home competitors, or subconsciously influence the officials to favour the home team (Nevill & Holder, 1999).

Support for the latter of these hypotheses comes from studies that report officials consistently making more subjective decisions in favour of the home team (Glamser, 1990; Greer, 1983; Lefebrve & Passer, 1974; Lehman & Reifman, 1987; Sumner & Mobley, 1981; Varca, 1980). Moreover, Nevill et al. (1996) confirmed that not only do officials in English and Scottish association football make more subjective decisions in favour of the home team (penalties and sendings-off), but the observed imbalance appears to increase in divisions with larger crowds. More recently, experimental studies (Balmer et al., 2001a; Nevill et al., 1999; Chapter 4) have also provided support for the latter proposal, as crowd noise has been shown to result in an imbalance of decisions in favour of the home side.

Two sources of systematic error have been identified which would suggest the crowd would have an influence upon officiating (see Wickens & Holland, 2000). Wallsten and Barton (1982) showed that when participants are placed under time constraints they are likely to focus on the most salient sues. These tend to be cues that attract the greatest attention or those that are easier to process regardless of their diagnostic value (Payne, 1980). A suggestion is that when faced with a contentious decision the effects of crowd noise will be particularly salient for referees by guiding or constraining their search towards cues that favour the home team. This is confirmed by research suggesting that information that is difficult to interpret will be under processed or ignored (Bettman, Johnson & Payne, 1990; Johnson, Payne & Bettman, 1988; Stone, Yates, & Parker, 1997). Since crowd noise lacks reliability and is not diagnostic in nature, this would result in systematic error in favour of the home side.

Similarly, research involving the use of heuristics in decision making suggest that crowd noise should be influential. Heuristics are rules of thumb used to reduce complex judgements to more simple ones, though they frequently result in systematic errors (Tversky & Kahneman, 1974). Specifically, the 'as if' heuristic suggests that if cues are not perfectly reliable or diagnostic, such cues will be utilised 'as if' they are of equal importance (Wickens & Holland, 2000). This leads to the extraction of more information than is warranted from an unreliable or uninformative cue (Johnson, Cavanagh, Spooner, & Samert, 1973; Schum, 1975). With regard to a potential bias in decision making, the referee may place equal importance on the auditory information from the crowd as much as that presented visually within the display leading to an imbalance of decisions in favour of the home side.

In the case of the 'as if' heuristic trained nurses (experts) are equally susceptible to errors in processing as novices (Rossi & Madden, 1979), while participants trained in statistical theory are unable to apply this expertise to overcome similar predictive errors (Kahneman & Tvesky, 1973). However, this does not imply that experts would make errors of a similar magnitude to novices. Previous research suggests that experience can help alleviate the potentially negative effects of stress on performance (e.g., see Janelle, Singer, & Williams, 1999; Williams & Elliott, 1999). Experienced referees are likely to have greater control over their emotional states (e.g., see Hardy, Jones, & Gould, 1996) and more enhanced task specific knowledge bases that facilitate skilled decision making in stressful environments (Williams, Davids, & Williams, 1999).

The present study assessed whether qualified referees opinions of tackles/challenges, recorded on videotape, could be influenced by a partisan crowd's reactions. The potential association of refereeing experience as well as the source of any imbalance were also determined (i.e., under-penalising the home team, over-penalising the away team or both). It is proposed that crowd noise results in fewer fouls against home players and more fouls against away players. Moreover, it is hypothesised that increasingly experienced referees are less susceptible to the influence of crowd noise, compared to their less experienced counterparts.

5.2 Methods

(i) Participants

Forty qualified referees from the North Staffordshire Referees Club volunteered to take part in the present study (experience ranged from newly qualified referees to 43 years of refereeing experience). The referees were asked to assess the legality of 47 challenges/incidents recorded during an English Premier League match between Liverpool (home) and Leicester City (away) from the 1998/99 season. Participants gave their informed consent prior to taking part in this study.

(ii) Test Film and Apparatus

The incidents were projected in chronological order, interspersed with sequences of action, onto a 1.24-m × 1.24-m screen (Bell & Howard) using video-projection system (Panasonic PT-L595E) and videocassette recorder (Panasonic NV-HD680). The videotape was edited such that the presentation stopped for six seconds immediately after each incident, but fractionally before the match official's decision could be observed. The videotape comprised of 47 incidents ($\underline{M}$ = 8.93s, $\underline{SD}$ = 2.17 (excluding 6 s pause)), with a further 13 action sequences ($\underline{M}$ = 17.21s, $\underline{SD}$ = 5.08). Noise level was measured using a digital sound level meter (Tenma 72-680), with a 1 kHz test tone yielding 75 dB (absolute) at 1 m.

(iii) Procedure

The referees were randomly allocated to a noise group featuring crowd noise but no commentary, or a silent condition group. Twenty-two of the referees observed the video with the crowd noise audible (the noise condition group), whilst 18 referees viewed the video in silence. Preceding presentation, participants were informed as to the identity and strip colour of the home and away teams. Throughout the six-second pause, the corresponding incident number appeared on the screen during which time participants were invited to record their adjudications on a response sheet. Unfortunately, due to time constraints, three of the referees from the silent group were unable to complete the exercise. Participants were asked to give their opinion on whether the 47 challenges were either legal (no foul) or illegal (a foul). If the challenge was deemed illegal, the referees were asked to indicate whether it was a home (home foul) or an away player (away foul) who had committed the foul. A fourth 'uncertain' option was also available on the response sheet, although it was recognised that in a 'live' game situation, if uncertain, the referee would have chosen the 'no foul' option. Consequently, in response to each challenge, the referees were asked to choose one of four possible options, either 1) home foul, 2) away foul, 3) no foul or 4) uncertain.

(iv) Analysis

If the referees' responses had been continuous, unbounded and measured on the interval or ratio scale, then analysis of variance (ANOVA) could have been used to assess the effect of crowd noise on referees' decisions. However, since the response variable was categorical (home foul vs. away foul vs. no foul vs. uncertain), the assumptions necessary to conduct hypothesis tests using ANOVA are likely to be violated. For example, it is unreasonable to assume the residual errors from an ANOVA analysis of categorical data are independent and normally distributed. A more appropriate multivariate technique to analyse categorical data is logistic regression. The analysis will estimate the probabilities (or more correctly the odds) associated with the four categorical options and how these probabilities will vary due to differences in the predictor/independent variables (see Kleinbaun, 1994). Note that in order to describe the strength of an effect (equivalent to an effect size in traditional ANOVA), logistic regression calculates the odds ratio, i.e. the ratio of the odds of, for example, penalising the home players under silent condition, compared with (divided by) the odds of penalising the home player under the noise condition.

As described above, when viewing the 47 challenges, referees were asked to choose one of four possible options, either 1) home foul, 2) away foul, 3) no foul or 4) uncertain. Hence, for each of the 40 referees, the 47 decisions were collapsed into one of these four options. For example, referee number 1 chose 12 'home fouls', 6 'away fouls', '14 'no fouls' and 15 'uncertain' (note that the sum of the responses to the 4 options will always total 47). Binary logistic regression was used to assess the effect of the independent variables, crowd noise and years of experience, on each outcome variable/option separately. For example when analysing the 'home foul' option, binary logistic regression estimates the probability of awarding a home foul (p) versus not awarding a home foul (1-p) and how this probability will vary due to the differences in, or the effects of, the independent variables. For the purpose of the present analysis, 'years of experience' was entered as a continuous variable with both linear and quadratic terms. This would enable the analysis to identify non-linear trends in the referees' responses with years of experience. The statistical software Generalised Linear Interactive Modelling (GLIM; Atkin *et al.* 1989) was used to analyse the binomial response variables. The method of model simplification adopted was '*backward elimination*' (for a discussion of this and other methods see Draper and Smith 1981, Chapter 6) in which at each step the least important variable was dropped from the current model. Importance was assessed by the 'change in deviance' (χ^2) that resulted from dropping the variable in question from the current model. All error bars on figures denote standard errors of means.

5.3 Results

Figure 5.1 illustrates the mean number of challenges for each option awarded by the noise and silent condition groups. In comparison with the noise group, the silent condition participants were more certain with their decisions (fewer uncertain responses), awarded a greater number of fouls against home players, and chose more 'no foul' options.

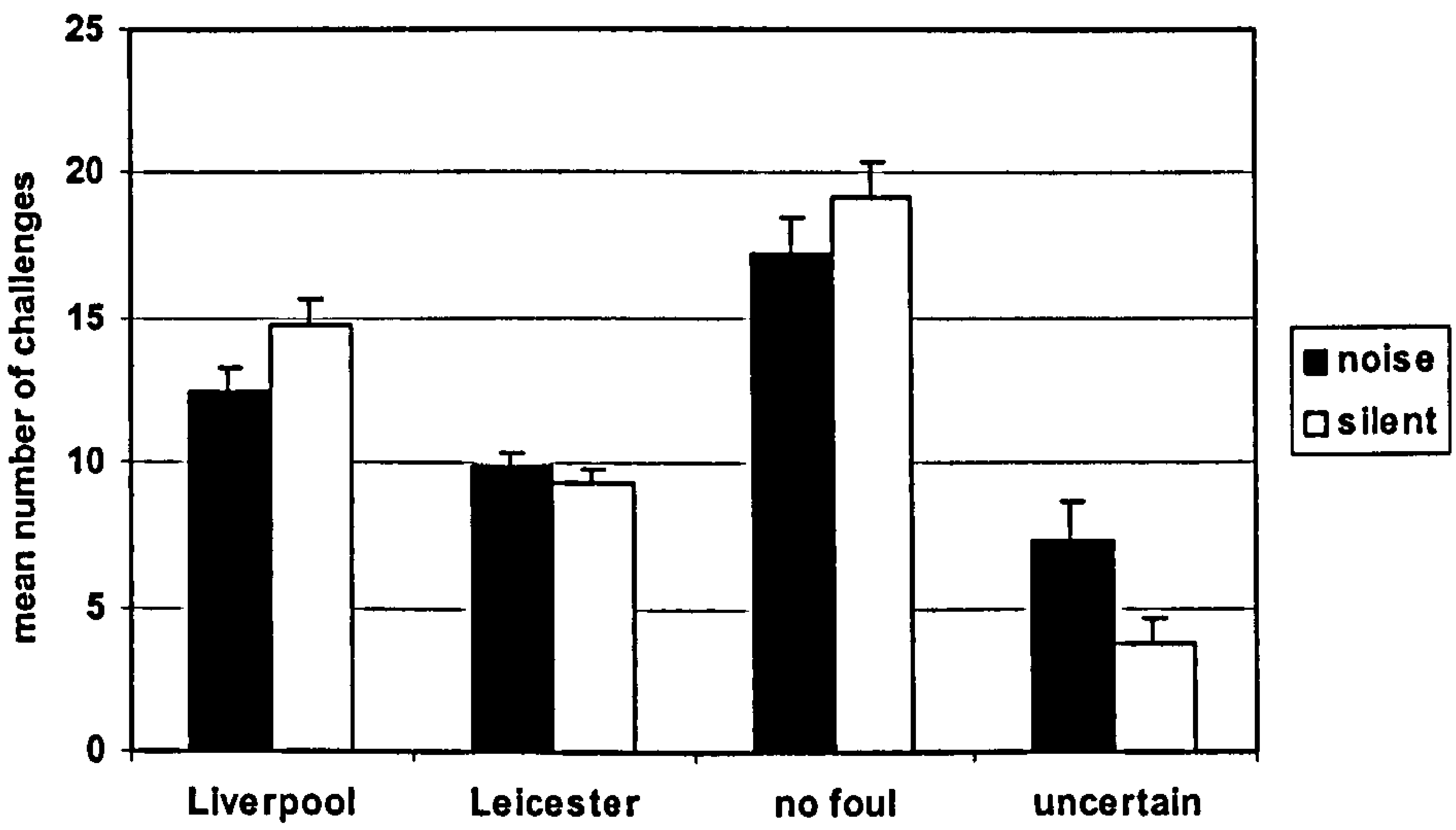

Figure 5.1. Mean number of challenges for each of the four response options awarded by the noise and silent condition groups.

To compare the responses of the referees with those of the match referee, the 'no foul' and 'uncertain' options were collapsed into a single 'no foul' option. The mean number of challenges for the three remaining options ('home foul', 'away foul', and 'no foul') awarded by the two groups of referees and the match referee are illustrated in Figure 5.2. Interestingly, the responses made by the referees in the noise condition group agree very closely with those of the match referee.

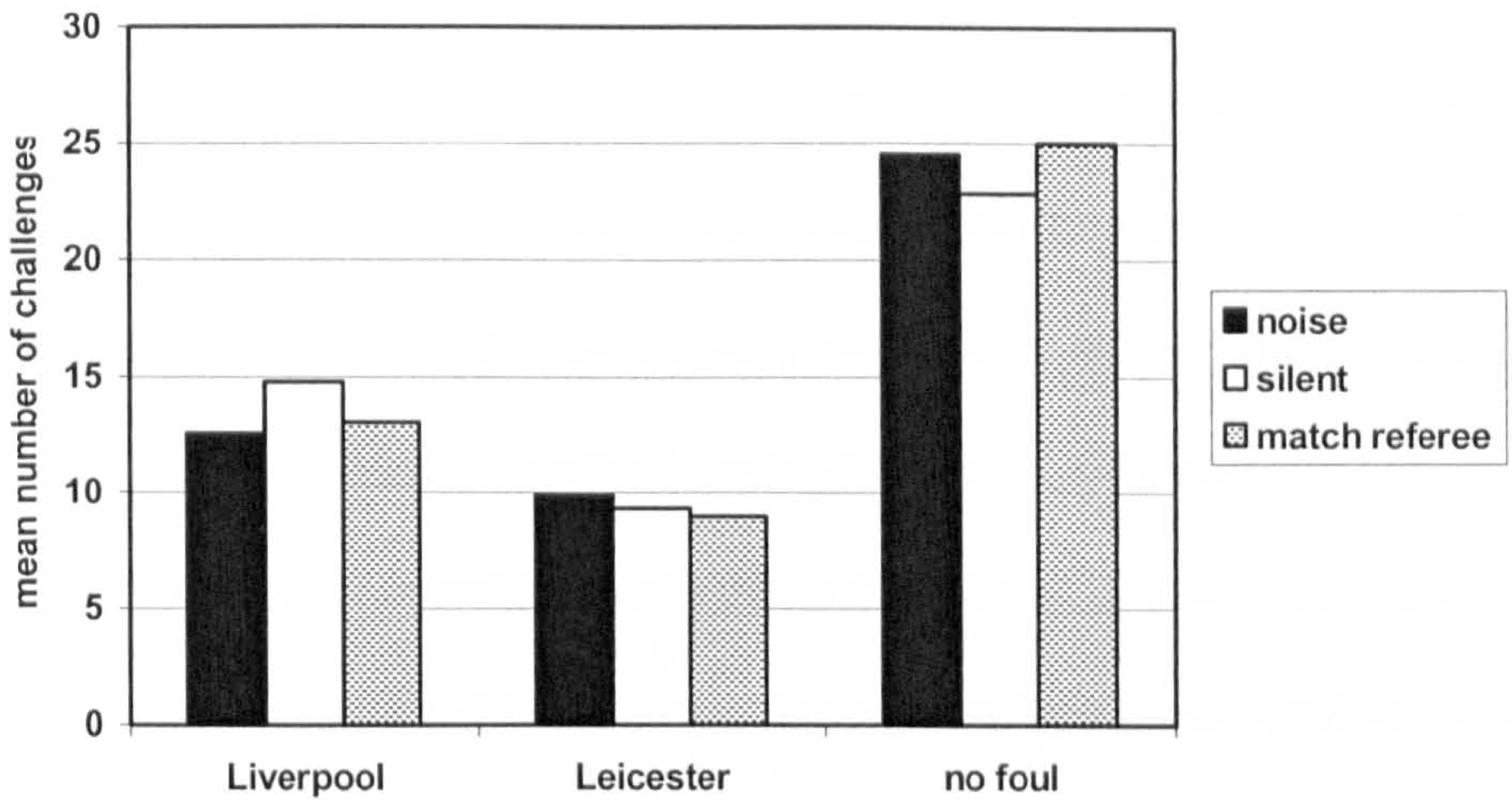

Figure 5.2. Mean number of challenges for the remaining three response options awarded by the noise condition group, silent condition group and match referee, (no foul and uncertain options collapsed into a single no foul option).

Differences were investigated separately for each option (home foul, away foul, no foul and uncertain) separately using binary logistic regression.

5.3.1 Binary logistic regression analyses

For home fouls, binary logistic regression analysis identified a significant effect due to 'crowd noise'. Removing the noise group factor from the final model resulted in a significantly large change in scaled deviance, $\chi^2_1 = 3.875$, $P < 0.05$. The group of referees watching the video with the crowd noise audible awarded significantly less fouls (15.5%) against the home players (M = 12.5) compared with referees in the silent group (M = 14.8) (see Figure 5.1).

Binary regression also identified a significant non-linear effect of 'years of experience' on the number of home fouls awarded by the referees. Again backward elimination of both linear, $\chi^2_1 = 4.443$, $P < 0.05$, and quadratic, $\chi^2_1 = 6.059$, $P < 0.05$, years of experience resulted in large changes in deviance. The positive linear (0.031) and negative quadratic term (-0.00096) identified in the analysis (both $P < 0.01$), suggests that the number of home fouls increased with years of experience until a peak at 16 years of refereeing experience (using elementary differential calculus), thereafter a decline in home fouls was observed. Importantly, introduction of experience by noise group interaction terms yielded insignificant changes in deviance, suggesting that the influence of crowd noise on home fouls is not dependent upon refereeing experience.

When the away fouls were analysed, the linear and quadratic 'years of experience' and factor 'crowd noise' had no significant effect on the referees' decisions. Removing the 'crowd noise' factor resulted in small change in deviance, $\chi^2_1 = 0.265$, $P > 0.05$.

For the 'no foul' option, removal of 'crowd noise' resulted in a significant change in scaled deviance, $\chi^2_1 = 3.652$, $P < 0.05$, with the noise condition group of referees awarding an average of 17.2 'no fouls' compared with 19.2 'no fouls' awarded by the silent condition group. There was also a significant 'years of experience' effect (linear term only), $\chi^2_1 = 6.578$, $P < 0.05$. The linear trend of years of experience reflected a significant reduction in 'no fouls' by the most experienced referees. As with the 'home foul' option, introduction of experience by noise group interaction terms had little influence.

Analysis of the 'uncertain' option was similar to for the 'no foul' decisions. Again, removal of 'crowd noise' resulted in highly significant changes in deviance $\chi^2_1 = 25.97$, $P < 0.01$, as did 'years of experience' (linear term only), $\chi^2_1 = 13.13$, $P < 0.01$. The positive linear regression term of 'years of experience' suggests that the most experienced referees were more 'uncertain' when making their decisions. However, most importantly, there was an increase in the number of uncertain decisions by referees in the noise (M = 7.4) compared with the silent (M = 3.7) condition group (see Figure 5.1). As with both 'home foul' and 'no foul' analyses, introduction of experience by noise group interactions led to insignificant changes in deviance.

5.4 Discussion

The present study had two objectives. First, the study examined whether the decisions made by qualified association football referees' could be influenced by the noise of a partisan crowd. Second, an attempt was made to determine the covariation of refereeing experience with any imbalance of decisions. It was hypothesised that crowd noise would result in greater leniency toward the home, and greater severity toward the away team. Increasing experience was expected to diminish this imbalance.

The presence or absence of crowd noise did have a dramatic effect on the decisions made by the qualified referees. The bias observed was in agreement with the hypothesis that the crowd is able to influence officiating (Nevill & Holder, 1999; Nevill et al., 1999 (see Chapter 4)). Those referees viewing challenges in the noise condition were more uncertain when making their decisions, and awarded significantly fewer fouls (15.5%) against the home team (M = 12.5) than the silent group (M = 14.8). Although in absolute terms, 2.3 fewer home fouls (noise group) out of a total 14.8 (silent group) does not appear to be large, in percentage terms (15.5%), it reflects approximately the same percentage difference/advantage reported for home wins in football (i.e., 63.9% including draws or 68.3% excluding draws). Although the noise group did penalize the away team more often (M = 9.9 fouls) than the silent group (M = 9.3 fouls), this difference was marginal and not significant.

Interestingly, the present study indicated that the dominant effect of crowd noise was to significantly reduce the number of fouls awarded against the home team, rather than increase the number of fouls against the away team. This finding seems reasonable given previous research in basketball which showed that fewer fouls were given against 'star' players at home, though this was not the case with 'non-stars' (Lehman & Reifman, 1987). The present findings, therefore, could be partially a result of such a star player effect. The noise group's decisions also mirrored very closely those of the match referee (see Figure 5.2), providing strong 'external validity' for the experiment. Presumably, the partisan crowd was able to influence the referees in the noise condition group in a similar way to the match referee.

Years of experience had a significant effect on the number of fouls awarded by the referees against the home players. The number of fouls against the home players increased with years of experience until a peak at approximately 16 years, thereafter a decline was observed. The other major effect of 'refereeing experience' was to significantly increase the number of uncertain decisions by the most experienced/older referees. Despite these differences, the lack of an interaction between 'refereeing experience' and 'crowd noise' suggests that these observed changes with refereeing experience were consistent between noise conditions. Evidently, here as in previous research (e.g., Craven, 1998; Larsen & Rainey, 1991; Oudejans et al., 2000; Rainey et al., 1989; Rainey, Larsen, & Willard, 1987; Sanabria et al., 1998), officiating errors are inevitable. Such errors were confirmed in the present study by the substantial disagreement and variation in the referees' decisions. Indeed, none of the 47 challenges resulted in a unanimous decision by all 40 qualified referees. Clearly, with such evidence of conflicting opinions amongst qualified referees, some of the referees must be making mistakes/errors on a regular basis. More concerning, however, is the systematic error observed with crowd noise, particularly if governing bodies such as FIFA (Fédération Internationale de Football Association) consider employing video replay to aid on-pitch officials. Is more than one official necessary to help adjudicate such contentious replays, and most importantly, should the officials judge from a soundproof booth, avoiding the influence of crowd noise?

A number of articles have provided anecdotal evidence to suggest that referees decisions can be influenced by the crowds' reactions to favour the home team. For example, Askins (1978) stated that "during the course of any contest there are many incidents which appear ambiguous, even to the most veteran officials. When this occurs, officials do basically what all humans do in such a situation, they seek clarification through any means available at the time. Crowd reaction may sometimes provide the cue which prompts the decision" (p. 18).

The imbalance observed between noise conditions for the home fouls is consistent with that predicted by both cue salience and use of heuristics. It would appear that in the noise condition referees rely on the salient yet potentially biased judgement of the crowd (e.g., see Wallsten & Barton, 1982). Alternatively, they may apply an 'as if' heuristic, with the information from the crowd assuming equal or greater weight than that presented visually (e.g., see Rossi & Madden, 1979). The systematic error observed with crowd noise may be a reflection of the inevitable error resulting from the use of such heuristics to integrate information (Tversky & Kahneman, 1974).

Additionally, the findings seem entirely plausible based on work investigating officials' coping strategies in response to stressful events (Anshel & Weinberg, 1999; Kaissidis-Rodafinos, Anshel, & Porter, 1997). Research has identified that 'making a bad call' is the single most important stressor amongst officials in volleyball (Stewart & Ellery, 1998), a finding that was echoed in both basketball (Kaissidis & Anshel, 1993), and association football (Taylor, 1990). Given that 'making a bad call' and 'crowd noise' will raise levels of stress in the 'noise group' referees in a similar way to that of the match referee (sources of stress felt to be difficult to control), the coping strategy is likely to be one of avoidance. As the crowd are likely to make it clear if they feel a decision was 'wrong', avoidance could be interpreted as simply not making the unpopular decision to penalise the home team when assessing less clear or contentious challenges. Whenever a home player commits a foul, the crowd's reaction is capable of activating the potent stressor of 'making a bad call', thus increasing the level of uncertainty or indecision among referees, resulting in no decision (avoidance) and fewer fouls against the home team.

The results from the present study suggest how crowd noise may effect referees' decisions. Rather than penalising the away players more, the dominant effect of crowd noise would appear to influence qualified referees to penalise the home players less. It seems plausible that this imbalance may be a result of over processing salient though undiagnostic crowd noise. This attention to the partisan home crowd results in systematic error in favour of the home team. Additionally, the noise condition participants may be adopting the coping strategy of 'avoidance' in an attempt to reduce the stress of 'making a bad call'. In this case, avoidance by the referee could be interpreted as simply not making the unpopular decision to penalise the home player, thus creating the observed bias in favour of the home team.

Chapter 6. Home advantage in the Summer Olympics (1896-1996)

6.1 Introduction

Chapter 6 aims to compare the home advantage observed in team games to both subjectively and objectively judged individual events. By isolating officiating style, and controlling for confounding factors, Chapter 6 will put the influence of crowd noise (Chapters 4 and 5) in context. By controlling for factors such as 'athlete participation' and 'team quality' an estimate of the influence of crowd noise upon officiating will be made in terms of absolute home advantage. As with Chapter 3, events will be split into groups, this time based on officiating style. If the crowd noise effect observed in the present study is particularly influential in terms of raw home advantage, team games should exhibit significantly greater home advantage than objectively judged events.

Although the existence of home advantage in major team sports has been well established (for a review, see Chapter 2), its prevalence in both individual sport and unbalanced competition is less clear. For individual sports contested at the Olympics, some evidence of home advantage has been identified in cross-country running (McCutcheon, 1984), high school wrestling (Gayton & Langevin, 1992) and world cup alpine skiing (Bray & Carron, 1993). In contrast, once quality of athlete had been accounted for, home advantage was not found to be a major influence on performance in individual 'grand slam' tennis and 'major' golf tournaments (Nevill et al., 1997). Holder and Nevill (1997) confirm these findings, suggesting that any apparent home advantage is mainly an artefact of selection procedures that favour increased entry of lower ranked home competitors. The authors suggested that lack of home advantage could be due to both objective scoring systems and relatively little subjective input from officials.

When officials do have greater subjective input (i.e. team sports), home advantage is consistently observed. Examples include professional baseball (Adams & Kupper, 1994) and football (Nevill at al., 1996; Pollard, 1986), junior ice hockey (Agnew & Carron, 1994) and college basketball (Moore & Brylinsky, 1995). In contrast to the individual sports with little officiating input, referees in the majority of team sports are expected to make numerous subjective decisions. For major league baseball, Schwartz and Barsky (1977) identified increasing home advantage with crowd density, while also attempting to control for team quality. Consequently, Nevill et al. (1996) demonstrated frequency of penalties and sendings-off to favour the home side, this discrepancy increasing with crowd size. The authors concluded that the crowd might either influence away players to play more recklessly or affect the match officials' decisions in favour of the home side. There is now growing experimental support for the latter hypothesis, with Nevill et al., (1999) (Chapter 4a) and Balmer et al., (2001a) (Chapter 4b) both showing the presence of crowd noise to result in an imbalance of refereeing decisions in favour of the home side.

As demonstrated for winter Olympic competition (Balmer et al., 2001b), home advantage is significantly larger for disciplines where officials directly judge outcome. There is extensive evidence of officiating bias in such events (e.g. gymnastics, figure skating, diving) though the majority of this examines specific nationalistic or political bias, rather than a more general home advantage. Nationalistic and/or political biases have been demonstrated for a range of subjectively judged events including Olympic diving (Park & Werthner, 1977), figure skating (Seltzer & Glass, 1991) and gymnastics (Ansorge & Scheer, 1988; Whissell at al., 1993). More detailed discussion of this type of bias and possible underlying mechanisms can be found in Chapter 2 (see section 2.7.1)

With nationalistic and political bias having been identified, a number of measures have been taken to reduce their impact. Techniques such as trimming of high and low scores, and use of median marks (e.g. International Skating Union, 2000) or the 'generalised efficient skatingrule' (Frederiksen & Machol, 1988) however, do not address, and may even enhance general home advantage. While they control for outliers or specific paradoxes, they do not address more consistent systematic error that could lead to home advantage. For winter Olympic competition, events relying on subjective assessment by judges (figure skating and freestyle skiing) have been shown to demonstrate significantly higher home advantage than other events (Balmer et al., 2001b) (see Chapter 3), suggesting that officials may be inclined to score home competitors disproportionately highly. The complexity of the task may partially explain this imbalance. Research examining the home advantage in football has suggested that the crowd's influence upon officiating is more potent (in creating an imbalance of decisions in favour of the home side), for increasingly complex or contentious decisions (e.g. see Balmer et al., 2001a; Chapter 4b). Judging artistic events such as gymnastics is perhaps one of the most complex forms of officiating. Women's gymnastics judging, for example, requires the ability to identify a huge range of movements (over 900) and their qualities/attributes in routines of up to 90 seconds (O'Brien, 1991). Additionally, rapid development of competitors has not matched considerations regarding the capacity of judged to assess routines (Plessner, 1999). This increased task complexity may then be accompanied by a more potent crowd influence upon officials, and therefore increased home advantage.

In addition to officiating and crowd considerations, a number of other factors are thought to influence degree of home advantage (see Chapter 2, section 2.2). Travel has been proposed as a possible influence, though evidence has been conflicting. For basketball, Snyder and Purdy (1985) found a significantly greater home advantage when away teams travelled further than 200 miles. In contrast, for football, Pollard (1986) found no discrepancy, using a larger sample of games and the same 200-mile cut-off. How soon before competition athletes arrive may also be an important moderator in any travel effect. Studies reporting impaired performance with time-zones traversed generally consider athletes who do not arrive in good time (e.g. Jehue et al., 1993; Waterhouse et al., 1997). For winter Olympic competition, the fact that athletes generally arrive well in advance of competition may account for the lack of variance in the home advantage explained by time zones traversed (R^2 = 0.4%) (see Balmer et al., 2001b; Chapter 3). Presumably, summer Olympic athletes also arrive in good time, negating any jet-lag effect. For these reasons, consideration of time zones traversed is excluded from the present study. Familiarity with local conditions is again, a well researched, though a principally unproven source of home advantage (Dowie, 1982; Pollard, 1986; Schwartz & Barsky, 1977). These studies, however, covered sports with little potential for variation in conditions (ice-hockey, basketball, baseball and association football) and when larger variations have been permitted, there has been some evidence of increased home advantage. A notable example is the increased home advantage enjoyed by teams with artificial playing surfaces in association football (Barnett & Hilditch, 1993). For the present analysis, event groups were chosen to negate the influence of familiarity with local conditions, and isolate the 'officiating style' factor. Although environmental conditions will vary between Olympics, the events chosen have consistent equipment dimensions, pitch/ring/track sizes and race lengths, reducing familiarity as a confounding factor.

Clearly for Olympic competition, as for tennis and golf tournaments (Nevill et al., 1997), team/competitor quality is also a major consideration, given the highly variable medal winning potential of host nations. In summer Olympic competition, for example, The United States has won nearly fifty times more medals than Mexico, though both have been host nations. Assessing home advantage must, therefore, involve only comparison of home and away performance by nation/team. Previous research has highlighted team quality as a likely influence, with 'superior' teams tending to exhibit greater home advantage (Schwartz & Barsky, 1977), though some authors have made reservations regarding the classification of quality (Madrigal & James, 1999). While the above examples concerned team games where an assessment of the quality of home and away teams can be made, Olympic competition typically involves many simultaneous competitors with a diverse range of ability, creating some difficulty in formally assessing quality. Madrigal and James (1999) proposed that a proportion of the team quality effect may be due to superior teams enjoying larger/denser and more supportive audiences, though this is not the case for summer Olympics, as success is not related to large home crowds. The date of the Olympic is more significant, as number of spectators simply increase over time. For Olympic competition stronger nations dominance in a given event would severely reduce weaker host nations opportunity for home advantage. Similarly, stronger nations, with more athletes capable of winning medals, should be able to produce more consistent home advantage. Evidently then, team quality must be considered to correctly measure home advantage.

In addition to the consideration of team quality, Olympic competition requires attention to a number of additional factors, many of which are not a consideration in single event or balanced studies. Many of these factors have been considered for winter Olympic competition (Balmer et al., 2001b) (Chapter 3), though the present study aims to avoid a similar reduction in the size of the data set. The following factors must be considered to accurately measure home advantage:

1. Variable constraints on maximum possible performance/medals on offer;
2. Discrepancy between the numbers of athletes entered home and away;
3. Changes in competition/athlete numbers over time;
4. Team/nation quality.

These, and further, factors are fully discussed in the methods section in establishing a fair measure of home advantage. Having obtained a measure of home advantage, the present study aims to compare home advantage between groups of events with varying styles of officiating. This will put the consistent home advantage of team games in context alongside both objectively and subjectively judged individual competition. It is hypothesised that significant home advantage is observed in both subjectively judged events (i.e. gymnastics, boxing) and when officials must make a number of subjective decisions (i.e. team games). In contrast, it is hypothesised that events with predominantly objective scoring and little input from officials have no home advantage.

6.2 Methods

6.2.1 Establishing unbiased home advantage

(i) Points and maximum points

Performance was measured using a simple points system, with three for a gold medal, two for silver and one for bronze. A fair estimation of performance requires not only points scored, but also consideration of the number of points available. Therefore, points were considered as a binomial proportion of maximum points available, this maximum varying with event. For the majority of cases in team games/events (e.g. Football, Hockey, 4x100m etc.) the maximum is three (i.e. a single gold) as only one team may be entered. Elsewhere, the maximum is typically six as three or more competitors of the same nationality could win gold, silver and bronze (6 points) in a given event and Olympic. There were also a few anomalous maximum values, notably for boxing where from the 1952 Helsinki Olympics onwards, no third place bouts were boxed, resulting in two bronze medals and a maximum of seven points.

Both points and maximum points values were combined for each event group (defined in *(iii) selection of events*). The result is a sum of points for all events in which each given hosting nation has been successful (on any single occasion), for each Olympic relevant to the set of events. Event groups and number of constituent events/weight categories are presented in Table 1. An observation is a single binomial proportion for a given country, in a given event group and Olympic. The total observations are all proportions (which may be 0/n) for all nations, in each event group, and at each contested Olympic for that event group. A nation is removed if it has never contested the events, or has never won a point (home or away) in a given event group.

All data were obtained from an unpublished series (Lyberg, 1999a, 1999b, 1999c, 1999d, 1999e, 1999f, 1999g, 1999h, 1999i) obtained from the Olympic museum, Lausanne.

Table 6.1. Event groups included in the analysis and number of constituent events.

Event Group	Number of Constituent Events/ Weight Divisions	Dates Competed	Observations in Analysis		No. of Olympics
			Pre War	Post War	
Track and Field	25	1896-1996	71	144	23
Gymnastics	8	1896-1996	32	86	23
Weight lifting	10	1896, 1904, 1920-1996	25	115	20
Boxing	12	1904-1908, 1920-1996	29	142	20
Team Games	5	1900-1996	44	103	22
Total			**201**	**590**	

(ii) Inclusions and Exclusions

Given the large quantity of summer Olympic data, a subset of event groups were chosen, made up of track and field athletics, gymnastics, team games, boxing and weight lifting. The rational for the choice of events is presented in **(iii) selection of events.**

Assessment of home advantage requires nations who have hosted an Olympic (hosting nations) with intra-nation comparison (home vs. away by nation) being central to a fair assessment. Including a large quantity of weaker non-hosting nations as away data would simply lead to unrealistically large home advantage (see Chapter 2, section 2.3.1). To ensure the maximum number of hosting nations, therefore, only male data were used, as women typically did not compete until 1928, and in many cases much later (prohibiting a thorough pre second world war analysis). Having no data before

1928 alone excludes all data for Greece, France, Belgium and Holland, while women's' hockey (began in 1980) or basketball (began in 1976) for instance, represent an unacceptable loss of data.

If a given hosting nation has neither won home nor away in an event, at all Olympics, they are excluded. This results in a differing number of hosting nations between events, both as a result of which Olympics each event was held at, and hosting nation performance. A single medal won, home or away, qualifies a hosting nation for inclusion in the analysis, classifying them as a successful hosting nation for a given event or group of events.

(iii) Selection of Events

Event groups were chosen firstly on the basis of longevity (i.e. how many Olympics they have been contested), and secondly, and most importantly, to allow contrasts between officiating style. From very little or no input in weight lifting or athletics, to the large number of subjective decisions required in team games, to deciding the majority of outcomes in boxing and all outcomes in the artistic disciplines of gymnastics. The following groupings were employed.

1. Track and field athletics have been included as they form the focal point of modern Olympic games, as well as a comprehensive and continuous source of data. Athletics as a whole contributes 12 of the 16 individual events contested at all Olympics, and one of the five event groups (Greenberg, 2000). Most importantly though, events have objectively measurable outcomes, and little subjective input from officials. As a result of this, track and field athletics should have little or no home advantage.

2. Weightlifting again is an almost entirely objective discipline. Outcome has generally been decided by an aggregate measure of weight lifted in two or three disciplines, which have changed on a number of occasions over time (notably through the abolition of single handed lifts from 1928 onwards). Although judges adjudicate on the success of each lift, it is assumed that their input will be minimal, with most decisions clear-cut. Moreover, any ambiguity was further reduced when the 'press' component was removed in 1976 owing to judging difficulty (Greenberg, 2000). Given its predominantly objective officiating, weightlifting should again have little or no home advantage.

3. For Gymnastics, judging represents the outcome with judges consequently having a large subjective input. Ansorge and Scheer (1988) claimed that the "effects of biased officiating are potentially most dramatic in sports in which the officials actually score the points through judging the performance of athletes with some combination of objective and subjective criteria" (p. 103). Gymnastics provides an example of such an artistic event and should exhibit highly significant home advantage.

4. Historically, boxing has generated the most controversy of any Olympic sport, including attacks on officials, sit down protests and full-scale riots. Much of this controversy has focused upon the five ringside judges and referee. Indeed, recent measures (Barcelona 1992 onwards) have included banning officials from cocktail parties and daily alcohol tests, to ensure they are 'out of reach' of influence from national associations and their officials (Wallechinsky, 2000). Despite such concerns, little research has addressed possible inflated home advantage in boxing. Although a small proportion are decided by knockout, the majority of Olympic bouts rely on the subjective assessment of judges (85.95% of Olympic bouts (Lyberg, 1999j)). Given this subjective judging, boxing should display highly significant home advantage.

5. Team games, have an objective scoring system (e.g. goals, baskets etc.), though officials have substantial subjective input during matches. Home advantage for major team games is well proven (Nevill & Holder, 1999), though it has not been put into context alongside other major individual sports. Given the proven influence of crowd noise upon officiating (Balmer et al., 2001a; Nevill et al., 1999), team games should demonstrate significant home advantage, though perhaps not as large as artistic event groups where judges directly decide outcome.

6.2.2 Variables

6.2.2.1 Response variable

The response or dependent variable was taken as the proportion of points won by each nation as a ratio of the maximum number of points available to all competing nations, as described in 6.3.1 (i).

6.2.2.2 Explanatory variables

(i) Home vs. away

A binary home vs. away indicator variable was entered to allow assessment of the difference between home and away performance.

(ii) Proportion of athletes/teams competing

Number of athletes (or teams) for each nation, entered as a proportion of the total athletes/teams, was included as a possible covariate likely in influence the proportion of points won. The majority of pre-second world war Olympics had few limits on maximum number of competitors, leading to inflated home team sizes, or even additional teams in some early team games. At the 1904 St. Louis Olympics, for example, the host nation entered two of a total of three competing teams (Wallechinsky, 2000). Even after the instigation of maxima, however, many nations used the opportunity of a home Olympic to reach the maximum level when otherwise further competitors at considerable cost would not have been worthwhile. Evidently further competitors at home would enhance the given host nations ability to win medals (however slightly). In order to reach an unbiased home advantage, an athlete (athlete/team) covariate is included in analysis.

This covariate involved dividing number of athletes/teams by the total number for all nations, obtaining the proportion of competitors entered by each 'hosting nation', in each event/event group, at each Olympic. Using this value rather than raw number of athletes/teams accounts for changing (generally growing) athlete/team participation over time. This covariate will be referred to simply as 'athletes' in analysis.

(iii) Winning Nation

Evidently, stronger host nations win more points, and may enjoy greater home advantage, (e.g. Madrigal & James, 1999; Schwartz & Barsky, 1977). Consideration of winning (target) nation as a factor allows differences in nation quality to be evaluated and accounted for.

(iv) Pre-war post-war differences

Differences over time exist both in number of competitors entered (particularly home competitors) and number of nations entering. Generally after 1936, restrictions were placed upon number of competitors entering, preventing vast numbers of home competitors. Increased number of away nations has also increased competition and may further reduce home advantage. Separate analyses were conducted pre and post war to allow for differences in the athlete covariate. The full rationale for this split is explained in ***6.2.3 Analysis.***

(v) Event group/officiating style

Consideration of the above variables allows both accurate measurement of home advantage in each event group and comparison between groups with differing officiating style. It is hypothesised that once confounding variables are controlled, no significant home advantage is observed in weightlifting and athletics, where outcome is objectively quantified and officials have comparatively little input (Nevill et al., 1997). In contrast, the suggestion is that a highly significant home advantage is present in boxing and gymnastics, where judges generally or entirely decide outcome. Team games are hypothesised to show an intermediate, significant level of home advantage, as although outcome is measured by goals or baskets, officials are expected to make a large number of subjective decisions.

6.2.3 Analysis

The proportion of medals won by each nation was analysed using two separate methods. Firstly, traditional analysis of covariance (ANCOVA) was used, with measurements relating to the proportion of competitors entered as a covariate. The general linear model used assumes normality. However, response variables consisting of binomial proportions typically result in departures from normality due a large amount of particularly large or small proportions (Zar, 1999). An arcsine transformation (Winer, 1972) was used in an attempt to stabilise variances and produce a more acceptably normal distribution. The transformation, however, failed to significantly improve deviations from normality either pre war, $A^2 = 2.13$, $P < 0.0005$ (proportions) vs. $A^2 = 9.81$, $P < 0.0005$ (transformed), or post war, $A^2 = 11.81$, $P < 0.0005$ (proportions) vs. $A^2 = 32.81$, $P < 0.0005$ (transformed). The transformations failure to correct heteroscedacity is highlighted by plotting means against standard deviations for each event group home and away (see Figure 6.1).

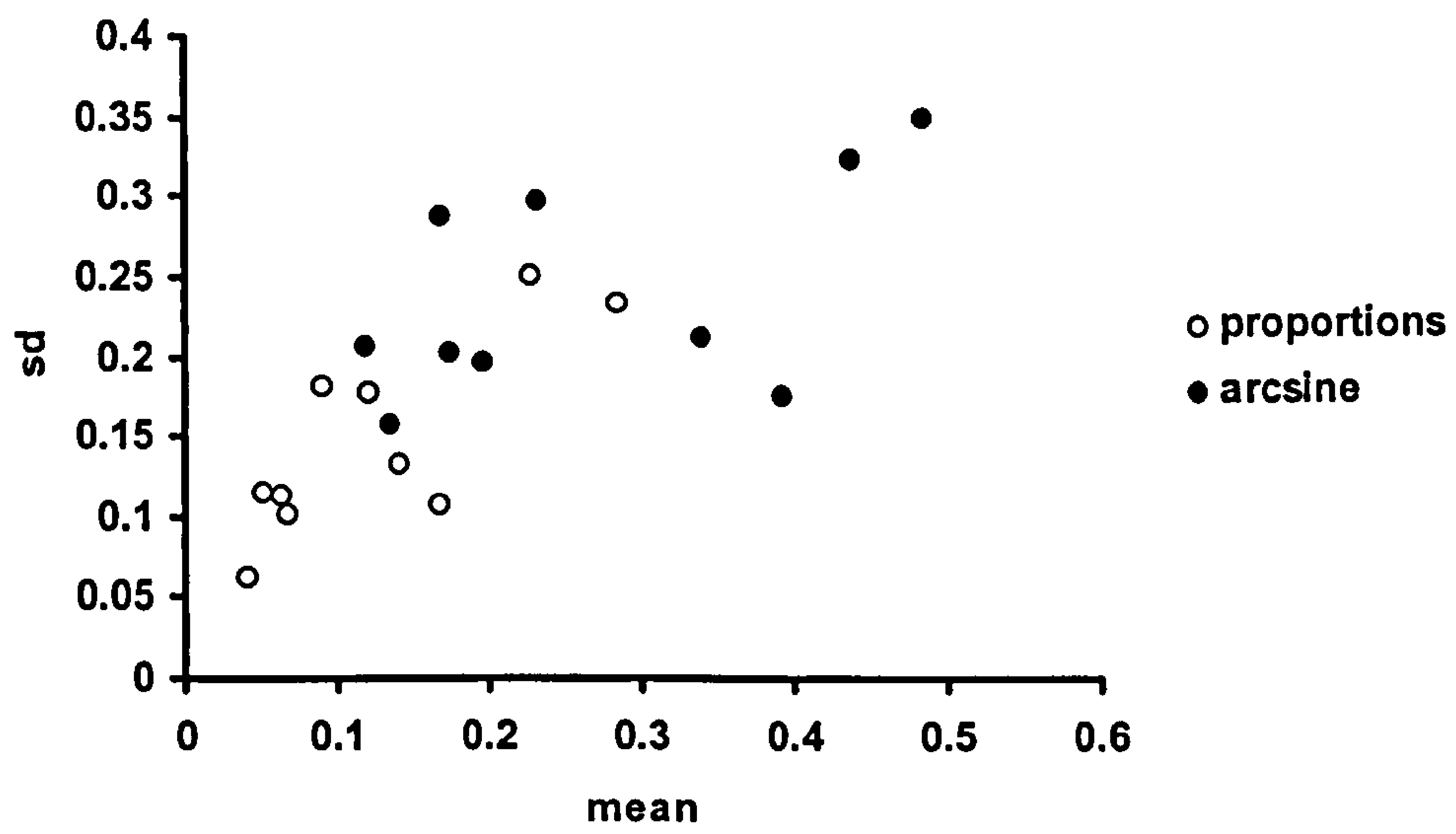

Figure 6.1. Mean proportion of points won plotted against standard deviation, before and after arcsine transformation, for each events group, home and way (20 observations). Demonstrates the arcsine transformations failure to correct unequal variances between groups.

Preliminary exploration of the data also highlighted the need to split the analysis pre and post war. This was mainly a result of post war competitor restrictions leading to a far less influential 'proportion of competitors' covariate, with a markedly different slope (see Figure 6.2).

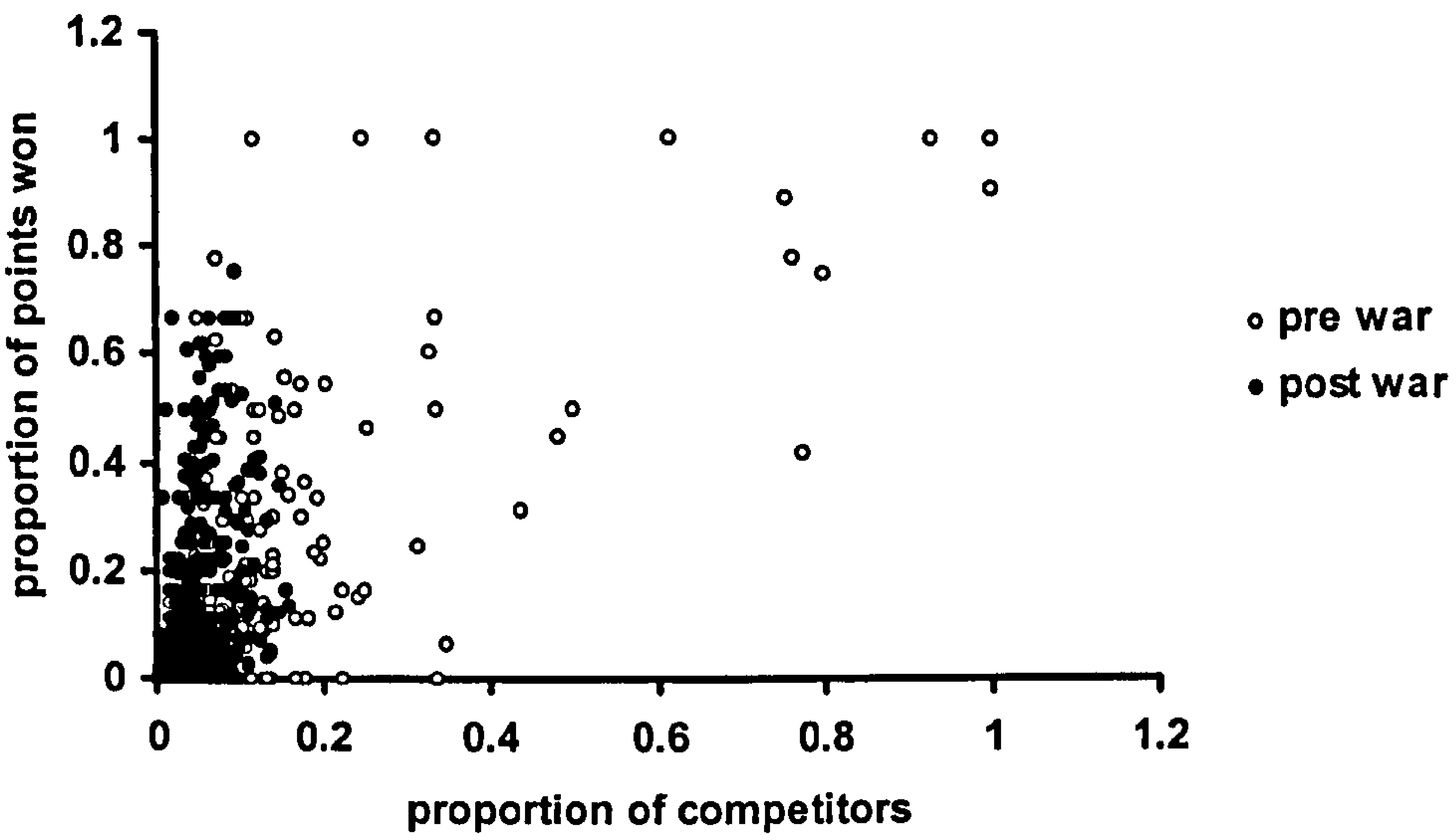

Figure 6.2. Proportion of competitors entered plotted against proportion of points won, for each Olympic, nation and event group. Highlights the need to split the analysis pre and post war.

As with Study 4.1 (Chapter 4), a more appropriate method of analysing these data was to analysis the proportion of points won by each nation as a binomial response variable (e.g., if a nation won a silver medal in the 100 m athletics final, 2 out of 6 points would be allocated to that nation for that Olympics) using Generalised Linear Interactive Modelling (GLIM, Aitkin et al.; 1989). Rather than assuming the response variable has a linear function of the covariates with an approximate normal error, GLIM is able to assess the effect of all the explanatory variables on the proportion of points won assuming the exact binomial error distribution (r points from a possible n).

Separate GLIM analyses were performed on the pre- and post-war data, due to differing 'athletes' covariates. Having considered differences in home advantage between event groups, analyses were split by event group both pre and post-war. This allowed absolute home advantage to be calculated for each group.

6.3 Results

6.3.1 GLIM analysis

(i) Pre-war

Fitting the covariate 'athletes', the main effects 'host', 'event group' and 'home versus away' plus the interaction between 'event group' and 'home versus away' term explained a loss in deviance of -1628.9 with 17 degrees of freedom (df) ($P < 0.0001$). When we attempted to remove the interaction term, the covariate or any of the main effects from the model, the increase in deviance was too large in all cases ($P < 0.01$). Consequently, all terms were retained in the final pre-war model describing the proportion of points won by the 8 'hosting' nations. The unadjusted and adjusted (for athletes) mean proportion of points won by all successful hosting nations pre war, both home and away for each event group are given in Figures 6.3 and 6.4 respectively.

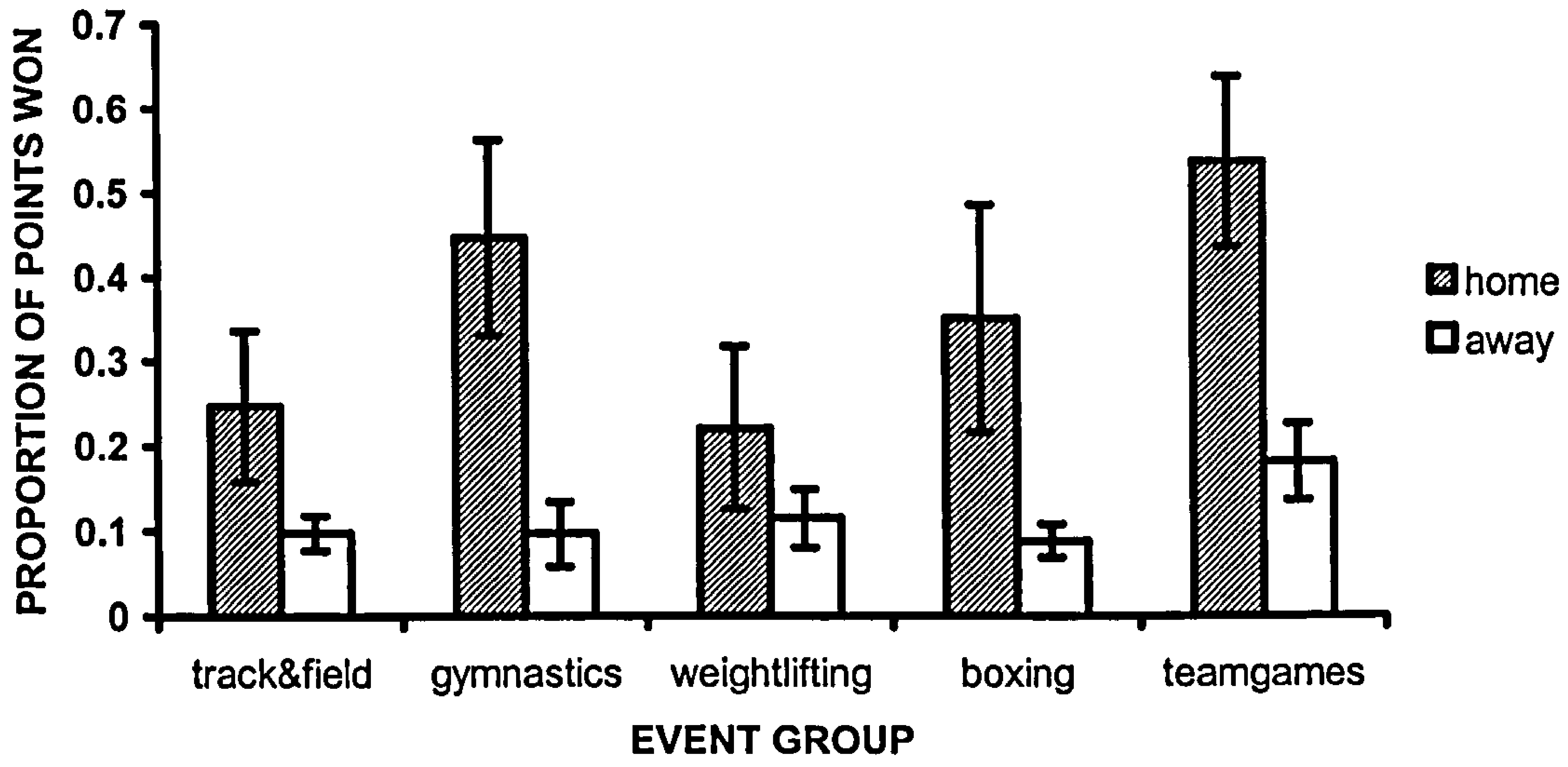

Figure 6.3. Mean proportion of points won by all successful hosting nations pre war, home and away and for each event group.

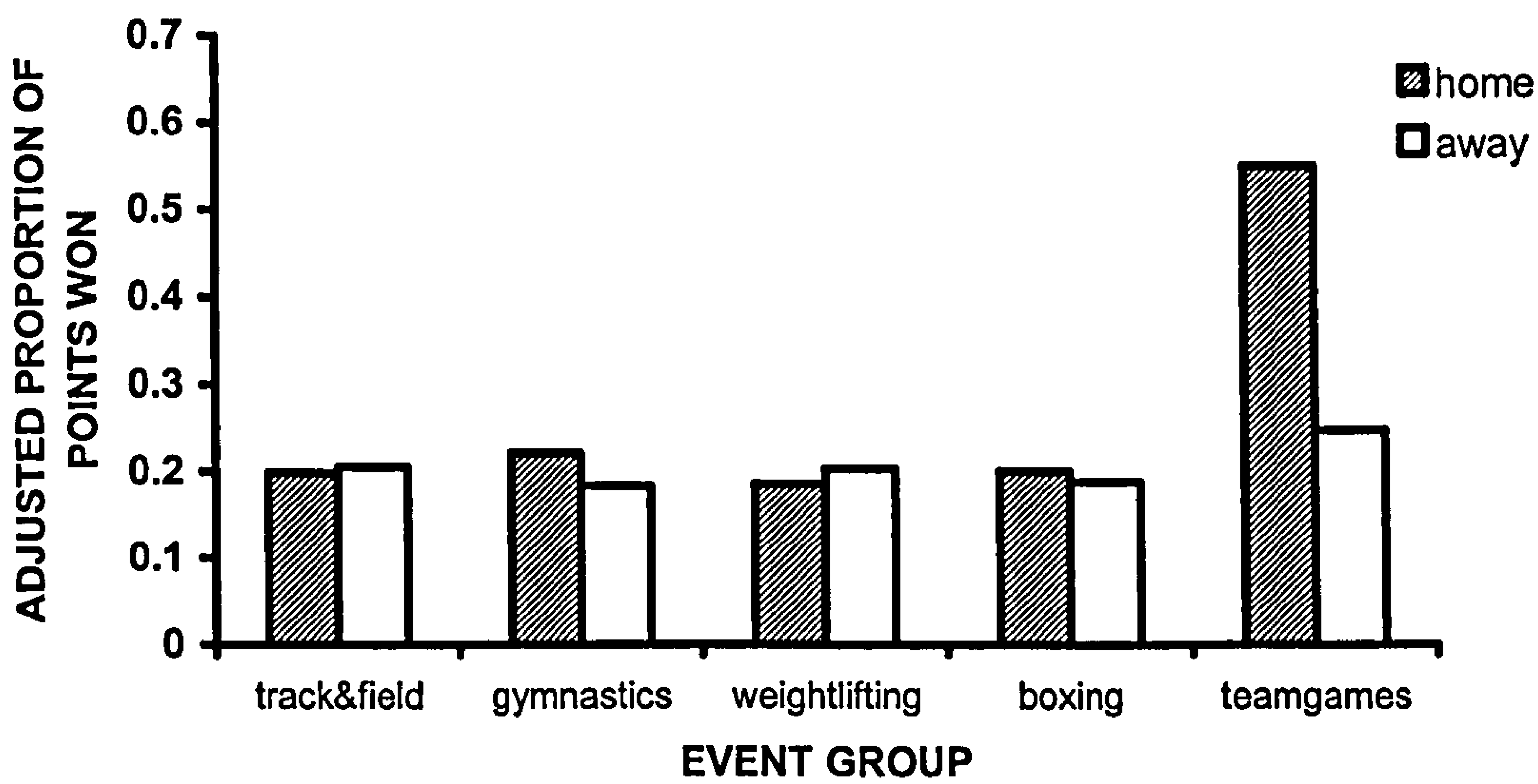

Figure 6.4. Adjusted mean proportion of points won by all successful hosting nations pre war, home and away and for each event group. Proportions are adjusted to account for number of athletes entered.

Five simplified models were then fitted for each event group, with the single 'athletes' covariate, and main effects 'host' and 'home versus away'. This allowed absolute measurement of home advantage for each group. Table 6.2 presents the direction (home advantage/away advantage) and significance (change in scaled deviance as a result of removal from final model) of the factor 'home versus away'.

Table 6.2. Degree and direction of home advantage for each of the five event groups pre-war.

Event group	**Direction of advantage**	**Change in scaled deviance, χ^2**	**Degrees of freedom**	**P-value**
Track and Field	Away	0.2197	1	>.05
Gymnastics	Home	5.244	1	<.05
Weightlifting	Home	1.460	1	>.05
Boxing	Home	2.468	1	>.05
Team Games	Home	19.38	1	<.001

With the factor 'host' and covariate 'athletes' entered, no home advantage was found for 'track and field', 'weightlifting' or 'boxing'. In contrast, 'gymnastics' yielded significant home advantage, $\chi^2_1 = 5.244$, $P < 0.05$, as did 'team games', $\chi^2_1 = 19.38$, $P < 0.001$. For all event groups, as with the global analysis, increase in deviance was too large to remove either 'host' or 'athletes', confirming their importance.

(ii) Post-war

Adopting the same methodological approach to analysing the pre-war results, the covariate 'athletes', the main effects 'host', 'event group' and 'home versus away' were fitted, plus the interaction between 'event group' and 'home versus away' term to explain the proportion of points won by the 12 hosting nations. These terms explained a loss in deviance of -2657.1 with 21 degrees of freedom (df) ($P < 0.0001$). As with the pre-war analysis, when an attempt was made to remove the interaction term, the covariate or any of the main effects from the model, the increase in deviance was too large in all cases ($P < 0.01$). As with the pre-war model, all terms were retained in the final post-war model describing the proportion of points won by the 12 'hosting' nations. The unadjusted and adjusted (for athletes) mean proportion of points won by all successful hosting nations post war, both home and away for each event group are given in Figures 6.5 and 6.6, respectively.

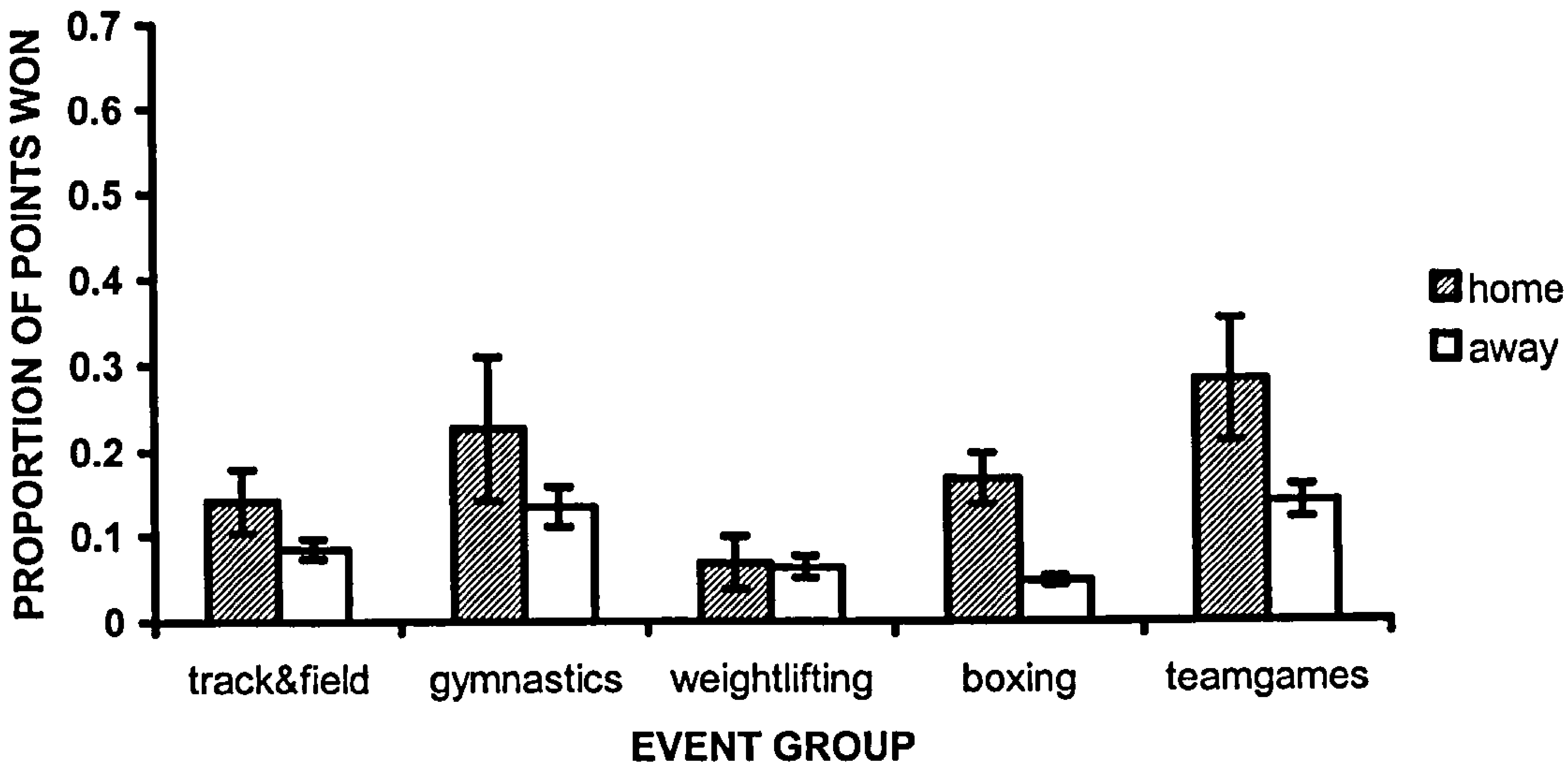

Figure 6.5. Mean proportion of points won by all successful hosting nations post war, home and away and for each event group.

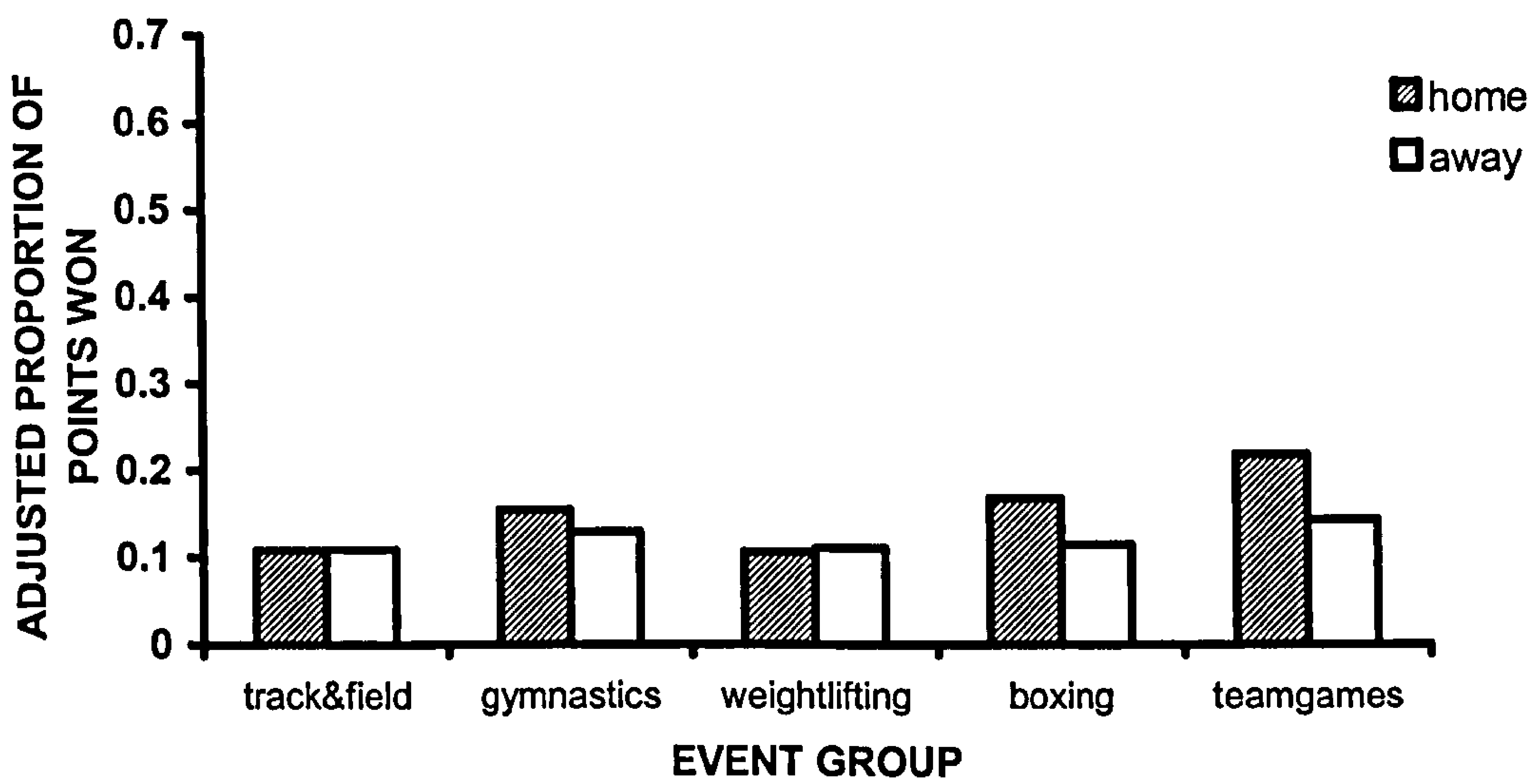

Figure 6.6. Adjusted mean proportion of points won by all successful hosting nations post war, home and away and for each event group. Proportions are adjusted to account for number of athletes entered.

Separate models were fitted for each event group, using an identical procedure to that of the pre-war analysis. Table 6.3 presents the direction (home advantage/away advantage) and significance (change in scaled deviance as a result of removal from final model) of the factor 'home versus away'.

Table 6.3. Degree and direction of home advantage for each of the five event groups post-war.

Event group	Direction of advantage	Change in scaled deviance, χ^2	Degrees of freedom	P-value
Track and Field	Home	0.1957	1	>.05
Gymnastics	Home	25.23	1	<.001
Weightlifting	Away	6.214	1	<.05
Boxing	Home	42.92	1	<.001
Team Games	Home	9.989	1	<.005

Again, home advantage was established by removing the factor 'home versus away' from a model containing the factor 'target' and covariate 'athletes' As with the pre-war analysis 'track and field' yielded no home advantage. Interestingly, once 'athletes' had been accounted for, 'weightlifting' now exhibited significant away advantage $\chi^2_1 = 6.214$, $P < 0.05$. Meanwhile, a large significant home advantage was observed for 'gymnastics' $\chi^2_1 = 25.23$, $P < 0.001$, and 'team games' $\chi^2_1 = 9.989$, $P < 0.005$, as well as 'boxing' $\chi^2_1 = 42.92$, $P < 0.001$. As with previous analyses, increase in deviance was too large to remove either 'host' or 'athletes', confirming their importance in the model.

6.4 Discussion

The present study had two objectives. First, to quantify home advantage in a subset of Summer Olympic event groups, while controlling for confounding factors. Second, to examine differences in home advantage between groups of events relying on differing officiating styles. It was hypothesised that sports requiring subjective judgement (boxing, gymnastics) or subjective decisions (team games) would yield highly significant home advantage. In contrast, little or no home advantage was expected for sports where officiating is predominantly an objective or less involved process (track and field, weightlifting).

In both pre-war and post-war analyses, overall home advantage was found to be significant, highlighted by the large change in deviance when attempting to remove the 'home vs. away' main effect. The 'athletes' covariate was also found to be highly influential both pre and post war, indicating the importance of proportion of athletes/teams to successful performance. Controlling for this covariate proved central to a fair measure of home advantage, highlighted by the marked difference between non-adjusted (Figures 6.3 and 6.5) and adjusted performance (Figures 6.4 and 6.6). Significantly different slopes (estimate) for the 'athletes' covariate illustrated the need to split the analysis pre and post war as suggested in Figure 6.2. Likewise, significant differences existed between 'target' nations point winning performance. Entry of a nation main effect accounted for a large proportion of variance (due to substantial nation differences) confirming team quality concerns of previous research (e.g. Holder & Nevill, 1997; Madrigal & James, 1999; Nevill et al., 1997; Schwartz & Barsky, 1977).

Most important, however, was the significance of the home/away by event group interaction, both pre and post-war. Subsequent analysis for each individual event group revealed the source of this significant interaction term. Pre-war, the significant home/away by group interaction term was a result of a small away advantage in the two objectively judged groups, compared significantly greater positive home advantage in the gymnastics and vast home advantage for team games. Post-war, when athlete participation had stabilised to some extent (due to restrictions), the home/away by group interaction was a result of significantly greater home advantage in both subjectively judged event groups and team games over the two objective groups.

Highly significant home advantage was found in event groups which were either subjectively judged (gymnastics, boxing) or rely on subjective decisions (team games). Home advantage for these three groups was significantly greater than that of the two objectively judged groups (track and field, weight lifting). These objectively judged groups showed no home advantage (and even away advantage), both pre and post-war, once proportion of athletes competing had been controlled (see adjusted Figures 6.4 and 6.6). With respect to subjectively judged events, this confirms previous winter Olympic findings (Balmer et al., 2001b) that such disciplines enjoy significantly greater home advantage than events with little officiating input. Evidently, this officiating component is vital to the degree of (and indeed existence of) home advantage in individual sports. This could explain why significant home advantage has been observed in wrestling (Gayton & Langevin, 1992) even at high school level, but not international tennis or golf (Nevill et al., 1997; Holder & Nevill, 1997). It would seem the potential for biased officiating in subjectively judged events predicted by Ansorge and Scheer (1988) is realised for home advantage.

Team games, as hypothesised, demonstrated highly significant home advantage both pre and post-war though the size of this imbalance was surprisingly large. Team games demonstrated by far the largest home advantage pre-war (Table 6.2) and comparable highly significant home advantage post-war (Figure 6.3). Pre-war, lack of competitive away teams and failure to completely account for additional home teams ('athletes') may partially explain this imbalance. Post-war, following instigation of entry restrictions, home advantage remains highly significant ($P < 0.005$), though as hypothesised, slightly smaller than the subjectively judged groups ($P < 0.001$).

Previous research has highlighted crowd factors as dominant cause of home advantage, able to either influence players or officials to alter performance to favour the home side/nation (Pollard 1986; Nevill et al., 1996). Competitors in all of the event groups enjoy consistently large and vocal crowds. If these crowds were able to influence players/athletes performance, home advantage would be observed for all event groups, which was not the case. Significantly home advantage in the three event groups with substantial officiating input supports the latter hypothesis, that the crowd is able to influence officials to favour the home side. Experimental research has provided support for a crowd influence upon officials in association football (see Balmer et al., 2001a; Nevill et al., 1999; Chapters 4 and 5). However, while a consistent imbalance of decisions was identified, this was not quantified in terms of home advantage. The present study suggests that the imbalance observed with crowd noise in football translates to a sizeable home advantage, significantly larger than objectively judged events and comparable to that of subjectively judged events. Having identified the influence of crowd noise in Chapters 4 and 5, the present study was able to put home advantage observed in team sports in context, providing support for the crowd noise effect in terms of absolute home advantage.

Chapter 7. Mechanisms underlying the influence of crowd noise

7.1 Introduction

Having established highly significant home advantage in team games in Chapter 6, Chapter 7 aims to replicate findings of Chapters 4 and 5, while investigating mechanisms underlying the imbalance. Measurements of mental effort and anxiety will be taken, using both questionnaires and physiological measurements, in a repeated measures design, more sensitive than those in Chapters 4 and 5. This should provide thorough confirmation of the crowd noise effect, and indications of why such an effect occurs. Two theories were proposed in Chapter 5 to explain the crowd noise effect. First, increased relative saliency of the auditory cue could lead to over processing, and an imbalance in favour of the home side. Second, participants may be using a coping strategy of avoidance to prevent the potentially negative effects of crowd noise. These theories will be tested in Chapter 7, though measurement of confidence of decision, anxiety and mental effort.

A number of studies have established that officials consistently make more subjective decisions in favour of the home team (Glamser, 1990; Greer, 1983; Lefebrve & Passer, 1974; Lehman & Reifman, 1987; Sumner & Mobley, 1981; Varca, 1980). In British football this imbalance (in terms of penalties and sendings-off) has been shown to increase with crowd size or density (Nevill et al., 1996). Subsequent experimental work has provided strong evidence that crowd noise plays a major role in this imbalance (see Chapters 4 and 5). These studies suggest that as decisions become more contentious, the imbalance increases (see Chapter 4, Study 4.2) and refereeing experience does not diminish the influence of crowd noise (see Chapter 5). Archival Summer Olympic research (Chapter 6) put the home advantage observed in team games (including football) in to context, finding it not only to be significant, but amongst the largest of the event groups analysed. It was proposed that the influence of crowd noise is not only influential in altering the decisions of referees, but also in creating inflated home advantage. Despite such findings, mechanisms underlying the crowd noise effect have been proposed, without empirical verification.

Several mechanisms have been proposed to explain the influence of crowd noise (Nevill, Balmer & Williams, in press) (chapter 5). One suggestion is that the saliency of informatory cues changes with and without crowd noise. When crowd noise is present, the auditory saliency of an incident is increased without increasing its predictive value. As the visual cue becomes increasingly difficult to judge, the auditory cue (crowd noise) is likely to become increasingly salient and influential. Moreover, participants have been shown to focus upon the most salient cue when placed under time constraints (Wallsten & Barton, 1982). This is consistent with previous experimental protocols (see Chapters 4 and 5) where participants were offered a six second pause in which to make decisions, and actual refereeing, where decisions are expected to be immediate. The fact that the effect of crowd noise seems to increase with contentious decisions (Balmer et al., 2001a) (see Chapter 4) would seem to support a saliency argument. Imbalance of decisions in favour of the home side was shown to increase as decisions became increasingly difficult to judge.

Coping strategies have also been offered as a possible explanation for the crowd noise effect (see Chapter 5). A number of studies have identified that 'making a bad call' is the single most important stressor in sports officiating (Kaissidis & Anshel, 1993; Stewart & Ellery, 1998; Taylor, 1990). Humphreys and Revelle (1984) suggested that the effects of stress and anxiety on individuals vary depending upon their personality characteristics, motivation and the requirements of the task. In general, those tasks that require the use of short-term memory, such as decision-making, are negatively affected via an increase in cognitive worry and physiological arousal. According to this theory, when threatened by a perceived stressor such as the reactions of a partisan crowd, worry can motivate a referee to adopt an avoidance motivation strategy, reducing on-task (mental) effort which is likely to impair performance. Research evidence suggests that when sources of stress are difficult to control (e.g., crowd reaction to a contentious decision) individuals often deal with them proactively via the use of an avoidance coping strategy (Anshel & Weinberg, 1999; Kaissidis-Rodafinos, Anshel & Porter, 1997). However, Eysenck and Calvo (1992) suggested that in most real-life situations, individuals cannot simply remove themselves from a threatening or stressful situation without the possibility of aversive consequences (e.g., negative evaluation by others, decrement in self-esteem). Therefore, referees are likely to anticipate such aversive consequences, and become motivated to avoid the negative repercussions of 'making a bad call' by actually increasing the mental effort they allocate to the task. The increased effort is hypothesised to counteract the negative effects of anxiety and maintain performance at an effective level. However, if anxiety levels are too high, processing efficiency is reduced, or the perceived ability to cope with the potentially stressful situation is low, then performance may be impaired or the negative consequences avoided (Eysenck, 1992; Eysenck & Calvo, 1992; Smith & Lazarus, 1993). Furthermore, those referees who are particularly prone to high levels of anxiety may negatively interpret neutral situations (i.e., situations which are not threatening or difficult to interpret) and make a decision that is less contentious (Eysenck, 1992). In sum, referees may attempt to avoid the stress of making a bad call by favouring the home side

Both subjective ratings and physiological measures can be used to infer anxiety. If partisan crowd noise were to increase levels of stress/anxiety this would be indicated by changes in physiological arousal (e.g. heart rate), or in responses to anxiety rating scales (e.g., CSAI-2) (Martens et al., 1990). Measurement of mental effort/workload may also provide insight into possible mechanisms. Previous research has demonstrated that as workload increases so mental effort must increase to maintain performance (Gaillard & Wientjes, 1994; Hockey, 1986). Workload is deemed to be high when the difference between task demand and participant capacity is small (Veltman & Gaillard, 1996). Mental effort has been successfully measured using both subjective rating scales (Zijlstra, 1993) and physiological ECG measurements (for a review, see Jorna, 1992). Rating scales, while providing a fair indication of total workload, have been criticised for being unable to discriminate between actual and perceived hard work (Veltman & Gaillard, 1996). In this respect, spectral analysis of ECG data (i.e., heart-rate variability) may provide a more sensitive index of mental effort and has been successfully employed in studies of both driver (De Waard, 1996; Fairclough & Graham, 1999) and pilot (Veltman & Gaillard, 1996) performance as well as in memory search tasks (Meijman, 1995; Meijman, 1997).

The present study assessed whether participants' opinions of challenges could be influenced by partisan crowd noise. Moreover, a number of physiological and psychological measures (subjective ratings) are collected in order to investigate the mechanisms underlying any imbalance. Cue saliency will be measured by asking participants to express their confidence following each decision. The certainty of the decision (in silence) is hypothesised to be at its greatest for challenges with least overall bias in favour of the home side. Decisions accompanied by the lowest scores in the silent condition should subsequently have the most salient auditory cue in the noise condition (i.e. a negative relationship between certainty in silence and bias).

Subjective ratings and physiological measures of mental effort will be taken, using the RSME effort scale (Zijstra, 1993) and spectral analysis of inter beat intervals of heart rate. Subjective ratings and physiological measures of anxiety will also be taken, using STAI (Spielberger et al., 1970) and the modified CSAI-2 (Martens et al., 1990; Jones and Swain, 1992) questionnaires and measures of mean heart rate for baseline and test periods. Firstly, it is hypothesised that as with previous research (see Chapters 4 and 5), the addition of crowd noise results in a significant imbalance of decisions in favour of the home side. Secondly, in favour of a saliency argument, it is hypothesised that the influence of crowd noise is greater for incidents that participants found difficult to judge in the silent condition. As visual cues alone are increasingly difficult to judge, auditory cues should become increasingly salient. Thirdly, it is hypothesised that participants with the greatest decision bias in favour of the home side, also exhibit higher levels of anxiety. Moreover, those participants who exhibit a high level of anxiety are likely to allocate a greater number of cognitive resources (i.e., mental effort) to the task in order to reduce the negative consequences of 'making a bad call'.

7.2 Methods

(i) Participants

Twenty-six experienced participants volunteered to take part in the present study, all of whom had watched football and had either coaching, playing and/or refereeing experience. The referees were asked to assess the legality of 47 challenges/incidents recorded during an English Premier League match between

Liverpool (home) and Leicester City (away) from the 1998/99 season. Participants gave their informed consent prior to taking part in this study.

(ii) Test film and apparatus

The incidents were block randomised by half (first vs. second) and back projected onto a 3-m × 3.5-m screen (Cinefold) using video-projection system (Sharp XG-NV2E) and videocassette recorder (Panasonic NV-HD680). The videotape was edited such that the presentation stopped for six seconds immediately after each incident, but again fractionally before the match official's decision could be observed. The videotape (same as Chapter 5) comprised of 47 incidents (M = 8.93s, SD = 2.17 (excluding 6 s pause). Noise level was measured using a digital sound level meter (Tenma 72-680), with a 1 kHz test tone yielding 75 dB (absolute) at 1 m. Electrocardiogram readings were made using Maclab for Macintosh, and analysed using Chart software.

(iii) Procedure

The participants were randomly allocated to a noise group featuring crowd noise but no commentary, or a silent condition group, with a retest on the opposite condition following a one-week 'washout' period. Thirteen participants began with the crowd noise audible (noise condition), whilst thirteen participants initially viewed the video in silence (silent condition). Preceding presentation, participants were informed as to the identity of the two teams and the location of the match. Throughout the six-second pause, the corresponding incident number appeared on the screen during which time participants were invited to verbally indicate their decision, with the experimenter recording responses on a response sheet. Participants were asked to make one of three decisions in response to each incident. These were Liverpool foul (a foul committed by a Liverpool player), Leicester foul (a foul committed by a Leicester player), or no foul. Rather than including a further 'uncertain' option, participants were asked to follow each response with a number between one (absolutely uncertain) and ten (absolutely certain) expressing their confidence in the decision made. For example, typical responses could be 'Liverpool six', 'Leicester eight' or 'no foul ten'. Three separate types of questionnaire were also administered as illustrated in the experimental protocol (Figure 7.1).

(iv) Trait anxiety

Participants' trait level of anxiety was measured using the trait component of Spielberger et al.'s (1970) State Trait Anxiety Inventory (STAI). Trait measures were taken to provide an indication of those participants predisposed to react with higher levels of state of anxiety under test conditions. The inventory comprised 21 items, with intensity of response for each item was rated on a 4-point Likert scale, ranging from 1 '*Not at all*' to 4 '*Very much so*'. This yielded a single measure of trait anxiety for each participant.

(v) State anxiety

Participants also completed a modified Competitive Sport Anxiety Inventory (CSAI-2, Martens et al., 1990) incorporating Jones and Swain's (1992) directional scale prior to the first test period (baseline), and following testing in both conditions. The modified CSAI-2 questionnaires following testing were adapted to gauge participants' feelings during testing (i.e. present tense was converted to past tense). The CSAI-2 (Martens et al., 1990) comprised 27 items, with 9 items on separate sub-scales of cognitive anxiety, somatic anxiety and self-confidence. Responses indicated participants experience of cognitive anxiety, somatic anxiety and self-confidence both preceding and during each of the test periods. Intensity of response for each item was rated on a 4-point Likert scale, ranging from 1 '*Not at all*' to 4 '*Very much so*'. This yielded a range of scores from 9 to 36 on each sub-scale. The modified inventory also included directional scales, aiming to assess whether participants perceive their state anxiety as either debilitating or facilitating performance (Jones and Swain, 1992). The directional items comprised of a 7-point Likert scale ranging from –3 '*Very Negative (Debilitative)*' to 0 '*Undecided*' to +3 '*Very Positive (Facilitative)*'. This yielded a range of scores from –27 to +27 on each sub-scale.

(vi) Mental effort

Following presentation of the test tape (in each noise condition), participants were asked to rate their effort on the Rating Scale Mental Effort (RSME; Zijstra, 1993). The RSME comprised of a vertical scale ranging from 0 to 150. A further nine descriptive indicators on the scale (e.g. some effort, extreme effort) translate these quantities to effort. Electrocardiogram (ECG) data were recorded using a standard three lead ECG. Data were collected for a baseline of approximately four minutes, and for the duration of the test tape in each condition (silent and noise). Times of each R-peak (i.e., polarisation of the left ventricle) were calculated separately for baseline and test period, following manual correction of detection parameters. This correction ensured that R-peaks were correctly detected without false detection of artefacts. Spectral analysis of the inter-beat intervals (time between each R-peak) was split into three bandwidths (Mulder, 1979), and the heart rate variability for the mid-range frequency (0.07-0.13 Hz) extracted. Extraction of this mid-band was used to provide an index of effort/mental load (Jorna, 1992) both between baseline and test periods and more importantly between conditions. Mean heart rate values for each participant were also recorded for the baseline period and during the test tape in both conditions.

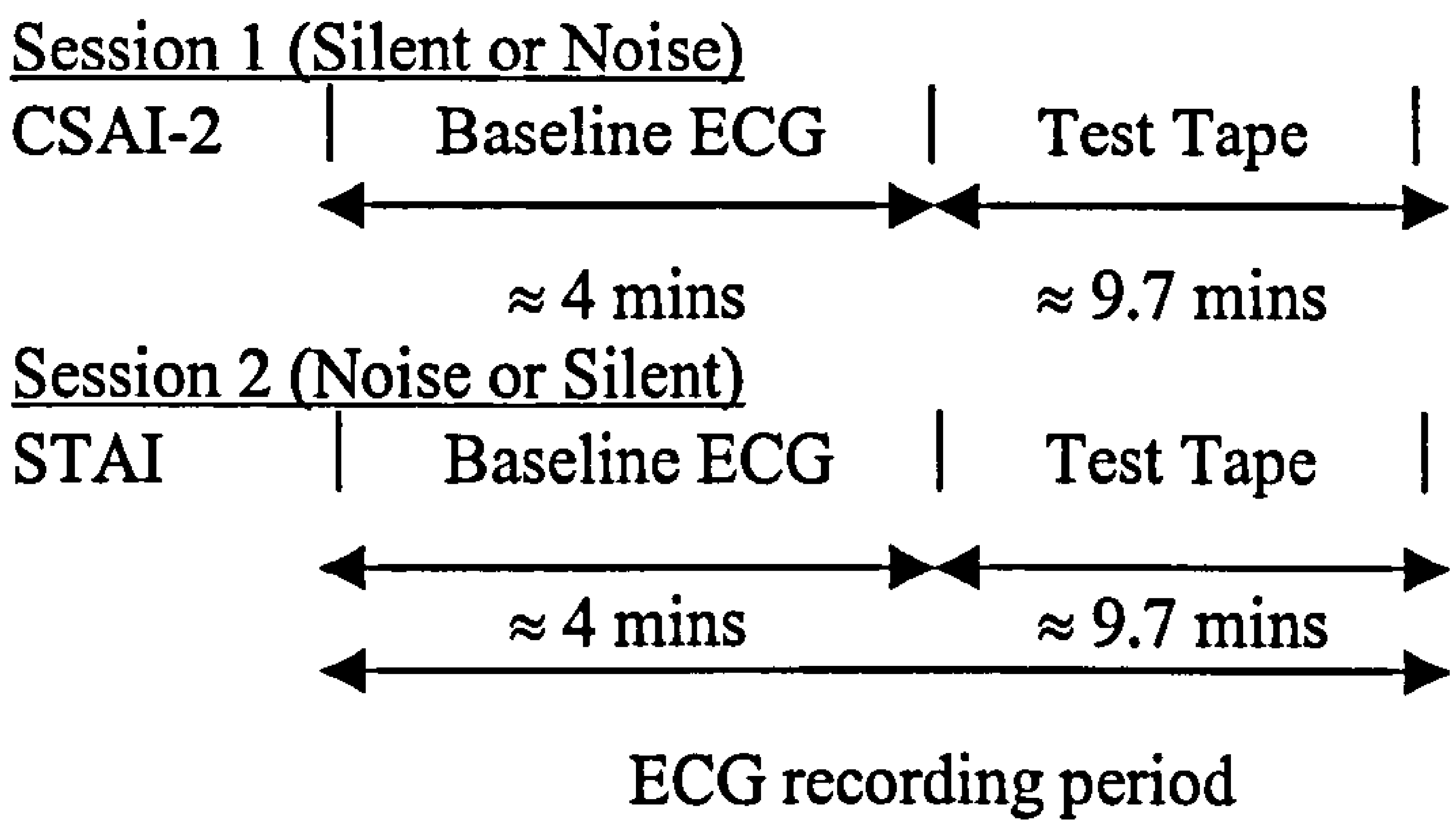

Figure 7.1. Experimental protocol

(vii) Analysis

Firstly, as with the analysis in Chapter 5, traditional ANOVA was not appropriate due to a categorical response variable. Again, a more appropriate multivariate technique is logistic regression. The analysis will estimate the probabilities (or more correctly the odds ratios) associated with the three categorical options and how these probabilities will vary due to differences in the predictor/independent variables (see Kleinbaun, 1994). Multinomial nominal logistic regression was used to assess the effect of crowd noise upon the participants' decisions. Participants' subjective ratings of certainty for each decision were entered as a continuous covariate.

Indices of anxiety/mental effort yielded two measures per participant (one noise, one silent). Therefore, a secondary analysis assessed the relationship between bias exhibited by each participant (differences in number of decisions in favour of the home side with crowd noise) and indices of anxiety/mental effort. A similar analysis is carried out relating each of the 47 challenges certainty in silence (and change in certainty between noise conditions) to bias in favour of the home side. All error bars on figures denote standard errors of means.

7.3 Results

(i) Logistic regression analysis

A nominal logistic regression analysis was performed to assess prediction of membership of each of three response categories (home foul, away foul, no foul), on the basis of 3 categorical predictors (noise group, challenge number, subject) and a single covariate (certainty).

Table 7.1. The results of the multinomial logistic regression analysis, a) the likelihood ratio tests, and b) the goodness of fit tests. Predictors are abbreviated to 'noise cond.' (2 levels), 'challenge #' (47 challenges) and 'subject' (26 participants).

a)

Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	p.
Intercept	2517.135	.000	0	.
CERTAINTY	2552.847	35.712	2	<.001
CHALLENGE #	4901.433	2384.298	92	<.001
SUBJECT	2737.618	220.483	50	<.001
NOISE COND.	2544.261	27.126	2	<.001

b)

	Chi-Square	df	Sig.
Pearson	3709.200	4740	1.000
Deviance	2517.135	4740	1.000

Table 7.1a demonstrates the consequence (i.e., the change in deviance = -2 Log Likelihood) of omitting an effect/factor from the final model containing the continuous covariate 'certainty' and the three main effects 'challenge number', 'subject' and 'noise

condition'. The size and significance of the χ^2 statistics confirm the importance of retaining all effects; 'challenge number' χ^2_{92} = 2384.30, $P < 0.001$, 'subject' χ^2_{50} = 220.48, $P < 0.001$, and 'noise condition', $\chi^2_2 = 27.13$, $P < 0.001$ (n = 2444 in all cases). Table 5.2b provides 'goodness-of-fit' information associated with the final model. *P*-values for the Pearson and deviance tests are both 1.00, providing strong evidence that the model fits the data well. Only *P*-values less than 0.05 would indicate an inadequate fit. This is further illustrated by pseudo R^2 values (Nagalkerke = 0.739) explaining a significant proportion of the variance.

Figure 7.2 illustrates the mean number of decisions made for each option awarded in noise and silent conditions. In comparison with the silent condition, when in the noise condition participants awarded less fouls against the home side, marginally more against away and more 'no foul' options.

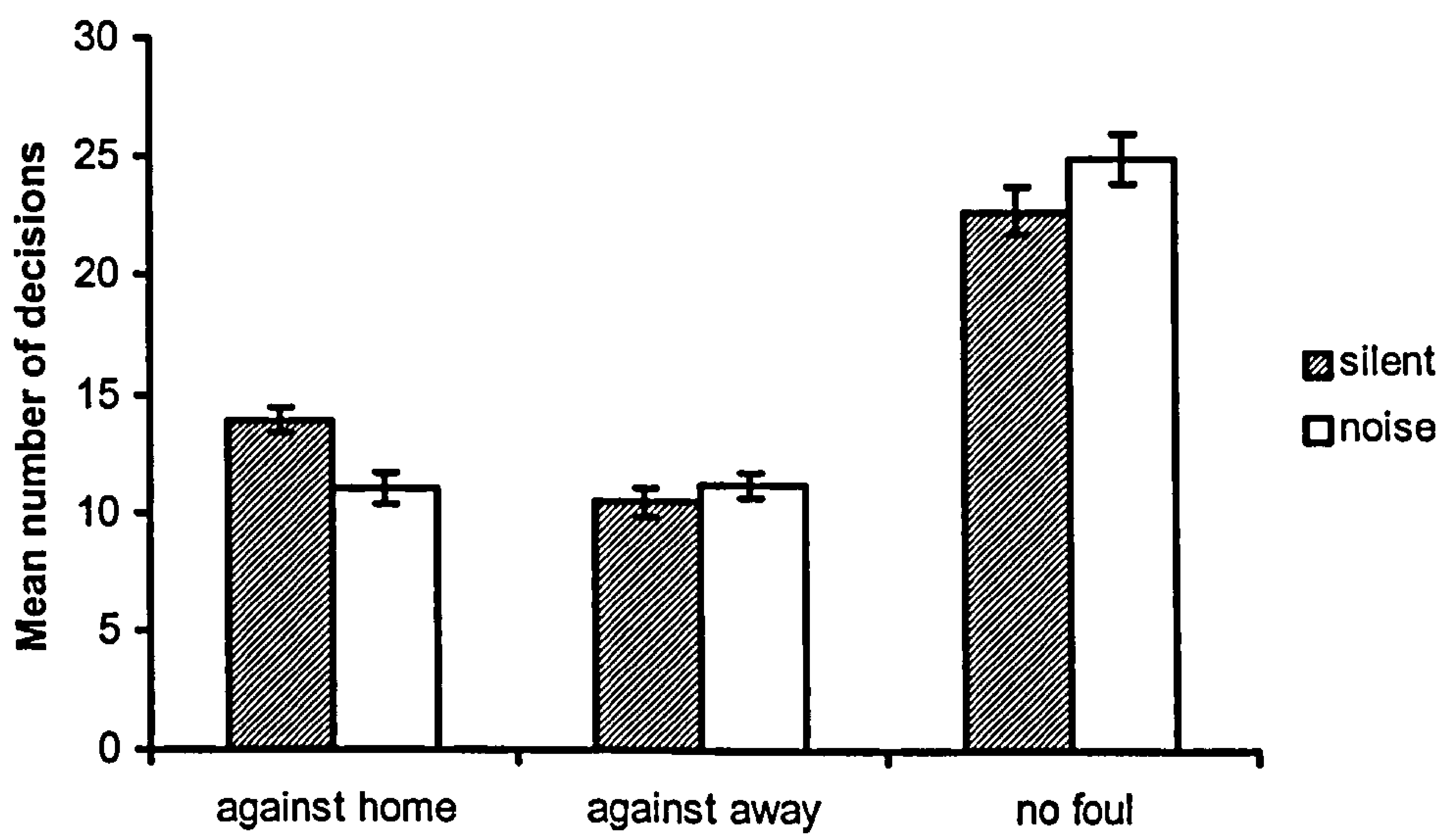

Figure 7.2. Mean number of decisions for each of the three response options awarded in noise and silent conditions.

The fitted model demonstrates the specific influence of noise condition on the probability of making decisions against the home or away side. Using the 'no foul' decision as baseline, crowd noise (compared to silence) resulted in a significantly lower likelihood of a decision against the home side compared with baseline 'no foul'; $W(Wald)_1 = 25.30$, Odds ratio, $Exp(\beta) = 0.503$, $P < 0.001$. In contrast, for away fouls, the noise condition resulted in a marginally higher likelihood of awarding a decision against the away side, compared with the baseline 'no foul'; $W_1 = 0.27$, Odds ratio, $Exp(\beta) = 1.079$, $P = 0.603$, though this was non-significant.

Participants were also significantly less certain when awarding fouls over 'no foul decisions'. This was true for both 'home fouls', $W_1 = 18.27$, Odds ratio, $Exp(\beta) = 0.834$, $P < 0.001$, and 'away fouls', $W_1 = 20.72$, Odds ratio, $Exp(\beta) = 0.818$, $P < 0.001$. Mean values for heart rate, heart rate variability and mental effort (RSME) are presented in Table 7.2, while CSAI-2 values can be found in Table 7.3.

Table 7.2. Mean values (with standard deviations) for RSME, heart rate and heart rate variability measurements

	RSME	Baseline HR	Test HR	Baseline HRV	Test HRV
Silent	64.4 (22.1)	68.5 (9.29)	67.6 (12.5)	1143.8 (824.2)	985.0 (689.6)
Noise	63.9 (22.4)	70.0 (9.0)	70.4 (12.5)	920.0 (707.7)	872.8 (537.0)

Table 7.3. Mean values (and standard deviations) for CSAI-2 subscales.

	Cognitive Anxiety (Intensity)	Cognitive Anxiety (Direction)	Somatic Anxiety (Intensity)	Somatic Anxiety (Direction)	Confidence (Intensity)	Confidence (Direction)
Baseline	11.7 (3.2)	13.5 (11.8)	10.7 (1.8)	17.1 (8.4)	27.5 (5.4)	16.8 (8.4)
Silent	12.6 (3.1)	12.4 (12.2)	11.5 (3.3)	15.3 (9.3)	26.2 (6.4)	16.8 (7.9)
Noise	12.9 (4.0)	13.6 (11.4)	11.2 (2.5)	16.5 (9.1)	26.2 (6.0)	16.9 (7.6)

(ii) Bias analysis

A measure of bias was calculated for each participant, relating to the change in number of decisions in favour of the home side as a result of crowd noise. Data were coded '1' (home foul), '0' (no foul) and '-1' (away foul). These values were summed for each participant and all challenges, in each noise group. Subtracting noise from silent condition values, yielded each participants' bias toward the home side. A value of +4, for example, would indicate a participant giving four more decisions in favour of the home side in the noise condition, than in silence. Similarly –2 would indicate the noise condition resulting in two more decisions in favour of the away side. Evidently, changing decision from 'no foul' to 'home or away foul' or vice versa, for any given challenge, would result in scores of +1 or –1. Changing between 'home foul' to 'away foul', or vice versa (overlooking 'no foul'), would yield scores of +2 or –2. This procedure generates a single measure of bias for each participant, which can be related to various continuous measures of anxiety and mental effort. A one-sample t-test on bias confirms the findings of the logistic regression. Bias was found to be significantly greater than zero ($\underline{M} = 3.62$), $T = 6.36$, $P < 0.001$.

A number of anxiety predictors were used; trait anxiety 'STAI', and the following state measures from modified CSAI-2; cognitive anxiety intensity, cognitive anxiety direction, somatic anxiety intensity, somatic anxiety direction, confidence intensity, and confidence direction. Mental effort predictors included subjective 'RSME' and physiological heart rate variability measurement from spectral analysis 'HRV'. ECG equipment also yielded a measure of mean heart rate. CSAI-2 measures, 'HRV' and heart rate measurements for both silent and noise conditions were converted to deviations from baseline measures. Bias was correlated with differences in deviations between silent and noise groups.

Having established normality in all measures of anxiety, one-tailed Pearson's correlations showed significant positive relationships between participant bias and three predictor variables. These were 'cognitive anxiety intensity' (r = 0.551, P = 0.002) 'RSME' (r = 0.535, P = 0.003) and 'HRV' (r = 0.354, P = 0.038). These relationships are individually represented in Figures 7.3, 7.4.and 7.5.

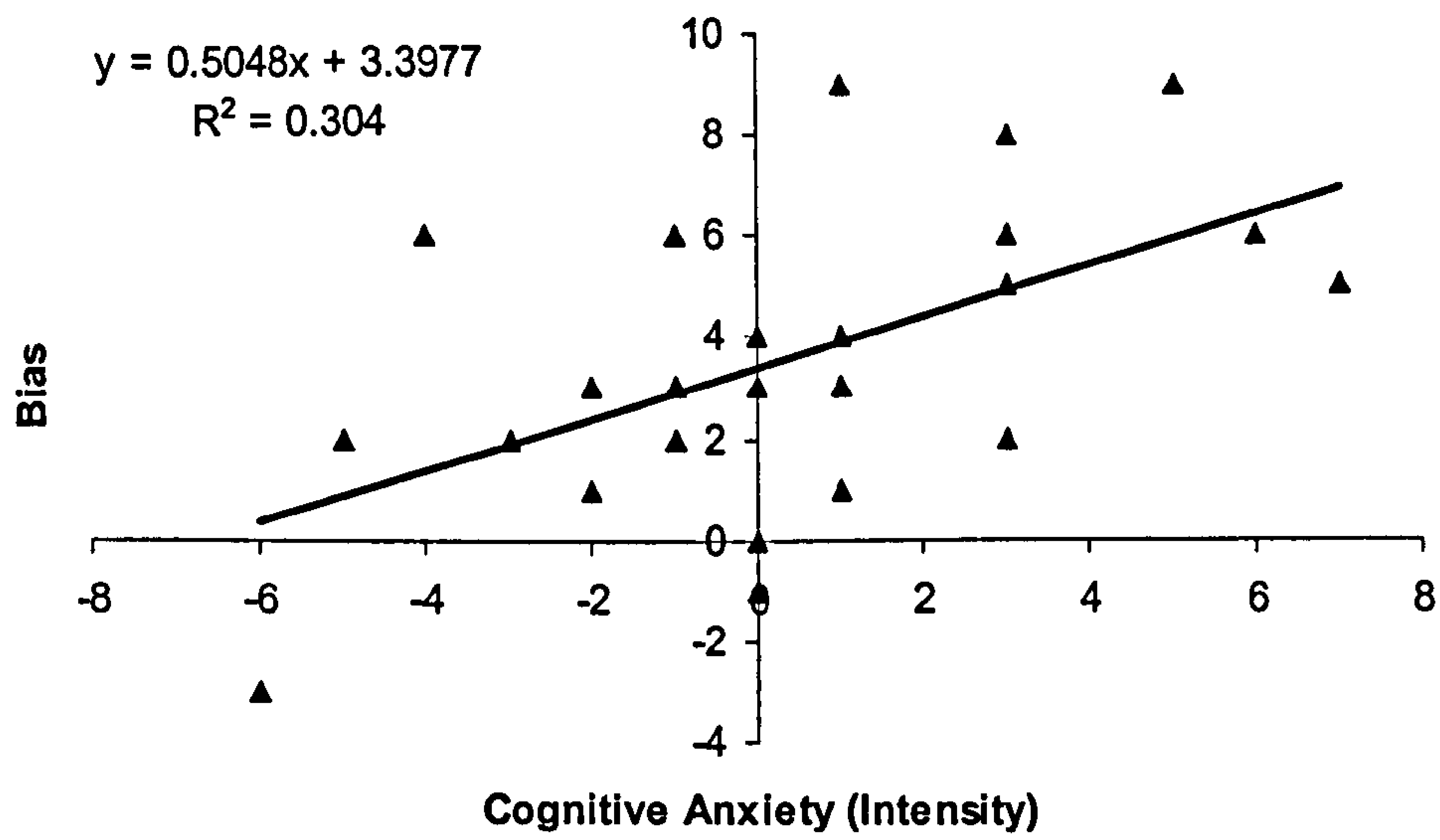

Figure 7.3. Relationship between difference in intensity change of cognitive anxiety between silent and noise conditions and home side bias with crowd noise.

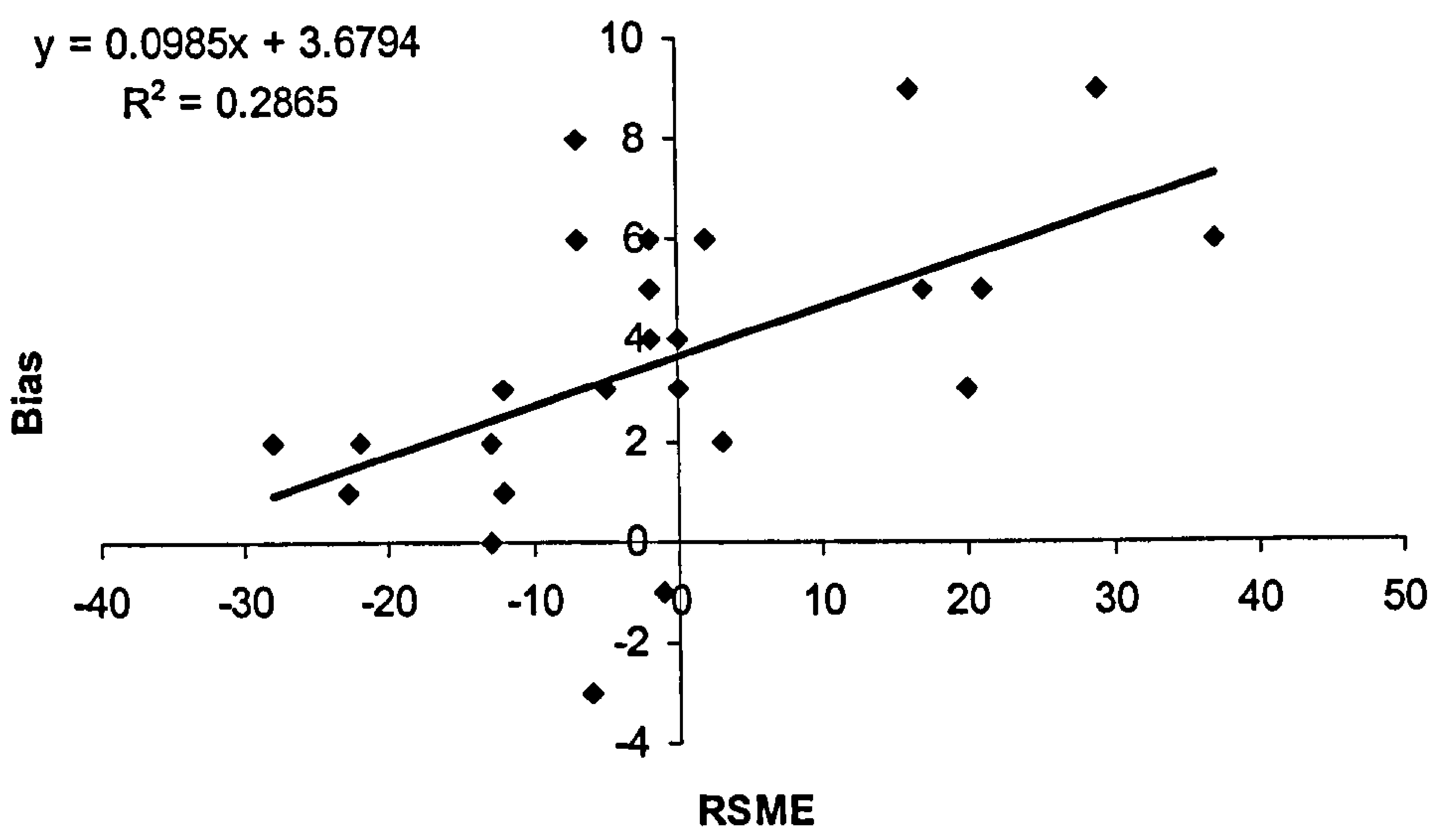

Figure 7.4. Relationship between change in mental effort (RSME) between silent and noise conditions and home side bias with crowd noise.

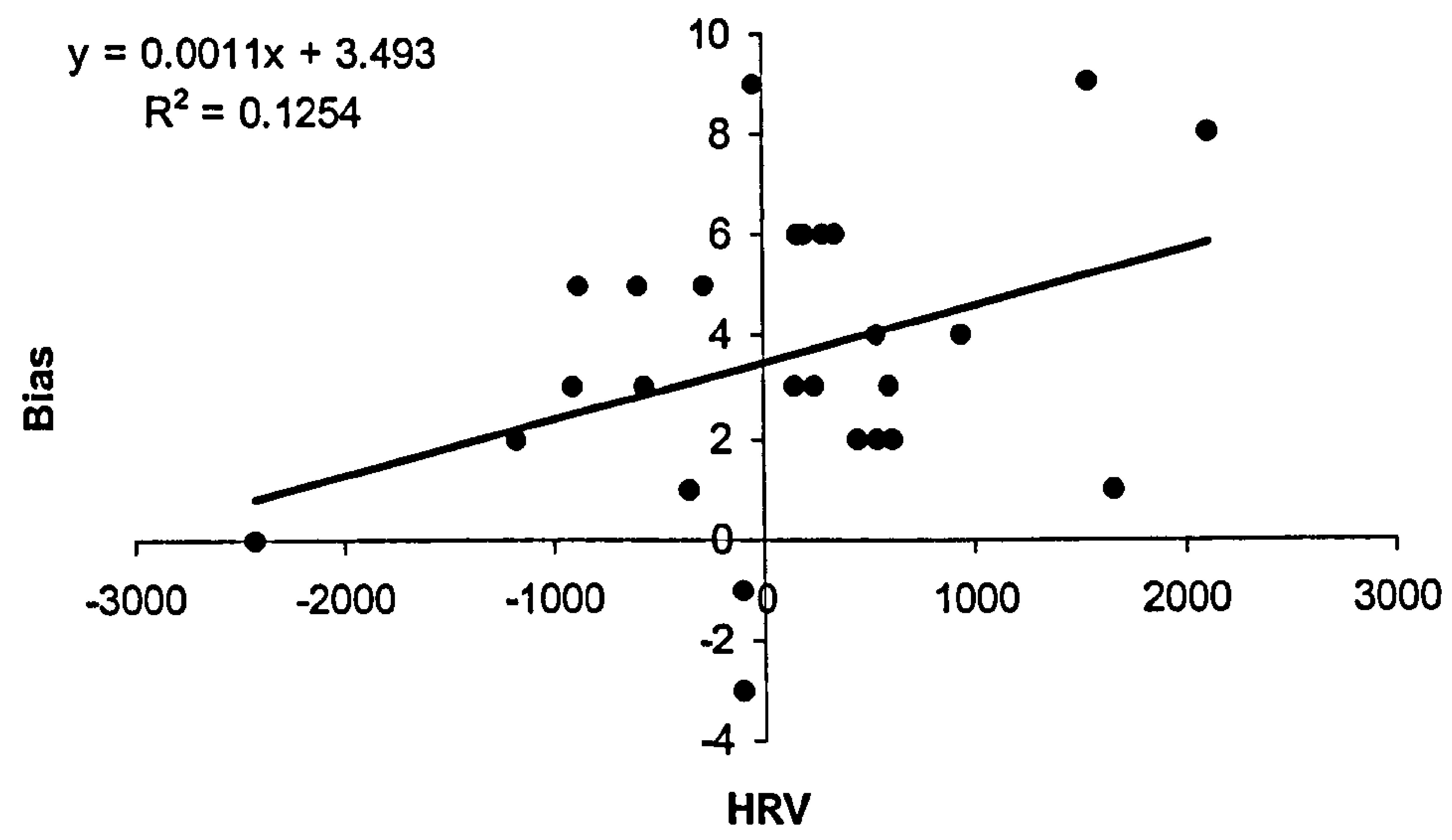

Figure 7.5. Relationship between difference in the change in mental effort (HRV) between silent and noise conditions and home side bias with crowd noise.

These three measures were then fitted as independent variables in a stepwise (backward selection) regression analysis. Intensity of cognitive anxiety was selected first confirming it as the best simple regression model for bias data (T = 3.17, *P* = 0.004), explaining 30.4% of the variation (R^2). The best model for two independent variables added 'RSME' (T = 1.99, *P* = 0.060), whilst slightly reducing the influence of cognitive anxiety (T = 2.14, *P* = 0.043). Finally, fitting all three predictors resulted in a further rise in proportion of variance explained (R^2 = 54.5). However, while 'RSME' and 'HRV' remained significant predictors of bias (T = 2.68, *P* = 0.014 and T = 2.49, *P* = 0.021 respectively), addition of a third independent further reduced the influence of 'cognitive anxiety intensity' (T = 1.84, *P* = 0.08). Despite being the single strongest predictor of bias, much of the variance explained by 'cognitive anxiety intensity' is more thoroughly described by the two mental effort predictors.

Table 7.4. Output of stepwise regression analysis

Step	Constant	Cognitive anxiety (intensity)	RSME	HRV	R^2 (R^2 adjusted)
3	3.40	Coef.=.28 T-value=1.84 P-value =.080	Coef.=0.083 T-value=2.68 P-value=.014	Coef.=.0018 T-value=2.49 P-value=.021	54.45 (47.94)
2	3.50	Coef.=.36 T-value=2.14 P-value=.043	Coef.=.067 T-value=1.99 P-value=.060		40.98 (35.62)
1	3.34	Coef.=.50 T-value=3.17 P-value=.004			30.40 (27.37)

R for regression was significantly different from zero in one ($F_{1,23}$ = 10.05, *P* = 0.004), two ($F_{2,22}$ = 7.64, *P* = 0.003) and three parameter models ($F_{3,21}$ = 8.37, *P* = 0.001).

Bias for each of the 47 challenges was calculated with a similar method to that for the 26 participants. Bias was related to measures of certainty in the silent condition, and change in certainty between noise conditions again using simple Pearson's correlations. Relationships between bias and certainty in silence (r = 0.057, *P* = 0.702), and change in certainty between noise conditions (r = 0.031, P = 0.835) were both weak.

7.4 Discussion

The present study aimed to replicate previous findings (that the presence of crowd noise results in an imbalance of decisions in favour of the home side), while employing a more sensitive repeated measures protocol (see Figure 6.1). Secondly, mechanisms underlying this imbalance were investigated through measurement of anxiety, mental effort and certainty of decision. It was hypothesised that crowd noise would result in an imbalance of decisions in favour of the home side, particularly greater leniency toward the home (see Chapter 5). Certainty in silence (or change in certainty between noise conditions) for each challenge was also hypothesised to decrease with increasing bias. This would support both work on contentiousness of decision (Balmer et al., 2001a) and a cue saliency argument. Those subjects showing the largest imbalance of decisions with crowd noise were also hypothesised to display higher levels of state anxiety and mental effort in the noise condition, supporting the use of an avoidance coping strategy.

As in previous research (Balmer et al., 2001a; Nevill et al., 1999) (see Chapters 4 and 5), the presence or absence of crowd noise had a powerful effect on the participants' decisions. When in the noise condition, participants awarded fewer fouls against home players ($\underline{M}$ = 10.9) than when adjudicating in silence ($\underline{M}$ = 13.9). As with Chapter 5, this discrepancy was not matched for fouls against the away team, with only marginally more fouls against the away team in noise ($\underline{M}$ = 11.1) than in silence ($\underline{M}$ = 10.4). The decrease in decisions against home players with crowd noise was highly significant, with a much lower likelihood of a decision against the home side compared with baseline 'no foul'.

Certainty was found to decrease when participants were awarding fouls (home or away) over 'no foul' decisions. This may simply reflect the test tape containing more clear-cut 'no fouls' than fouls (home or away). More importantly, no relationship was found either between bias and certainty in silence, or change in certainty between noise conditions, for the 47 incidents. If cue saliency particularly important in the crowd noise effect, significant relationships should be found in both cases. As the visual cue becomes weaker (greater uncertainty) so the undiagnostic auditory cue should become increasingly salient resulting in greater bias. With the auditory cue attracting greater attention, it should be over processed regardless of diagnostic value (Payne, 1980) with information that is difficult to interpret (visual cue) being under processed (Bettman, Johnson & Payne, 1990; Johnson, Payne & Bettman, 1988; Stone, Yates, & Parker, 1997). The lack of relationships between certainty and bias questions the validity of such a mechanism, and the sensitivity of subjective ratings of certainty (mean scores only ranged from 6.4 to 8.9). A more objective measure of certainty may be required to satisfactorily resolve the cue saliency mechanism. Formal identification of a cue saliency effect (e.g. see Wallsten & Barton, 1982) is further confounded by the possibility that the crowd may provide contradictory or supportive noise for any given home or away incident. Specific analysis, or manipulation of crowd noise could determine whether crowd noise should result in more or less certainty.

Significant relationships between bias and measures of cognitive anxiety and mental effort provide direct support for the coping strategy argument. It was hypothesized that increasingly anxious participants should anticipate and detect threatening situations and be motivated to avoid the negative or aversive consequences of such incidences by increasing available on-task resources (i.e., mental effort) (Eysenck, 1992). Given the potency of 'making a bad call' in increasing stress in officiating (Kaissidis & Anshel, 1993; Stewart & Ellery, 1998; Taylor, 1990), and the difficulty in controlling the crowd, participants were hypothesised to employ an avoidance-type coping strategy (Anshel & Weinberg, 1999; Kaissidis-Rodafinos, Anshel & Porter, 1997). A significant positive relationship between decision bias and intensity of cognitive anxiety provided strong support for such a strategy, as participants demonstrating greatest bias also exhibited the highest cognitive anxiety values (CSAI-2). Significant positive relationships were also revealed between bias and both measures of mental effort (RSME and HRV). Participants most influenced by crowd noise dealt with their increased anxiety proactively, by making more decisions in favour of the home side. Subsequent stepwise regression analysis provided further powerful evidence for an avoidance coping strategy. While all three predictors (cognitive anxiety intensity, RSME, HRV) alone were significantly related to bias, when all were fitted simultaneously, the influence of cognitive anxiety was reduced. This suggested that the two mental effort measures (RSME, HRV) were explaining similar variance in bias to cognitive anxiety, with an increased allocation of cognitive resources in response to increased anxiety (Eysenck, 1992).

Participants could not completely remove themselves from the decision-making situation (Humphreys and Revelle, 1984) to avoid the perceived stress of making a bad call. Instead, those prone to higher levels of cognitive anxiety (or larger increases with crowd noise) increased mental effort accordingly. This resulted in anticipation and 'avoidance' of further negative consequences (i.e. increased anxiety) of making a 'bad call' or 'contentious decision' (Eysenck & Calvo, 1992). As hypothesised, avoidance took the form of an imbalance of decisions in favour of the home side, and therefore, relationships between bias and allocation of cognitive resources. Importantly, all three predictors (cognitive anxiety, RSME, HRV), whilst related to bias, showed evidence of decreasing as well as increasing in the noise condition (deviation from baseline compared to silent condition). This suggests that the increased allocation of cognitive resources and avoidance strategy, determine degree of bias rather than providing a formal cause.

The findings have implications in the selection of top-flight referees. Increased bias was related to larger increases in levels of cognitive anxiety and mental effort, from baseline to experiment, between noise conditions. Those participants showing the largest bias with crowd noise were also showing larger increases in mental effort (RSME, HRV) and intensity of cognitive anxiety (CSAI-2). Selecting referees who possess a superior coping strategy in such a task could reduce the imbalance of decisions in favour of the home side and subsequent home advantage.

Chapter 8. Summary and future directions

8.1 Summary

The current thesis contributes to the body of knowledge on home advantage and officiating bias. The findings expand upon previous research, developing novel statistical solutions to both the archival quantification of home advantage and measurement of the influence of crowd noise upon officials' decisions. The present epilogue summarises these findings and their implications, as well as providing possible directions for future research.

8.1.1 Quantifying archival home advantage

In Chapter 3 indices of home advantage were obtained for Winter Olympic competition from 1908 to 1998. These indices assessed home advantage while controlling for nation strength, changes in the number of medals on offer and the performance of 'non-hosting' nations. Some evidence of home advantage was found in figure skating, freestyle skiing, ski jumping, alpine skiing and short track speed skating. In contrast, little or no home advantage was observed in ice hockey, Nordic combined, Nordic skiing, bobsled, luge, biathlon and speed skating. Most significantly, when events were grouped according to whether they were subjectively assessed by judges or not, significantly greater home advantage was observed in the subjectively assessed events ($P = 0.037$). This was a reflection of superior home performance, suggesting that judges were scoring home competitors disproportionately higher than away competitors. This also questioned the existence of home advantage in objectively judged events and/or events with little input from officials, with such events exhibiting negligible home advantage. Familiarity with local conditions was shown to have some effect, particularly in alpine skiing, though the bobsled and luge showed little or no advantage over other events. Regression analysis showed that the number of time zones and direction of travel produced no discernible trends or differences in performance, though this may have been a reflection of the lack of information regarding time of arrival/event. Techniques used in Chapter 3 were further developed in archival summer Olympic research in Chapter 6 in obtaining fair indices of home advantage.

8.1.2 Explaining the influence of crowd density

Previous quasi-experimental research has established that increasing crowd density (e.g. Agnew and Carron, 1992; Schwartz and Barsky, 1977) or crowd noise (Acker, 1997; Zeller & Jurkovac, 1989a; Zeller & Jurkovac, 1989b) enhances home advantage in major team games. Officials have also been shown to make more subjective decisions in favour of the home side (Nevill et al., 1996). This led to the suggestion that the crowd may influence officials to subconsciously favour the home side (e.g. see Nevill et al., 1996; Pollard et al., 1986). Laboratory based experimental research in Chapters 4 and 5 tested this proposal, by asking participants to make refereeing decisions either in the presence of recorded crowd noise, or in silence. Two preliminary studies (Chapter 4) demonstrated the influence of crowd noise upon participants. In the first of these (Study 4.1), ANOVA (with an arcsine transformation to stabilise variances) showed a significant two-way 'noise group' x 'team representation interaction (P = 0.019) for 11 experienced participants. This was followed by examination of a subset of more contentious incidents (25 of 47 where total agreement was not achieved). These were analysed as binomial proportions, again demonstrating the importance of the 'noise' by 'team representation' interaction (P<0.01). The importance of this interaction term showed the participants tendency to over penalise the away team and under penalise the home team when adjudicating in the presence of crowd noise. In addition to this finding, the similarity of the match referee's decisions to the noise group supports the influence of crowd noise and gives a possible explanation for the phenomenon of home advantage in team sports.

Particularly complex refereeing tasks have often resulted in systematic errors from officials. This has been demonstrated for both subjectively judged sports (e.g. Ansorge & Scheer, 1988; Ste-Marie, 1996) and sports where officials enforce rules without judging outcome (e.g. Oedejans et al., 2000; Sanabria et al., 1999). The second preliminary study (Study 4.2) used the same test tape as Study 4.1, with two additional options to gauge participants' confidence. Participants were able to respond no foul (certain), no foul (uncertain), foul (uncertain) or foul (certain) in a four alternative forced choice protocol. This allowed assessment of complexity/contentiousness of decision, and whether any imbalance in favour of the home side increases with an increasingly contentious subset of incidents. Normalised standard score t-values measured the size of the crowd noise effect upon decisions, as least contentious challenges were systematically removed. Those challenges exhibiting greatest agreement between participants and greater certainty were eliminated first, leaving challenges with decreasing certainty and agreement. Imbalance in favour of the home side with crowd noise was shown to increase as less contentious decisions were removed, peaking for 36 of 52 incidents ($P = 0.031$). Following this peak, the t-values generally decreased, as number of incidents grew small. These results supported the previous study (Nevill et al., 1999) (Study 4.1) and provided some evidence that the influence of crowd noise increased with increasing contentiousness of decision. However, the decrease in effect size following the peak questioned the effectiveness of the assessment of contentiousness/complexity. Chapters 5 and 7 expand upon the preliminary findings of Chapter 4, with improved protocol and larger/more experienced groups of participants.

In Chapter 5 the findings of Chapter 4 were replicated and expanded, with a large sample of qualified referees and improved experimental protocol. The study again examined whether the presence or absence of crowd noise might influence participants when assessing various tackles/challenges recorded on videotape. In this case, however, four different decision options were offered; home foul, away foul, no foul or uncertain (no foul). This improved upon previous methodology by eliminating the need for possibly subjective judgement of who initiated each foul (home or away). This in turn allowed complete disagreement between participants as to who committed a given foul, which was not possible in the protocols of Chapter 4. In addition, participants were forty qualified referees (from newly qualified to 43 years of refereeing experience), allowing refereeing experience to be entered as a continuous covariate (with both linear and quadratic terms). Logistic regression was used to assess the effect of crowd noise and years of experience on referees' decisions. Despite some differences with experience, most importantly, the lack of an interaction between 'refereeing experience' and 'crowd noise' suggests that these observed changes with refereeing experience were consistent between noise conditions. The presence of crowd noise, however, had a dramatic overall effect on the decisions made by qualified referees. Those viewing the challenges with background crowd noise were more uncertain in their decision-making and awarded significantly fewer fouls (15.5%) against the home team, compared with those watching in silence. The noise of the crowd influenced referees' decisions to favour the home team. Proposals are made to explain the mechanisms underlying the replicable crowd noise effect. Firstly, it is suggested that referees' decisions may be influenced by the salient nature of crowd noise and the potential use of heuristic strategies. It is proposed that in increasingly difficult decisions, the auditory stimulus (crowd noise) will become progressively more salient compared with the visual stimulus. Previous research has demonstrated a tendency to attend to the most salient cue, regardless of its diagnostic value (e.g. Payne, 1980; Wallsten and Barton, 1982). Similarly, the 'as if' heuristic suggests that if cues are not perfectly reliable or diagnostic, such cues will be utilised 'as if' they are of equal importance (Wickens & Holland, 2000). Use of either of these strategies could explain the existence of a crowd noise effect. Secondly, a stress/anxiety argument proposes that referees may be avoiding potential crowd displeasure by making decisions in favour of the home team (Anshel & Weinberg, 1999; Kaissidis-Rodafinos, Anshel, & Porter, 1997).

8.1.3 Putting team games in context

In Chapter 6 home advantage was assessed for five event groups in summer Olympic competition. The chapter expanded upon archival work in Chapter 3 by using a larger data set and more sophisticated Generalised Linear Interactive Modelling (GLIM) software for binomial response variables (r points from a possible n). This analysis was necessitated by the failure of the traditional arcsine transformation to correct heteroscedacity, and marked departures from normality (see Figure 6.1). As with Chapter 3, Chapter 6 aimed to identify differences in home advantage between groups of events. In Chapter 6 home advantage was compared in two subjectively judged groups (gymnastics, boxing), two objectively judged (track and field, weightlifting) and team games (where officials enforce rules, without directly scoring outcome).

Importantly, analysis identified and controlled for a number of confounding factors. Notably, an 'athletes' covariate (proportion of total athletes entered) was found to co vary with successful performance. Controlling for this covariate proved central to fair assessment of home advantage. Difference in slopes (estimates) for this covariate highlighted the need to split analysis pre and post-war, with its overall influence apparent in the marked difference between non-adjusted and adjusted performance. Similarly, a highly significant 'nation' main effect throughout, confirmed concerns of previous research over the need to control for 'team/competitor quality' (Holder & Nevill, 1997; Madrigal & James, 1999; Nevill et al., 1997; Schwartz & Barsky, 1977).

As with Chapter 3, analysis established a significant home/away by event group interaction, both pre and post-war. Highly significant home advantage was found in event groups, which were either subjectively judged (gymnastics, boxing) or relied on subjective decisions (team games). Home advantage for these three groups was significantly greater than that of the two objectively judged groups (track and field, weight lifting). These objectively judged groups showed no home advantage (and even away advantage), pre and post-war. With respect to subjectively judged events, this confirms previous winter Olympic findings (Balmer et al., 2001b), that such disciplines enjoy significantly greater home advantage than events with little officiating input. Evidently, this officiating component is vital to the degree of (and indeed existence of) home advantage in individual sports, with the potential for biased officiating in subjectively judged events (Ansorge & Scheer, 1988), realised for home advantage.

A significantly large home advantage for team games (comparable to subjectively judged groups) supported previous experimental work demonstrating the influence of crowd noise upon refereeing decisions (see Balmer et al., 2001a; Nevill et al., 1999; Chapters 4 and 5). Previous research has highlighted crowd factors as the dominant cause of home advantage, able to either influence players or officials to alter performance to favour the home side/nation (Nevill et al., 1996; Pollard 1986). Competitors in all of the event groups enjoyed consistently large and vocal crowds. If these crowds were able to influence players/athletes performance, home advantage would be observed for all event groups. Significant home advantage in the three event groups with substantial officiating input supports the latter hypothesis, that the crowd is able to influence officials to favour the home side. By controlling for other possible factors, Chapter 6 placed both home advantage in team games, and the crowd noise effect into context. The study suggested that the imbalance observed with crowd noise in football translates to a sizeable home advantage, significantly larger than objectively judged events and comparable to that of subjectively judged events.

8.1.4 Mechanisms underlying the influence of crowd noise

In Chapter 7, the findings of Chapters 4 and 5 are replicated, while investigating mechanisms underlying the imbalance. The protocol used was similar to that of Chapter 5, with 26 participants taking part. The study improved upon Chapter 5 in two key areas; firstly, a repeated measures design was used with each participant adjudicating with crowd noise and in silence, and secondly, subjective ratings and physiological measurements were taken to examine possible causes for the observed imbalance. In Chapter 5 two theories to explain the crowd noise effect were proposed. First, increased relative saliency of the auditory cue could lead to it being over processed, resulting in bias in favour of the home side. Second, participants may be using a coping strategy of avoidance to prevent the potentially negative effects of crowd noise. Measurement of decision certainty, anxiety (STAI, CSAI-2, heart rate) and mental effort (RSME, heart rate variability (HRV) tested the plausibility of these theories. Certainty in the silent condition for each challenge was hypothesised to decrease with increasing bias (as the auditory cue should be increasingly influential). This would support both work on contentiousness of decision (Balmer et al., 2001a) and a cue saliency argument (Wallsten & Barton, 1982). Those subjects showing the largest imbalance of decisions with crowd noise were also hypothesised to display higher levels of state anxiety and mental effort in the noise condition, supporting the use of an avoidance coping strategy.

As in previous research (see Balmer et al., 2001a; Nevill et al., 1999; Chapters 4 and 5), the presence or absence of crowd noise had a powerful effect on the participants' decisions, with this discrepancy (as in Chapter 5) being primarily for 'home fouls'. When in the noise condition, participants awarded fewer fouls against home players ($\underline{M}$ = 10.9) than when adjudicating in silence ($\underline{M}$ = 13.9). This decrease was highly significant, with a much lower likelihood ($\underline{p} < .001$) of a decision against the home side compared with baseline 'no foul'. No relationship was found either between bias and certainty in silence, or change in certainty between noise conditions, for the 47 incidents, questioning the validity of such a mechanism. The finding could also reflect a lack of sensitivity in subjective ratings of certainty (mean scores ranging from 6.4 to 8.9 out of 10). A more objective measure of certainty may be required to satisfactorily resolve the cue saliency mechanism.

In contrast, significant relationships were observed between bias and measures of cognitive anxiety and mental effort providing support for a coping strategy argument (Anshel & Weinberg, 1999; Kaissidis-Rodafinos, Anshel & Porter, 1997). Participants demonstrating greatest bias also exhibited highest cognitive anxiety (CSAI-2) and mental effort (RSME and HRV). Additional stepwise regression suggested that these two mental effort measures (RSME, HRV) were explaining similar variance in bias to cognitive anxiety, with a general increased allocation of cognitive resources in response to increased anxiety (Eysenck, 1992). As hypothesised, increasingly anxious participants were motivated to avoid the negative or aversive consequences of unpopular decisions incidences by increasing available on-task resources (i.e., mental effort) (Eysenck, 1992). These participants manifested this avoidance coping strategy by making more decisions in favour of the home side.

8.2 Future directions

8.2.1 Methodology

The current programme of work has both methodological implications for future quasi-experimental research, and provides directions for experimental studies. Following initial attempts to simply identify home advantage (e.g. Edwards, 1979; Schwartz & Barsky, 1977), much quasi-experimental research has focused upon isolating particular factors (e.g. travel, familiarity) and assessing their contribution to home advantage (e.g. Balmer et al., 2001b; Barnett & Hilditch, 1993; Courneya & Carron, 1991). In all such cases it is essential to obtain a fair measure of home advantage (controlling for confounding variables). Previous research has identified team/competitor quality as a confounding variable (e.g. Madrigal & James, 1999; Nevill & Holder, 1997). Both Chapter 3 and Chapter 6 confirm the influence of team quality, proposing two differing techniques to partition out its influence (prior to, or during analysis). Importantly, though, both quasi-experimental Chapters identified further confounding variables, including 'away team performance', 'rule changes' and significantly, in Chapter 6, 'athlete participation'. In Chapter 6 the 'athlete participation' covariate was shown to have a vast influence upon home advantage, as well as demonstrating how such a covariate can be correctly entered in analysis. In the summer Olympics, controlling for 'athlete participation' demonstrated home advantage to be illusory for objectively judged event groups (post-war). Importantly, home advantage without such a covariate had been highly significant. Both Chapters 3 and 6 highlight the need to carefully identify confounding variables, and provide guidance in controlling for their influence. Future quasi-experimental research should employ similar techniques to avoid errors in assessing home advantage.

A number of analyses used binomial proportions (r from n) as response variables, and demonstrated the advantages (and simplicity) of binomial analyses in GLIM (General Linear Interactive Modelling) in such common situations. Such analyses were employed in Chapters 4 (Study 4.1), 5 and 6. Analyses addressed failure to fulfil distributional requirements of ANOVA in all cases, particularly in Chapter 6, where the arcsine transformation (e.g. Winer, 1962; Zar, 1999) was clearly not effective. Problems associated with repetition of the 'experience' covariate in Chapter 5 were also corrected by collapsing data into a binomial proportion, with follow up binomial analysis (equivalent to binary logistic regression). Future research should consider the use of similar analyses, as a more effective solution than traditional arcsine transformation (see Chapters 4 and 6) and in many cases as a more appropriate analysis than ANOVA or ANCOVA.

8.2.2 Experimental vs. archival research

In Chapters 3 and 6 the enhanced home advantage for events where officials directly judge outcome was highlighted, speculating that the crowd influence upon officials may be responsible. Laboratory based experimental work has been conducted for such events (Plessner, 1999; Scheer & Ansorge, 1975; Scheer, Ansorge & Howard, 1983), though as with quasi-experimental work the focus has been on other forms of bias (expectation bias, bias from false feedback, team order bias) and not home advantage. Future research could test this by applying a similar methodology to Chapters 4,5 and particularly 7 to subjectively judged events. As with team games (experimental Chapters 4,5 and 7 vs. archival Chapter 6), this could tie together the enhanced home advantage observed in subjective events (Chapters 3 and 6) with possible causes.

Focus on other forms of bias (particularly nationalistic/political, Ansorge & Scheer, (1988)) has resulted in scoring systems designed to negate such bias (e.g. Frederiksen & Machol, 1988; International Skating Union, 2000). As discussed in the general introduction, such scoring strategies do not address, and may even enhance home advantage. Future quasi-experimental work could examine how scoring adjustment systems' impact on home advantage, both within and between subjectively judged sports.

In Chapters 4,5 and 7 a strong and consistent crowd noise influence upon officiating was identified. While, intuitively, this effect should result in substantial home advantage, these experimental studies were unable to directly relate the observed imbalance to home advantage. With this in mind, the summer Olympic research in Chapter 6, put football (or more generally team games) in to context alongside other event groups. Traditional factors thought to influence home advantage were kept relatively constant, allowing focus upon crowd (and officiating) as causes of home advantage. Firstly, travel (though often great distances) was similar for all events, and had little influence in previous winter Olympic work (see Balmer et al., 2001b; Chapter 3). Secondly, event groups were chosen which had minimal changes in equipment or pitch dimensions between host nations, reducing influence of familiarity with local conditions. Finally, the sports chosen did not have differing rules for home and away teams/competitors (e.g. Courneya & Carron, 1990). Two explanations had been proposed to explain a crowd noise effect upon home advantage. Either, crowd noise is able to influence players/athletes to alter their performance, or influence officials to make more decisions in favour the home side/competitor (Nevill et al., 1996; Pollard 1986). All events in Chapter 6 featured large, supportive crowds. If players/athletes performance were altered, therefore, all event groups would demonstrate significant home advantage. In fact, Chapter 6 showed no home advantage for objectively judged events, and highly significant home advantage for team games. This not only provided powerful support for the latter explanation of the crowd noise effect (Nevill et al., 1996; Pollard 1986), but also for experimental work in Chapters 4, 5 and 7. The influence of crowd noise upon officials (see Balmer et al., 2001a; Nevill et al., 1999; Chapters 4, 5 and 7) translated to a sizeable home advantage, comparable to subjectively judged sports. Future work could further attempt to combine experimental and archival findings (particularly in the case of subjectively judged sports) to further explain why certain sports enjoy enhanced home advantage.

8.2.3 Explaining the influence of crowd noise (and its implications)

On four occasions in the current programme of work, experimental studies (Chapters 4,5 and 7) identified a significant influence of crowd noise upon decisions in football. These findings confirm the importance of crowd factors to the home advantage, and illustrate how the crowd may have an influence.

In the first instance (discussed in Chapter 5), these findings have practical implications for the possible use of a fourth 'video referee'. If such an official is to be used to adjudicate on contentious (and highly significant) decisions, they should do so in silence, avoiding the potential influence of crowd noise. Secondly, not all experimental participants were influenced by crowd noise to the same extent (see Chapters 5 and 7). Significantly, increased bias (greater noise influence) was related to larger increases in levels of cognitive anxiety and mental effort, from baseline to experiment, between noise conditions. Those participants showing the largest bias with crowd noise were also showing larger increases in mental effort (RSME, HRV) and intensity of cognitive anxiety (CSAI-2). This suggested that as speculated in Chapter 5, participants in Chapter 7 were employing an 'avoidance' coping strategy (e.g. Anshel & Weinberg, 1999; Kaissidis-Rodafinos, Anshel & Porter, 1997). These findings have practical implications upon selection of top-flight referees. Selecting referees who possess a superior coping strategy in such a task could reduce the imbalance of decisions in favour of the home side and subsequent home advantage. Similarly, teaching appropriate coping strategies may impact upon the crowd noise effect. Anshel and Weinberg (1999), suggest that psychological intervention could teach officials more adaptive coping strategies. While such interventions may reduce stress symptoms, it is unclear how they may influence the crowd noise effect. Future research could assess the impact of teaching coping strategies upon both stress/anxiety and the influence of crowd noise.

Developing perceptual expertise in referees could also reduce the influence of crowd noise. Video simulation used to train perceptual skill in players (for a review see Williams & Grant, 1999) could equally be applied to referees. Paired with instruction and feedback, video simulation could help referees to identify contentious incidents, and the potential influence of crowd noise, reducing its impact. Such an approach has been successfully employed for both anticipation of penalty kick (Williams & Burwitz, 1993) and tennis serve direction (Farrow, Chivers, Hardingham & Sachse, 1998) and could be generalised to a refereeing context. Future research should also test the external validity of this 'avoidance' strategy by assessing officials 'on field' performance, compared to physiological measures of anxiety and mental effort.

In Chapter 5, a number of possible mechanisms to explain the crowd noise effect were suggested. A cue saliency mechanism suggested that crowd noise may be over processed (leading to an imbalance) as decisions grew increasingly difficult (Payne, 1980) due to the experimental time constraints (Wallsten & Barton, 1982). An avoidance coping strategy (Anshel & Weinberg, 1999) was also proposed, suggesting that participants may 'avoid' the anxiety of making a bad call (e.g. Taylor, 1990) by making decisions in favour of the home side. Pilot work (Balmer et al., 2001a) (Chapter 4) did suggest that bias increased with contentiousness of decision, though testing the cue saliency argument more directly (Chapter 7) did not yield relationships between certainty of decision and bias. Some previous research has characterised types of crowd noise, and their relative effects upon player performance (Greer, 1983; Thirer & Rampey, 1979). Future research could employ a similar approach, and possibly manipulation of crowd noise, to more thoroughly address a cue saliency mechanism. This would allow control of both the ambiguity of the visual cue and the characteristics (saliency) of the auditory cue.

Overall, the programme of work has enhanced understanding of the home advantage, assessed possible causes and their underlying mechanisms. As Courneya and Carron (1992) suggested, the thesis addresses the 'when' and 'why' of home advantage, rather than simply its existence. Home advantage is shown to occur/increase when officials have a subjective input, either in enforcing rules or judging outcome. For team games (and quite possibly for subjectively judged sports), the influence of crowd noise seems to explain the increase and/or occurrence of home advantage. Experimental participants were shown to make an imbalance of decisions in favour of the home side when adjudicating with crowd noise, primarily by making fewer decisions against home players. Raised levels of cognitive anxiety and mental effort in referees most susceptible to crowd noise, suggest the imbalance is at least partially explained by the adoption of an 'avoidance' coping strategy (e.g. see Anshel & Weinberg, 1999). This has implications both for the training and selection of referees. These findings enhance our understanding of home advantage, though the phenomenon is still far from explained. Identifying the impact of officiating upon home advantage and the influence of crowd noise upon officiating, though, is a major step in this challenge.

References

References

Acker, J.C. (1997). Location variations in professional football. *Journal of Sport Behavior,* **20(3)**, 247-259.

Adams, R.D., & Kupper, S.J. (1994). The effect of expertise on peak performance: the case of home-field advantage. *Journal of Sport Behavior,* **17**, 108-119.

Agnew, G.A., & Carron, A.V. (1994). Crowd effects and the home advantage. *International Journal of Sport Psychology*, **25**, 53-62.

Aitkin, M., Anderson, D., Francis, B., & Hinde, J. (1989) *Statistical Modelling in GLIM.* Oxford University Press.

Anshel, M.H., & Weinberg, R.S. (1999). Re-examining coping among basketball referees following stressful events: implications for coping interventions. *Journal of Sport Behavior*, **22**, 141-161.

Ansorge, C.J., & Scheer, J.K. (1988). International bias detected in judging gymnastic competition at the 1984 Olympic games. *Research Quarterly for Exercise and Sport*, **59**, 103-107.

Ansorge, C.J., & Scheer, J.K., Laub, J., & Howard, J. (1978). Bias in judging women's gymnastics induced by expectations of within-team order. *Research Quarterly*, **49**, 339-405.

Askins, R.L. (1978). Observations- The official reacting to pressure. *Referee,* **4**, 17-20.

Balmer, N.J., Nevill, A.M. and Williams, A.M. (2001a). Crowd noise and the home advantage in Association Football: are crowds more able to influence 'contentious' decisions? (abstract). *Journal of Sports Sciences*, **19**, 15-16.

Balmer, N.J., Nevill, A.M., & Williams, A.M. (2001b). Home advantage in the Winter Olympics (1908-1998). *Journal of Sports Sciences*, **19**, 129-139.

Barnett, V., & Hilditch, S. (1993). The effect of an artificial pitch surface on home team performance in football (soccer). *Journal of the Royal Statistical Society*, **156,** 39-50.

Bray, S.R. (1999). The home advantage from an individual team perspective. *Journal of Applied Sport Psychology,* **11(1),** 116-125.

Bray, S.R., & Carron, A.V. (1993). The home advantage in alpine skiing. *The Australian Journal of Science and Medicine in Sport*, **25(4),** 76-81.

Bettman, J.R., Johnson, E.J., & Payne, J. (1990). A componential analysis of cognitive effort and choice. *Organizational Behavior and Human Performance*, **45,** 111-139.

Catterall, C., Reilly, T., Atkinson, G., & Coldwells, A. (1993). Analysis of the work rates and heart rates of association football referees. *British Journal of Sports Medicine,* **27(3),** 193-196.

Clarke, S.R., & Norman, J.M. (1995). Home ground advantage of individual clubs in English soccer. *The Statistician*, 44, 509-521.

Courneya, K.S., & Carron, A.V. (1990). Batting first versus last: Implications for the home advantage. *Journal of Sport and Exercise Psychology*, **12,** 312-316.

Courneya, K.S., & Carron, A.V. (1992). The home advantage in sport competitions: A literature review. *Journal of Sport and Exercise Psychology*, **14,** 13-27.

Craven, B.J. (1998). A psychophysical study of leg-before-wicket judgements in cricket. *British Journal of Psychology,* **89,** 555-578.

Davids, K., & Gill A. (1995). Multidimensional state anxiety prior to different levels of sport competition: Some problems with simulation tasks. *International Journal of Sport Psychology*, **23(3),** 359-382.

De Waard, D. (1996). *The measurement of driver mental workload.* Groningen, Netherlands: Rijksuniveriteit Groningen.

Dowie, J. (1982). Why Spain should win the world cup. *New Scientist*, **94**, 693-695.

Draper N.R., & Smith, H. (1981) *Applied regression analysis.* 2nd Edition, New York: Wiley.

Duffy, L.J., & Hinwood, D.P. (1997). Home field advantage: does anxiety contribute? *Perceptual and Motor Skills*, **84**, 283-286.

Edwards, J. (1979). The homefield advantage. In: J.H. Goldstein (Ed.), *Sports, games and play: social and psychological viewpoints.* (pp 409-430).Hillsdale, NJ: Erlbaum.

Eysenck, M.W. (1992). *Anxiety: The cognitive perspective.* Hove: Lawrence Erlbaum Associates Ltd.

Eysenck, M.W., & Calvo, M.G. (1992). Anxiety and performance: the processing efficiency theory. *Cognition and Emotion,* **6(6),** 409-434.

Fairclough, S.H., & Graham, R. (1999). Impairment of driving performance caused by sleep deprivation or alcohol: a comparative study. *Human Factors,* **41(1),** 118-128.

Farrow, D., Chivers, P., Hardingham, C., & Sachse, S. (1998). The effect of video-based perceptual training on the tennis return of serve. *International Journal of Sport Psychology,* **29(3),** 231-242.

Frederiksen, J.S., & Machol, R.E. (1988). Reduction of paradoxes in subjectively judged competitions. *European Journal of Operational Research,* **35,** 16-29.

Gaillard, A.W.K., & Wientjes, C.J.E. (1994). Mental load and work stress as two types of energy mobilization. *Work & Stress,* **8,** 141-152.

Gammon, C. (1988). Fighting a decision. *Sport Illustrated,* **69(21),** 62-64.

Gayton, W.F., & Coombs, R. (1995). The home advantage in high school basketball. *Perceptual and Motor Skills*, **81**, 1344-1346.

Gayton, W.F., Mutrie, S.A., & Hearns, J.F. (1987). Home advantage: Does it exist in women's sports. *Perceptual and Motor Skills*, **65**, 653-654.

Gayton, W.F., & Langevin, G. (1992). Home advantage: does it exist in individual sports? *Perceptual and Motor Skills*, **47**, 706.

Glamser, F.D. (1990). Contest location, player misconduct, and race: a case from English soccer. *Journal of Sport Behavior*, **13**, 41-49.

Gould , D., & Krane. (1992). The arousal-athletic performance relationship: Current status and future directions. In T.S. Horn (Ed.), Advances in Sport Psychology. (pp. 119-142). Champaign, IL: Human Kinetics.

Greenberg, S. (2000). *Whitaker's Olympic almanack. An encyclopaedia of the Olympic games.* London: The Stationary Office.

Greer, D.L. (1983). Spectator booing and the home advantage: A study of social influence in the basketball arena. *Social Psychology Quarterly*, **46**, 252-261.

Hanley, E.A. (2000). A perennial dilemma: artistic sports in the Olympic games. *Journal of Olympic History*, **8(2)**, 39-46.

Hansen, J., Ansorge, C., & Scheer, J. (1984). Judging gymnastics. *Referee*, **9(7)**, 29-31.

Hardy, L., Jones, J.G., & Gould, D. (1996). *Understanding psychological preparation for sport: Theory and practice of elite performers*. Chichester, UK: John Wiley & Sons.

Hockey, G.R.J. (1986). Changes in operator efficiency as a function of operator stress, fatigue, and circadian rhythms. In K.R. Boff, L.Kaufman, and J.P. Thomas (Eds.). *Handbook of perception and human performance.* (vol. 2, pp. 44.1-44.49). New York: John Wiley.

Holder, R.L., & Nevill, A.M. (1997). Modelling performance at international tennis and golf tournaments: is their a home advantage? *Statistician*, **46(4)**, 551-559.

Humphreys, M.S., & Revelle, W. (1984). Personality, motivation, and performance: a theory of the relationship between individual differences and information processing. *Psychological Review,* **91(2)**, 153-184.

International Skating Union (2000). *Special regulations figure skating 2000.* International Skating Union.

Janelle, C.M., Singer, R.N., & Williams, A.M. (1999). External distraction and attentional narrowing: Visual search evidence. *Journal of Sport and Exercise Psychology*, **21**, 70-91.

Jehue, R., Street, D., & Huizenga, R. (1993). Effect of time zone and game time changes on team performance: National Football League. *Medicine and Science in Sports and Exercise*, **25**, 127-131.

Johnson, E.J., Payne, J.W., & Bettman, J.R. (1988). Information displays and preference reversals. *Organizational Behavior and Human Decision Processes*, **42**, 1-21.

Johnson, E.M., Cavenaugh, R.C., Spooner, R.L., & Samet, M.G. (1973). Utilization of reliability estimates in Bayesian inference. *IEEE Transactions on Reliability*, **22**, 176-183.

Jones, G., & Swain, A. (1992).Intensity and direction dimensions of competitive state anxiety and relationships with competitiveness. *Perceptual and Motor Skills,* **74**, 467-472.

Jones, J.G., & Cale, A. (1989). Relationships between multidimensional competitive state anxiety and cognitive and motor subcomponents of performance. *Journal of Sports Sciences*, **7**, 129-140.

Jorna, P.G.A.M. (1992). Spectral analysis of heart rate and psychological state: A review of its validity as a workload index, ***BiologicalPsychology*, 34**, 237-257.

Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review*, **80**, 251-273.

Kaissidis, A.N., & Anshel, M.H. (1993). Sources and intensity of acute stress in adolescent and adult Australian basketball referees: a preliminary study. *The Australian Journal of Science and Medicine in Sport*, **25**, 97-103.

Kaissidis-Rodafinos, A., Anshel M..H., & Porter A. (1997). Personal and situational factors that predict coping strategies for acute stress among basketball referees. *Journal of Sports Sciences*, **15**, 427-436.

Kleinbaun, D.G. (1994). *Logistic regression: A self-learning text.* New York: Springer.

Larsen, J.D., & Rainey, D.W. (1991). Judgement bias in baseball umpires' first base calls: a computer simulation. *Journal of Sport and Exercise Psychology*, **13**, 75-79.

Lefebvre, L.M., & Passer, M.W. (1974). The effects of game location and importance on aggression in team sport. *International Journal of Sport Psychology*, **5**, 102-110.

Lehman, D.R., & Reifman, A. (1987). Spectator influence on basketball officiating. *Journal of Social Psychology*, **127**, 673-675.

Leonard, W.M. (1989). The "Home Advantage": the case of the modern Olympiads. *Journal of sport behavior*, **12(4)**, 227-241.

Lyberg, W. (1996a). *Fabulous 100 years of the IOC. Facts-figures-and much, much more.* Lausanne: International Olympic Committee.

Lyberg, W. (1999b). *The athletes of the summer Olympic games, 1896-1996; Athletics.* Bruty: Allsport.

Lyberg, W. (1999c). *The athletes of the summer Olympic games, 1896-1996; Basketball.* Bruty: Allsport.

Lyberg, W. (1999d). *The athletes of the summer Olympic games, 1896-1996; Boxing.* Bruty: Allsport.

Lyberg, W. (1999e). *The athletes of the summer Olympic games, 1896-1996; Football.* Bruty: Allsport.

Lyberg, W. (1999f). *The athletes of the summer Olympic games, 1896-1996; Gymnastics.* Bruty: Allsport.

Lyberg, W. (1999g). *The athletes of the summer Olympic games, 1896-1996; Hockey.* Bruty: Allsport.

Lyberg, W. (1999h). *The athletes of the summer Olympic games, 1896-1996; Volleyball.* Bruty: Allsport.

Lyberg, W. (1999i). *The athletes of the summer Olympic games, 1896-1996; Waterpolo.* Bruty: Allsport.

Lyberg, W. (1999j). *The athletes of the summer Olympic games, 1896-1996; Weightlifting.* Bruty: Allsport.

McCutcheon, L.E. (1984). The home advantage in high school athletics. *Journal of Sport Behavior*, **7,** 135-138.

Madrigal, R., & James, J. (1999). Team quality and the home advantage. *Journal of sport behavior*, **22(3),** 381-398.

Martens, R.M., Burton, D., Vealey, R.S., Bump, L.A., & Smith, D. (1990). The development of the competitive state anxiety inventory-2 (CSAI-2). In (Eds.) R. Martens, R.S. Vealey, & D. Burton. *Competitive state anxiety in sport* (pp. 117-190). Champaign, IL: Human Kinetics.

Meijman, T.F. (1995). Mental fatigue and the temporal structuring of working times. *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting:* San Diego (pp. 789-793).

Meijman, T.F. (1997). Mental fatigue and the efficiency of information processing in relation to work times. *International Journal of Industrial Ergonomics,* **20,** 31-38.

Mizruchi, M.S. (1985). Local sports teams and celebration of community: a comparative analysis of the home advantage. *The Sociological Quarterly,* **26(4),** 507-518.

Mohr, P.B., & Larsen, K. (1998). Ingroup favoritism in umpiring decisions in australian football. *The Journal of Social Psychology,* **138(4),** 485-504.

Moore, J.C., & Brylinsky, J.A. (1993). Spectator effect on team performance in college basketball. *Journal of Sport Behavior,* **16(2),** 77-84.

Mulder, G. (1979). Mental load, mental effort and attention. In N. Moray (Ed.), *Mental workload: Its\theory and measurement* (pp. 327-343). New York: Plenum.

Nevill, A.M., Balmer, N.J., & Williams, A.M. (1999). Crowd influence on decisions in association football. *The Lancet,* **353,** 1416.

Nevill, A.M., Balmer, N.J., & Williams, A.M. (1999). Can crowd reactions influence decisions in favour of the home side? *Journal of Sports Sciences,* **17,** 830.

Nevill, A.M., Balmer, N.J., & Williams, A.M. (in press). The influence of crowd noise and experience upon refereeing decisions in association football. *Psychology of Sport and Exercise.*

Nevill, A.M., & Holder, R.L. (1999). Home advantage in sport: an overview of studies on the advantage of playing at home. *Sports Medicine,* **28(4),** 221-236.

Nevill, A.M., Holder, R.L., Bardsley, A., Calvert, H., & Jones, S. (1997). Identifying home advantage in international tennis and golf tournaments. *Journal of Sports Sciences*, **15**, 437-443.

Nevill, A.M., Newell, S.M., & Gale, S. (1996). Factors associated with home advantage in English and Scottish soccer. *Journal of Sports Sciences*, **14**, 181-186.

Norusis, M.J. (1994). *SPSS for Windows: Base System User's Guide. Release 6.0.* Chicago, IL: SPSS Inc.

O'Brien, K. (1991). Bias in the judging of international elite gymnasts. In J. Standeven, K.Hardman and D. Fisher (Eds.), *Sport for all: into the 90s.* Aachen, Germany: Meyer & Meyer Verlag.

Oudejans, R.R.D., Verheijen, R., Bakker, F.C., Gerrits, J.C., Steinbrückner, M., & Beek, P.J. (2000). Errors in judging 'offside' in football. *Nature*, **404**, 33.

Pace, A., & Carron, A.V. (1992). Travel and the home advantage. *Canadian Journal of Sports Science*, **17(1)**, 60-64.

Pain, M. (1995). Social facilitation. In T. Morris and J. Summers (Eds.) *Sport Psychology: theory, applications and issues.* Brisbane: John Wiley.

Parfitt, C.J., & Hardy, L. (1987). Further evidence for the differential effects of competitive anxiety upon a number of cognitive and motor subsystems. *Journal of Sports Sciences,* **5**, 62-63.

Park, R., & Werthner, P. (1977). Analysis of politicized bias in judging at the Olympic diving competitions, Montreal, 1976. *Canadian Journal of Applied Sports Sciences*, **2(4)**, 225.

Payne, J.W. (1980). Information processing theory: Some concepts and methods applied to decision research. In T.S. Wallsten (Ed.), *Cognitive processes in choice and decision behavior*. Hillsdale, NJ: Erlbaum.

Pollard, R. (1986). Home advantage in soccer: A retrospective analysis. Journal of Sports Sciences, 4, 237-248.

Puhl, J. (1980). Use of video replay in judging gymnastics vaults. *Perceptual and Motor Skills*, **51(1)**, 51-54.

Rainey, D.W., & Duggan, P. (1998). Assaults on basketball referees: A statewide survey. *Journal of Sport Behavior*, **21**, 113-120.

Rainey, D.W., & Hardy, L. (1997). Ratings of stress by rugby referees. *Perceptual and Motor Skills,* **84,** 728-730.

Rainey, D.W., Larsen, J.D., & Stephenson, A. (1989). The effects of a pitcher's reputation on umpires' calls of balls and strikes. *Journal of Sport Behavior*, **12,** 139-150.

Rainey, D.W., Larsen, J.D., & Willard, M.J. (1987). A computer simulation of sport officiating behavior. *Journal of Sport Behavior*, **10,** 183-191.

Rainey, D., & Winterich, D. (1997). Magnitude of stress reported by basketball referees. *Perceptual and Motor Skills,* **84,** 728-730.

Rossi, A.L., & Madden, J.M. (1979). Clinical judgement of nurses. *Bulletin of the psychonomic society*, **14,** 281-284.

Sanabria, J., Cenjor, C., Márquez, F., Gutierrez, R., Martinez, D., & Prados-Garcia, J.L. (1998). Oculomotor movements and football's law 11. *The Lancet*, **351,** 268.

Scheer, J.K., & Ansorge, C.J. (1975). Effects of naturally induced judges' expectation on the ratings of physical paerformances. *Research Quarterly,* **46,** 463-470.

Schum, D. (1975). The weighing of testimony of judicial proceedings from sources having reduced credibility. *Human Factors*, **17,** 172-203.

Schwartz, B., & Barsky, S.F. (1977). The home advantage. *Social Forces*, **55,** 641-661.

Seltzer, R., & Glass, W. (1991). International politics and judging in Olympic skating events: 1968-1988. *Journal of Sport Behavior*, **14**, 189-200.

Smith, C.A., & Lazarus, R.S. (1993). Appraisal components, core relational themes, and the emotions. *Cognition and Emotion,* **7,** 233-269.

Snyder, E.E., & Purdy, D.A. (1985). The home advantage in collegiate basketball. *Sociology of Sport Journal*, **2**, 352-356.

Spielberger, C.D., Gorusch, R.L., & Lushene, R.E. (1970). *STAI Manual.*California, Consulting Psychologists Press, Inc.

Ste-Marie, D.M. (1996). International bias in gymnastic judging: conscious or unconscious influences? *Perceptual and Motor Skills,* **83(3),** 963-975.

Ste-Marie, D.M., & Lee, T.D. (1996). Prior processing effects on gymnastic judging. *Journal of Experimental Psychology: Learning, Memory and Cognition,* **17(1),** 126-136.

Ste-Marie, D.M., & Valiquette, S.M. (1996). Enduring memory-influenced biases in gymnastics judging. *Journal of Experimental Psychology: Learning, Memory and Cognition,* **12(6),** 1498-1502.

Stewart, M.J., & Ellery, P.J. (1998). Sources and magnitude of perceived psychological stress in high school volleyball officials. *Perceptual and Motor Skills,* **87,** 1275-1282.

Stone, E.R., Yates, J.F., & Parker, A.M. (1997). Effects of numerical and graphical displays on professed risk-taking behavior. *Journal of Experimental Psychology: Applied*, **3(4),** 243-256.

Sumner, J., & Mobley, M. (1981). Are cricket umpires biased? *New Scientist*, **91,** 29-31.

Swift, E.M. (1998). Blind justice. *Sports Illustrated*, **88,** 53-60.

Takei, Y. (1992). Blocking and postflight techniques of male gymnasts performing the compulsory vault at the 1988 Olympics. *International Journal of Sport Biomechanics*, **8**, 87-110.

Taylor, A.H. (1990). Perceived stress, psychological burnout and paths to turnover intentions among sport officials. *Applied Sport Psychology*, **2**, 84-97.

Thirer, J., & Rampey, M. (1979). Effects of abusive spectator behaviour on the performance of home and visiting intercollegiate basketball teams. *Perceptual and Motor Skills*, **48**, 1047-1053.

Trower, P., Gilbert, P., & Sherling, G. (1990). Social anxiety, evolution, and self-presentation: An interdisciplinary perspective. In H. Leitenberg (Ed.), *Handbook of Social and Evaluation Anxiety* (pp. 1-44) USA: Plenum Press.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, **185**, 1124-1131.

Varca, P. (1980). An analysis of home and away game performance of male college basketball teams. *Journal of Sport Psychology*, **2**, 245-257.

Van Meerbeek, R., Van Gool, D., Bollens, J. (1988). Analysis of the refereeing decisions during the world soccer championship in 1986 in Mexico. In T. Reilly, A. Lees, K. Davids, and W.J. Murphy (Eds.), *Science and Football* London: E & FN Spon.

Veltman, J.A., & Gaillard, A.W.K. (1996). Physiological indices of workload in a simulated flight task. *Biological Psychology*, **42**, 323-342.

Wallechinsky, D. (2000). *The complete book of the Olympics*. London: Aurum Press.

Wallsten, T.S., & Barton, C. (1982). Processing probabilistic multidimensional information for decisions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **8**, 361-384.

Waterhouse, J., Reilly, T., & Atkinson, G. (1997). Jet-lag. *The Lancet,* **350,** 1611-1616.

Watson, D., & Friend, R. (1969). Measurement of social-evaluative anxiety. *Journal of Consulting and Clinical Psychology*, **33,** 448-457.

Weinberg, R. S. (1978). The effects of success and failure on the patterning of neuromuscular energy. *Journal of Motor Behavior*, 10, 53-61.

Whissell, R., Lyons, S., Wilkinson, D., & Whissell, C. (1993). National bias in judgements of Olympic-level skating. *Perceptual and Motor Skills*, **77,** 355-358.

Wickens, C.D., & Hollands, J.G. (2000). *Engineering Psychology and Human Performance (Third Edition).* Prentice Hall: New Jersey.

Williams, A.M., & Burwitz, L. (1993). Advance cue utilisation in soccer. In T. Reilly, J. Clarys, and A. Stibbe (Eds.), *Science and football II* (pp. 239-244). London: E. & F.N. Spon.

Williams, A.M., Davids, K., & Williams, J.G. (1999) *Visual Perception and Action in Sport.* Routledge: London.

Williams, A.M., & Elliott, D. (1999). Anxiety and visual search strategy in karate. *Journal of Sport and Exercise Psychology*, **21(4),** 362-375.

Williams, A.M., & Grant, A. (1999). Training perceptual skill in sport. *International Journal of Sport Psychology,***30(2),** 194-220.

Wilson, W.R. (1979). Feeling more than we know: exposure effects without learning. *Journal of Personality and Social Psychology,* **37,** 811-821.

Winer, B.J. (1971*). Statistical Principles in Experimental Design (2nd ed.).* Tokyo: Mcgraw-Hill.

Zajonc, R.B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology,* **9,** Monograph supplement 2(2).

Zeller, R.A., & Jurkovac, T. (1989). A Dome Stadium: does it help the home team in the national football league? *Sport Place International,* **3**, 37-39.

Zeller, R.A., & Jurkovac, T. (1989). Doming the stadium: the case for baseball. *Sport Place International,* **3**, 35-38.

Zijlstra, F.R.H. (1993). Efficiency in work behavior. A design approach for modern tools. PhD thesis, Delft University of Technology. Delft, The Netherlands: Delft University Press.

Appendices

Chapter 3

Balmer, N.J., Nevill, A.M., & Williams, A.M. (2001). Home advantage in the Winter Olympics (1908-1998). *5th Annual Congress of the European College of Sport Science:* Jyvaskyla, (p. 146).

Balmer, N.J., Nevill, A.M., & Williams, A.M. (2001). Home advantage in the Winter Olympics (1908-1998). *Journal of Sports Sciences,* **19,** 129-139.

APPENDIX NOT COPIED

ON INSTRUCTION FROM

UNIVERSITY

Raw data for experimental chapters

Chapter 4 (Study 4.1)

All responses for all challenges

Columns = participants; Rows = challenges

1 = foul, 0 = no foul

silent1	silent2	silent3	silent4	silent5	silent6	referee
*	1	1	1	1	1	1
*	1	1	1	1	1	1
*	0	0	0	0	0	0
*	0	0	0	0	0	1
*	1	1	0	1	0	0
*	1	1	1	1	1	1
*	1	1	1	1	1	0
*	1	1	1	1	1	0
*	1	0	0	0	0	0
*	1	1	1	0	1	1
*	0	1	1	1	1	0
*	1	0	1	0	0	0
*	0	0	0	0	0	0
*	0	0	0	0	0	1
1	1	1	1	1	1	0
1	1	1	1	1	1	0
0	0	0	0	0	0	1
1	1	1	1	1	1	0
1	1	1	1	1	1	0
1	1	1	1	1	1	1
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	1
0	1	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
1	1	1	1	1	1	1
0	0	0	0	0	0	1
1	1	1	1	1	1	1
0	0	0	0	0	0	1
1	1	1	1	1	1	1
0	0	0	0	0	0	0
1	1	1	1	1	1	1
1	1	1	1	1	1	1
0	1	1	1	1	0	1

0	0	0	0	0	0	1
0	1	1	0	0	1	1
1	1	1	1	1	1	1
1	1	1	0	1	1	1
0	0	0	0	0	0	0
1	1	1	1	1	1	1
0	1	0	*	0	1	1
0	1	0	0	0	0	0
1	1	1	0	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	0
1	1	1	1	1	1	1
1	1	1	1	1	1	1
0	0	0	0	0	1	0
0	0	0	0	0	0	1
0	0	0	0	0	0	1
0	0	0	0	1	0	1

initiator	noise1	noise2	noise3	noise4	noise5
a	1	1	1	1	1
h	1	1	1	1	1
h	0	0	1	0	1
a	0	1	1	1	0
h	0	0	0	0	0
a	1	1	1	1	1
h	1	1	1	1	1
h	0	0	0	0	0
h	0	0	0	0	0
h	1	0	0	0	0
a	0	0	0	1	1
a	0	0	0	0	0
a	0	0	0	0	0
a	0	0	0	0	0
h	1	1	1	1	1
h	1	1	0	0	0
a	0	0	0	0	0
a	1	1	1	1	1
a	1	1	1	0	1
h	0	1	1	1	1
h	0	0	0	0	0
a	0	0	0	0	0
a	0	0	0	1	0
a	1	1	1	0	0
h	0	0	0	0	0
a	0	0	0	0	0
a	1	1	1	1	1
a	0	0	0	0	0
h	1	1	1	1	1

a	0	1	0	1	0
a	1	1	1	1	1
h	0	0	0	0	0
h	1	1	1	1	1
a	1	1	1	1	0
h	1	1	1	1	1
a	0	0	0	0	0
h	1	0	1	0	0
a	1	1	1	1	1
h	1	1	1	1	1
h	0	0	0	0	0
a	1	1	1	1	1
h	1	1	1	0	1
h	0	0	0	0	0
h	1	1	1	1	1
a	1	1	1	1	1
a	1	1	1	1	1
h	0	0	0	0	0
h	1	1	1	1	1
h	1	1	1	1	1
h	0	0	0	0	0
a	1	1	1	1	1
a	1	1	1	1	1

Subset of 25 'contentious' challenges

Rows = challenges

Player initiating (H vs. A)	Silent vs. Noise	# Fouls awarded	Total
1	1	0	5
2	1	0	5
1	1	3	5
1	1	5	5
1	1	1	5
1	1	4	5
2	1	4	5
2	1	2	5
1	1	6	6
2	1	6	6
1	1	6	6
2	1	0	6
2	1	1	6
2	1	0	6
2	1	6	6
1	1	4	6
1	1	3	6

1	1	5	6
1	1	2	5
1	1	1	6
1	1	4	6
1	1	6	6
1	1	1	6
2	1	0	6
2	1	1	6
1	2	2	5
2	2	3	5
1	2	0	5
1	2	0	5
1	2	0	5
1	2	1	5
2	2	2	5
2	2	0	5
1	2	2	5
2	2	4	5
1	2	4	5
2	2	1	5
2	2	3	5
2	2	2	5
2	2	4	5
1	2	5	5
1	2	2	5
1	2	5	5
1	2	4	5
1	2	0	5
1	2	5	5
1	2	0	5
1	2	5	5
2	2	5	5
2	2	5	5

Chapter 4 (study 4.2)

Columns = participants; Rows = challenges

q denotes silent group participant
n denotes noise group participant

q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	q11	q12
1	3	1	1	3	4	3	4	4	4	4	4
2	1	4	4	3	4	4	1	2	3	4	3
4	3	1	4	1	3	4	2	2	4	1	3
3	2	1	1	1	3	1	3	4	4	1	1
4	4	4	3	1	2	4	4	1	1	1	1
4	4	1	4	1	3	4	3	1	1	4	3
1	2	4	4	3	4	3	3	3	4	4	4
3	3	1	4	2	4	3	2	3	4	4	4
2	2	4	2	4	2	2	3	2	4	4	2
2	2	1	1	4	1	2	2	2	3	2	2
1	3	3	4	4	1	3	1	4	1	4	2
4	1	4	3	4	2	3	3	3	1	1	1
1	1	1	4	3	3	2	2	3	1	4	3
2	2	4	1	2	1	2	2	1	2	3	2
4	2	1	4	2	4	4	2	4	4	4	4
3	3	1	4	3	2	2	4	4	2	3	2
3	3	1	4	1	1	1	3	2	2	3	4
2	2	2	4	1	3	2	4	2	1	4	3
4	1	4	1	4	2	2	2	1	1	3	3
1	1	1	3	4	4	4	4	2	4	1	1
3	1	4	1	3	1	2	1	3	1	1	1
2	1	4	1	1	2	1	2	1	1	2	2
1	3	4	3	2	2	3	2	3	4	2	2
2	2	4	3	2	2	2	3	1	1	2	1
1	2	4	1	3	1	3	3	2	3	3	1
4	1	4	3	2	1	3	3	4	3	2	1
1	2	1	2	1	3	3	3	2	3	4	4
2	1	1	4	1	1	2	2	3	2	4	1
4	3	1	1	1	3	4	3	3	2	4	4
3	3	1	1	1	1	3	2	1	4	3	3
4	1	4	3	1	3	4	1	2	4	4	4
4	3	2	3	1	2	3	2	3	3	3	2
1	2	1	4	2	4	4	4	3	1	3	4
4	1	1	4	2	2	4	3	3	3	3	2
2	3	4	4	3	3	4	2	2	4	2	4
2	1	1	1	2	2	2	2	3	2	4	1
4	2	4	4	4	2	3	3	3	4	4	2
2	4	4	4	1	3	4	3	1	1	3	3
1	2	1	2	4	4	1	3	2	1	2	3

1	3	1	1	1	3	1	2	2	3	2	2
2	2	4	4	2	1	2	3	1	1	4	4
2	3	1	1	2	3	3	2	3	3	1	3
1	2	1	1	2	3	2	2	1	4	2	3
1	2	4	4	3	4	2	3	4	2	4	1
1	2	4	4	3	4	4	3	2	2	4	4
4	2	4	1	2	4	3	3	1	1	3	4
4	4	1	2	2	4	3	2	1	2	2	1
3	4	4	4	2	4	4	4	4	4	4	4
2	1	4	4	3	3	4	2	3	4	2	2
2	1	4	2	2	3	3	2	4	1	2	2
3	3	3	4	4	1	3	2	2	1	4	1
2	4	2	2	2	2	2	3	1	3	3	1

q13	q14	q15	n1	n2	n3	n4	n5	n6	n7	n8	n9
4	4	3	4	4	4	4	2	3	3	4	4
4	4	2	2	3	3	4	4	4	4	1	4
2	3	3	1	2	2	2	1	3	1	1	2
3	3	1	3	2	3	3	1	2	3	3	4
4	4	4	1	3	1	4	2	4	2	1	1
2	3	3	4	2	4	1	1	4	2	2	2
4	4	3	4	1	4	4	3	2	4	3	1
3	4	1	2	4	4	1	1	3	4	4	4
4	4	3	2	2	2	2	4	3	2	3	2
3	3	2	3	2	3	2	2	1	4	2	4
4	3	2	3	2	4	2	3	2	2	3	3
4	2	4	4	4	3	3	1	3	3	3	4
3	4	3	2	2	2	4	4	3	2	2	3
2	2	2	2	2	1	2	3	4	1	2	1
4	4	4	3	3	3	4	1	2	3	1	4
4	2	2	3	1	1	4	3	3	2	2	2
2	1	1	2	1	3	1	1	4	1	1	1
4	3	4	1	2	4	2	1	3	1	3	2
3	2	3	1	1	2	2	1	2	2	3	1
4	4	3	4	3	4	4	1	1	4	2	2
1	1	2	2	4	1	4	2	4	1	1	4
3	2	2	1	1	1	1	2	2	2	2	1
2	2	2	1	2	2	3	3	3	1	1	3
2	3	1	2	2	2	2	1	3	3	3	1
2	2	3	1	2	2	2	1	2	4	3	1
3	3	4	2	2	1	2	1	4	1	3	1
3	4	3	4	3	4	4	3	4	4	3	3
3	2	2	1	2	1	1	1	1	1	3	4
4	4	2	3	1	4	4	2	3	3	2	2
3	3	3	3	2	2	3	2	2	2	1	1
3	3	4	4	1	3	1	1	2	4	3	1
3	3	3	3	3	3	1	4	4	3	2	4
4	4	2	4	1	2	4	3	3	4	3	1

2	2	3	2	3	3	4	3	2	4	4	4
2	2	4	3	1	2	4	3	3	3	3	2
3	3	3	3	4	2	1	4	2	1	2	3
3	2	4	4	2	1	3	2	3	2	3	1
4	4	3	2	2	4	4	3	4	1	2	3
3	2	3	1	1	4	2	2	2	3	3	2
1	2	2	2	1	1	2	2	2	2	2	3
4	1	1	2	2	4	3	2	3	1	1	2
4	4	1	3	2	2	3	1	3	1	3	4
2	3	2	1	1	2	1	3	2	3	2	2
4	4	3	1	2	3	3	4	4	2	2	2
4	3	2	3	2	4	4	3	1	3	3	1
3	2	3	3	2	4	2	4	4	4	3	1
2	1	2	1	3	1	4	4	2	1	4	4
4	4	4	4	2	4	3	3	2	4	4	1
4	4	3	3	4	2	4	3	3	2	2	2
2	3	4	2	3	3	1	4	3	3	2	1
1	3	4	4	2	1	2	4	4	3	3	4
2	2	3	2	2	2	1	3	2	2	2	1

n10	n11	n12	n13	n14	n15	n16	n17	n18	n19	n20	n21
2	2	4	2	4	4	1	4	4	2	4	4
4	3	4	4	1	4	3	2	4	3	4	4
4	1	1	1	3	2	2	1	1	3	4	2
2	1	1	2	4	3	2	1	2	2	3	3
4	1	1	3	3	3	1	4	2	1	2	3
3	2	2	2	1	4	2	3	3	2	1	4
3	3	2	3	4	4	3	1	1	3	2	3
2	3	3	3	4	4	3	2	4	3	1	2
2	3	1	3	4	4	3	4	1	2	4	1
2	2	2	1	4	3	2	2	4	2	3	1
1	2	1	1	4	2	4	4	2	4	1	3
3	3	4	3	3	3	4	1	2	4	1	4
2	4	3	4	1	1	2	3	2	2	3	3
2	2	1	1	1	2	2	1	2	3	1	1
3	4	1	3	2	3	1	3	2	1	1	3
2	2	1	3	3	3	2	1	1	1	1	1
3	1	1	1	2	3	1	1	1	3	1	2
2	1	4	4	4	2	2	3	2	2	3	3
2	1	2	1	1	2	3	1	2	1	1	1
3	2	1	2	4	3	4	3	1	3	2	4
2	2	1	4	1	2	1	2	1	1	4	1
2	1	3	1	1	4	2	2	3	4	1	1
3	2	2	2	2	1	3	2	4	2	1	2
2	2	1	2	1	2	2	1	1	2	1	3
3	3	3	3	4	2	3	2	1	3	3	4
4	1	4	2	2	3	1	3	2	4	3	3
3	2	1	4	3	3	1	2	2	3	3	3

3	2	1	2	1	4	3	4	2	1	2	1
3	3	3	3	3	2	4	1	4	4	4	4
2	2	2	3	1	2	2	2	3	4	1	2
3	2	1	2	4	3	4	2	3	3	2	1
2	3	3	3	1	3	3	3	1	1	3	2
2	4	4	2	2	3	4	1	4	4	3	4
3	4	3	2	3	3	2	2	3	4	2	3
2	1	2	2	4	2	3	2	2	3	2	1
3	2	1	1	4	2	4	1	2	1	2	2
2	2	4	2	3	2	3	3	3	2	2	1
3	2	2	3	1	2	4	4	2	3	3	2
2	1	1	1	1	2	2	1	4	2	3	3
2	1	4	1	2	2	2	3	1	1	2	3
2	2	2	1	3	4	1	2	3	2	1	3
2	2	1	2	3	2	3	2	2	1	1	1
2	2	2	3	1	2	2	1	2	1	2	2
3	3	1	1	3	3	4	2	3	2	4	4
3	2	4	4	4	4	4	2	1	3	2	1
3	4	1	2	4	2	4	3	3	4	2	3
3	3	4	4	2	2	3	3	3	3	1	3
3	2	1	1	4	4	4	3	3	4	4	4
2	2	4	4	1	2	3	2	2	1	2	3
3	4	1	2	2	2	3	3	2	1	1	1
3	3	1	3	4	4	2	2	3	2	1	2
2	2	1	1	1	3	2	2	2	2	1	1

n22	n23	n24	n25	n26	qmean	nmean	mean	h1/a2
4	3	4	4	2	3.1875	3.28000	3.23375	2
1	1	1	4	1	2.9375	3.00000	2.96875	1
1	1	1	1	1	2.5625	1.76000	2.16125	1
1	1	2	1	1	2.1875	2.12000	2.15375	2
4	1	1	4	2	2.6875	2.32000	2.50375	1
4	2	3	4	3	2.8125	2.52000	2.66625	2
3	4	4	3	1	3.3750	2.76000	3.06750	1
3	1	4	4	1	2.9375	2.88000	2.90875	1
3	1	2	3	1	2.8750	2.48000	2.67750	1
2	3	2	1	1	2.1875	2.28000	2.23375	1
4	1	4	4	1	2.6875	2.56000	2.62375	2
3	2	4	2	3	2.7500	2.92000	2.83500	2
4	4	2	3	3	2.5000	2.72000	2.61000	2
1	1	1	1	1	2.0000	1.60000	1.80000	2
3	2	4	4	1	3.3750	2.48000	2.92750	1
1	2	2	4	1	2.7500	1.96000	2.35500	1
1	2	1	3	3	2.1250	1.72000	1.92250	2
1	4	4	4	1	2.6250	2.56000	2.59250	2
1	1	1	1	1	2.3125	1.48000	1.89625	2
4	2	3	2	1	2.8125	2.60000	2.70625	1
1	1	1	1	1	1.7500	1.92000	1.83500	1

1	1	1	2	1	1.7500	1.72000	1.73500	2
1	2	1	1	1	2.3750	2.00000	2.18750	2
3	1	3	1	1	2.0625	1.84000	1.95125	2
3	2	1	4	3	2.1875	2.56000	2.37375	1
1	1	1	1	3	2.6875	2.16000	2.42375	2
1	1	3	1	1	2.6875	2.60000	2.64375	2
3	1	2	4	1	2.0000	2.04000	2.02000	2
1	3	4	4	3	2.8750	2.96000	2.91750	1
1	2	2	3	1	2.3750	2.00000	2.18750	2
4	3	1	4	3	3.0625	2.44000	2.75125	2
2	1	4	1	1	2.6875	2.44000	2.56375	1
4	1	4	4	3	2.9375	2.96000	2.94875	1
4	1	1	2	1	2.5625	2.80000	2.68125	2
3	1	2	.1	3	3.0000	2.28000	2.64000	1
2	1	1	1	1	2.1875	2.00000	2.09375	2
2	2	2	1	1	3.2500	2.16000	2.70500	1
4	1	2	1	1	2.8750	2.52000	2.69750	2
3	4	3	4	1	2.1875	2.28000	2.23375	1
1	3	3	1	1	1.8125	1.92000	1.86625	1
1	4	2	2	1	2.3750	2.16000	2.26750	2
4	3	2	1	1	2.4375	2.08000	2.25875	1
3	2	3	1	1	2.0000	1.92000	1.96000	1
4	2	4	4	1	2.8750	2.80000	2.83750	1
4	2	4	1	1	3.0625	2.68000	2.87125	2
4	3	4	2	3	2.6875	3.00000	2.84375	2
4	1	2	1	2	2.1250	2.68000	2.40250	1
4	4	4	4	3	3.8125	3.16000	3.48625	1
1	2	2	1	2	3.0000	2.32000	2.66000	1
4	3	1	3	2	2.4375	2.32000	2.37875	1
2	1	4	4	1	2.6875	2.60000	2.64375	2
1	1	3	4	1	2.2500	1.80000	2.02500	2

Chapter 5

Columns = participants; Rows = challenges

n denotes noise condition
s denotes silent condition
final number denotes years of refereeing experience

n1-13	n2-31	n3-4	n4-4	n5-0	n6-34	n7-23	n8-40	n9-7	n10-5
0.1	-1.0	0	0.0	0.1	0.1	-1.0	0.1	-1.0	-1
0.0	-1.0	-1	-1.0	-1.0	0.1	0.0	0.1	0.1	0
0.0	0.0	0	0.0	0.0	1.0	1.0	0.1	-1.0	0
-1.0	0.0	1	0.0	0.1	0.1	1.0	0.1	1.0	0
0.0	1.0	1	0.0	1.0	-1.0	1.0	0.0	1.0	1
1.0	1.0	1	-1.0	1.0	-1.0	0.1	0.0	0.1	-1
0.0	0.0	0	0.0	-1.0	0.1	0.0	0.1	0.1	0
-1.0	0.0	0	0.0	0.0	0.0	1.0	0.0	1.0	0
0.1	1.0	1	1.0	0.0	0.1	1.0	0.1	0.0	0
0.0	0.0	0	0.1	0.1	0.1	0.0	0.1	0.0	0
0.0	0.0	1	0.0	0.0	-1.0	0.0	0.0	-1.0	1
0.1	0.0	0	0.1	-1.0	0.1	0.0	0.0	0.1	0
1.0	0.0	1	1.0	1.0	1.0	0.0	0.0	1.0	1
-1.0	0.0	-1	0.1	0.0	0.1	0.0	0.1	0.0	0
0.1	1.0	0	1.0	0.1	1.0	0.0	0.0	0.1	0
0.1	0.0	0	-1.0	0.0	0.0	0.0	-1.0	0.0	0
0.1	-1.0	-1	0.1	0.1	-1.0	0.1	-1.0	-1.0	0
0.0	0.0	1	0.1	0.0	-1.0	1.0	0.1	0.0	0
1.0	-1.0	-1	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	-1
0.1	0.0	0	0.0	0.0	0.1	0.0	0.0	1.0	1
1.0	0.0	-1	-1.0	1.0	1.0	0.0	0.1	-1.0	-1
0.1	-1.0	-1	0.0	0.1	-1.0	-1.0	0.1	0.1	0
-1.0	-1.0	0	-1.0	-1.0	1.0	-1.0	-1.0	1.0	-1
1.0	-1.0	-1	0.1	1.0	1.0	1.0	0.1	1.0	1
0.1	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	0
0.0	1.0	1	0.1	0.0	1.0	1.0	0.0	0.0	0
0.1	1.0	0	0.0	0.0	0.1	1.0	0.1	0.0	0
0.0	-1.0	-1	0.0	0.1	1.0	0.0	-1.0	0.0	-1
0.0	-1.0	-1	0.0	1.0	1.0	-1.0	-1.0	-1.0	-1
0.1	0.0	-1	-1.0	0.0	0.1	0.0	0.0	0.0	0
0.1	0.0	0	0.0	0.1	1.0	0.0	-1.0	0.0	0
1.0	1.0	0	0.1	-1.0	0.1	-1.0	-1.0	0.1	0
0.0	0.0	0	0.0	-1.0	0.1	0.0	0.0	0.0	0
1.0	1.0	1	0.0	1.0	0.0	1.0	-1.0	1.0	-1
1.0	1.0	1	1.0	1.0	1.0	1.0	1.0	1.0	1
1.0	1.0	1	0.0	-1.0	1.0	1.0	1.0	1.0	1
-1.0	-1.0	-1	1.0	0.1	1.0	-1.0	-1.0	-1.0	-1
0.1	0.0	-1	-1.0	1.0	0.1	0.0	0.1	0.0	0

1.0	1.0	1	0.0	1.0	0.1	1.0	1.0	1.0	1
0.0	1.0	1	1.0	1.0	1.0	1.0	-1.0	1.0	1
1.0	1.0	1	1.0	1.0	1.0	1.0	1.0	0.0	0
0.1	-1.0	0	1.0	0.1	-1.0	-1.0	-1.0	-1.0	0
0.0	0.0	0	0.1	-1.0	0.0	1.0	0.1	1.0	0
1.0	1.0	1	-1.0	1.0	0.0	0.0	1.0	1.0	1
0.0	0.0	-1	1.0	0.1	-1.0	0.0	-1.0	-1.0	0
-1.0	0.0	-1	0.1	-1.0	-1.0	0.0	-1.0	-1.0	0
0.1	1.0	0	-1.0	0.1	-1.0	-1.0	0.1	-1.0	-1

n11-34	n12-3	n13-1	n14-14	n15-?	n16-0	n17-5	n18-0	n19-0	n20-0
-1.0	0	0.0	-1.0	-1.0	0	0.0	0.1	0.0	0.0
0.0	-1	-1.0	0.0	0.0	-1	-1.0	-1.0	-1.0	0.0
0.1	0	0.0	0.0	0.0	1	0.0	0.0	1.0	0.0
0.0	0	0.1	0.0	0.0	0	0.1	0.0	0.0	0.0
1.0	1	0.0	1.0	1.0	0	0.0	1.0	1.0	1.0
1.0	1	1.0	1.0	0.1	0	0.0	-1.0	-1.0	0.1
0.0	0	0.0	0.0	0.0	1	0.0	0.1	0.0	0.0
0.0	1	0.0	0.1	0.0	1	1.0	1.0	0.1	0.0
0.0	0	0.0	1.0	1.0	0	1.0	1.0	1.0	0.1
0.0	0	-1.0	0.0	0.0	0	0.0	0.0	0.0	0.0
-1.0	1	-1.0	1.0	1.0	0	1.0	1.0	0.0	1.0
0.0	0	1.0	0.0	0.0	0	-1.0	0.0	0.0	0.0
1.0	1	1.0	1.0	1.0	0	1.0	1.0	0.0	0.0
0.0	0	0.1	0.0	0.0	0	0.0	0.0	-1.0	0.1
0.0	1	0.1	0.0	0.0	0	0.0	0.1	0.0	1.0
0.0	0	0.0	0.0	0.0	0	0.0	0.1	0.0	-1.0
-1.0	-1	0.1	-1.0	-1.0	-1	-1.0	0.0	0.0	-1.0
0.0	1	1.0	1.0	1.0	0	1.0	1.0	0.0	1.0
-1.0	-1	-1.0	-1.0	-1.0	-1	-1.0	-1.0	-1.0	-1.0
0.0	1	1.0	0.1	0.1	0	0.0	0.0	0.0	0.1
0.0	-1	-1.0	-1.0	-1.0	-1	-1.0	1.0	0.0	0.0
-1.0	-1	-1.0	0.0	0.0	0	0.0	0.0	-1.0	-1.0
1.0	-1	-1.0	-1.0	-1.0	-1	1.0	-1.0	-1.0	-1.0
1.0	1	-1.0	0.1	0.1	1	-1.0	1.0	1.0	0.1
0.0	0	0.1	0.0	0.0	0	1.0	0.0	0.1	0.1
0.0	0	1.0	0.0	0.0	0	1.0	1.0	0.0	1.0
0.0	0	0.0	0.0	0.0	0	0.0	1.0	0.0	1.0
0.0	0	-1.0	0.0	0.0	0	-1.0	-1.0	0.0	0.0
-1.0	1	0.0	-1.0	-1.0	-1	-1.0	-1.0	-1.0	1.0
0.0	0	0.0	0.0	0.0	0	0.0	0.1	0.1	0.0
1.0	0	0.0	0.0	0.0	0	0.0	-1.0	0.0	0.1
0.0	0	0.0	-1.0	0.0	0	0.1	1.0	-1.0	0.1
0.0	0	0.0	0.0	0.1	0	0.0	0.0	0.0	0.0
-1.0	-1	1.0	1.0	0.0	0	1.0	1.0	1.0	1.0
1.0	1	1.0	1.0	1.0	0	0.0	1.0	0.0	1.0

1.0	1	1.0	1.0	0.0	1	-1.0	1.0	1.0	-1.0
-1.0	-1	-1.0	0.1	1.0	-1	-1.0	-1.0	-1.0	-1.0
0.0	0	0.0	-1.0	0.1	0	0.1	0.1	0.0	0.0
1.0	1	1.0	1.0	0.1	1	1.0	1.0	1.0	1.0
1.0	0	-1.0	1.0	1.0	1	1.0	1.0	1.0	1.0
1.0	1	1.0	1.0	1.0	1	1.0	1.0	1.0	1.0
0.0	-1	0.0	0.1	1.0	-1	0.1	-1.0	0.1	0.1
0.0	0	1.0	1.0	0.1	0	1.0	1.0	0.0	-1.0
1.0	1	1.0	0.1	0.1	0	1.0	1.0	1.0	1.0
-1.0	0	0.0	-1.0	0.1	-1	1.0	0.1	0.0	-1.0
-1.0	0	-1.0	0.0	1.0	0	-1.0	-1.0	-1.0	0.0
1.0	1	0.0	0.0	0.1	0	0.0	0.0	0.0	0.1

n21-35	n22-26	s1-0	s2-12	s3-1	s4-0	s5-23	s6-30?	s7-12	s8-10
0.0	-1.0	-1	0.1	0.1	0.0	0.0	-1.0	0.1	-1.0
-1.0	1.0	0	-1.0	-1.0	-1.0	-1.0	-1.0	0.1	-1.0
0.0	0.1	0	0.0	0.1	0.0	0.0	1.0	0.1	0.0
1.0	0.1	0	1.0	1.0	0.1	1.0	1.0	1.0	0.1
1.0	0.0	-1	0.1	1.0	1.0	1.0	1.0	0.1	1.0
0.1	0.0	-1	1.0	0.1	0.0	0.0	1.0	0.1	1.0
0.0	0.1	1	0.0	0.1	0.0	0.0	0.0	0.1	0.0
0.0	0.1	1	-1.0	0.1	0.0	0.0	0.0	1.0	0.0
0.1	0.1	1	1.0	1.0	1.0	1.0	1.0	0.1	0.0
0.0	-1.0	0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
1.0	0.0	1	1.0	0.0	0.1	1.0	1.0	0.0	1.0
0.0	0.1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.1	0	0.0	0.0	1.0	1.0	1.0	0.0	1.0
0.0	-1.0	0	1.0	-1.0	0.1	-1.0	0.0	0.0	0.0
0.0	0.1	0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
0.0	0.1	0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.1	-1	1.0	0.1	0.0	-1.0	-1.0	-1.0	0.0
0.0	0.0	1	0.0	1.0	1.0	1.0	1.0	1.0	1.0
-1.0	-1.0	-1	1.0	-1.0	-1.0	-1.0	0.0	0.0	-1.0
0.1	-1.0	1	0.0	0.1	0.0	0.0	1.0	0.0	0.0
0.0	0.1	-1	1.0	1.0	0.0	-1.0	-1.0	0.0	0.0
0.0	0.0	0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	-1.0
-1.0	-1.0	-1	0.1	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
1.0	-1.0	0	1.0	1.0	0.0	1.0	1.0	1.0	0.0
0.1	0.1	0	0.0	0.0	0.0	1.0	1.0	0.1	0.0
0.0	0.0	1	-1.0	0.0	0.0	0.0	1.0	0.0	0.0
1.0	1.0	0	1.0	0.0	0.1	0.0	1.0	0.0	0.0
0.1	0.0	0	0.0	-1.0	-1.0	0.0	-1.0	0.1	-1.0
-1.0	0.1	1	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	-1.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	-1.0	0	1.0	0.1	0.0	0.0	0.1	-1.0	-1.0

0.1	0.0	0	0.0	1.0	0.0	0.0	1.0	0.0	0.0
-1.0	1.0	1	-1.0	-1.0	1.0	0.1	1.0	0.0	1.0
1.0	1.0	0	1.0	1.0	1.0	1.0	1.0	0.0	1.0
1.0	0.1	1	1.0	1.0	1.0	1.0	0.0	1.0	1.0
-1.0	-1.0	-1	-1.0	-1.0	-1.0	-1.0	0.1	-1.0	-1.0
0.1	0.0	0	0.0	0.0	0.0	0.0	1.0	0.1	0.0
1.0	1.0	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	0.1	1	-1.0	1.0	1.0	1.0	-1.0	1.0	1.0
1.0	1.0	1	1.0	1.0	1.0	1.0	0.0	1.0	1.0
0.1	0.1	0	1.0	0.0	0.0	0.0	1.0	0.0	0.0
0.0	0.1	0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
1.0	1.0	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.1	0.1	0	0.1	0.1	-1.0	0.1	-1.0	1.0	-1.0
-1.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.1	0	0.0	0.1	1.0	1.0	0.1	0.0	0.0

s9-10	s10-30	s11-43	s12-28	s13-0	s14-8	s15-6	s16-3	s17-3	s18-7
0	-1	-1.0	0.0	0.0	0	0	0.0	-1.0	-1.0
-1	-1	-1.0	-1.0	-1.0	0	-1	-1.0	-1.0	-1.0
1	1	0.0	0.0	-1.0	0	0	0.0	0.0	1.0
0	1	0.0	0.0	1.0	1	0	0.0	0.0	1.0
1	1	0.0	1.0	1.0	1	0	1.0	0.0	1.0
1	1	1.0	0.1	0.0	0	-1	0.0	1.0	0.1
0	0	0.0	1.0	0.0	0	1	0.0	1.0	0.0
0	0	0.0	1.0	0.0	0	1	0.0	1.0	1.0
0	1	1.0	1.0	1.0	1	0	0.0	1.0	1.0
0	0	0.0	1.0	0.0	0	0	0.0	0.0	0.0
0	1	0.0	-1.0	1.0	1	0	0.0	0.0	1.0
1	0	0.0	0.0	0.0	0	0	1.0	0.0	1.0
0	1	0.0	-1.0	1.0	1	1	0.0	0.0	0.0
0	0	-1.0	0.1	-1.0	0	0	0.0	0.0	0.0
0	0	0.0	1.0	0.0	1	0	0.0	1.0	1.0
0	0	0.0	0.1	0.0	0	0	0.0	0.1	0.0
0	-1	-1.0	0.1	0.1	-1	0	1.0	-1.0	-1.0
-1	0	0.0	0.0	0.0	1	1	0.1	0.0	1.0
0	-1	-1.0	1.0	-1.0	-1	-1	-1.0	-1.0	1.0
1	1	0.0	0.0	0.0	0	1	0.0	0.0	1.0
0	-1	-1.0	0.1	1.0	-1	-1	0.0	1.0	-1.0
0	-1	0.0	-1.0	0.0	-1	0	0.1	0.1	-1.0
1	-1	-1.0	-1.0	-1.0	0	0	-1.0	-1.0	1.0
1	1	0.0	-1.0	1.0	0	1	0.0	1.0	1.0
1	1	0.0	1.0	0.0	1	1	0.1	0.1	1.0
1	0	0.0	0.0	0.0	0	0	0.1	1.0	1.0
0	1	0.0	0.1	0.1	0	0	0.0	0.0	1.0
0	-1	0.0	-1.0	-1.0	-1	-1	0.0	0.0	-1.0
-1	-1	-1.0	1.0	-1.0	-1	-1	-1.0	-1.0	0.0

0	0	0.0	0.1	0.0	0	0	0.0	0.0	0.0
0	0	0.0	-1.0	0.0	0	0	0.0	0.0	0.0
0	-1	0.0	1.0	0.0	1	-1	-1.0	1.0	-1.0
0	0	0.1	0.1	0.0	0	1	0.0	0.0	0.0
-1	1	0.0	1.0	1.0	1	1	-1.0	0.0	1.0
1	1	0.1	1.0	1.0	1	0	1.0	1.0	1.0
1	1	1.0	1.0	1.0	1	1	1.0	1.0	1.0
-1	-1	-1.0	-1.0	-1.0	0	0	-1.0	-1.0	-1.0
0	0	0.1	0.1	0.1	0	-1	0.0	0.1	0.0
1	1	1.0	1.0	1.0	1	1	1.0	1.0	1.0
1	1	1.0	-1.0	1.0	1	1	1.0	1.0	1.0
1	1	0.0	1.0	1.0	1	1	1.0	1.0	1.0
0	0	-1.0	-1.0	-1.0	0	-1	0.1	-1.0	0.0
0	0	0.0	0.1	1.0	0	0	1.0	0.1	0.0
1	1	1.0	1.0	1.0	1	1	1.0	1.0	1.0
-1	-1	0.0	-1.0	1.0	-1	-1	1.0	-1.0	-1.0
-1	-1	-1.0	-1.0	-1.0	-1	-1	-1.0	0.0	-1.0
0	0	0.0	0.1	1.0	1	1	0.0	0.0	0.0

Chapter 7

Logistic regression analysis data set is too large to present in appendices

Bias analysis data

All values (except 'bias' and 'trait-stai') show changes with crowd noise. Measures from spectral analysis (lf) and heart rate (hr) also control for baseline measures for each subject.

'cog' = cognitive (CSAI2)
'som' = somatic (CSAI2)
'conf' = confidence (CSAI2)

'int' = intensity (CSAI2)
'fac' = facilitative/debilitative (CSAI2)

BIAS	TRAIT-STAI	change cog int	change cog fac	change som int	change som fac
9	33	5	-6	-1	7
8	30	3	-7	1	1
2	36	-3	-4	-3	-2
0	51	0	0	3	0
4	24	0	0	0	0
-1	34	0	3	1	1
5	39	7	-2	-1	8
5	38	3	-13	0	-5
6	35	-4	15	-2	11
4	31	1	-2	0	0
5	38	3	11	-12	8
1	40	-2	*	-3	*
3	42	-2	0	9	-9
6	38	6	4	2	11
2	41	3	-1	0	-10
2	27	-1	0	-2	0
6	49	-1	1	0	3
6	46	3	-8	1	-4
3	*	*	*	*	*
3	51	-1	3	0	-1
3	38	1	-2	4	-8
9	28	1	2	0	-3
3	30	0	0	0	0
2	32	-5	16	-2	2
-3	30	-6	*	0	*
1	27	1	1	0	3

change conf int	change conf fac	rsme-dif	lf-dif-with baseline	hr change with baseline
2	6	16	1545.36	-1.7
-1	4	-7	2125.56	-0.3
1	-2	-22	614.34	2.9
0	-1	-13	-2439.74	-1.6
3	-1	-2	940.46	-4.2
13	0	-1	-102.07	-1.3
0	0	-2	-604.01	5.5
-7	-13	17	-285.16	-1.1
5	6	-7	345.45	0.4
2	-2	0	535.11	5.8
-1	1	21	-875.50	2.9
11	*	-23	1655.90	-2.1
-19	-7	-12	-911.86	-1.9
2	0	37	189.53	1.4
1	0	-28	449.71	-2.0
0	0	-13	540.95	4.1
-2	-1	-2	164.63	4.4
-1	-2	2	280.61	2.5
*	*	*	144.50	9.7
-4	-1	-5	241.23	-1.5
-6	-2	20	-565.40	2.9
2	1	29	-46.00	1.8
1	1	0	601.20	2.0
-2	3	3	-1183.82	-0.7
2	*	-6	-102.10	1.1
-4	0	-12	-355.46	6.0