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Exploration of the perceptual-cognitive processes that contribute to in-game decision-making of Australian football umpires

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1   Running head: UMPIRE DECISION-MAKING PROCESS

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19 **Abstract**

20   Decision-making is fundamental to officiating in all sports. It is well established in

21 contemporary research that decision-making skills underpin umpire expertise; however, there is

22 little understanding of the cognitive processes that contribute to in-game decision-making. This

23 research implemented an in-depth case study approach, using qualitative methods, to explore the

24 in-game decision-making process of three Australian football umpires. Concurrent and

25 retrospective verbalisation methods were used to obtain verbal reports of the cognitive processes

26 associated with decision-making. Findings identified three salient themes related to both in-game

27 decision-making processes (i.e., decision evaluation, player intention during game-play) and

28 umpire performance (i.e., knowledge of game-play). These themes contributed to the

29 development of decision-making heuristics for Australian football umpires. This study provides

30 initial evidence of the factors that may contribute to and/or affect in-game decision-making

31 processes; however, additional exploration is necessary to further inform training programs

32 aimed to develop domain-specific decision-making skills and subsequent in-game performance.

33 **Keywords:**

34   Cognition, Sports officials, Decision-making process, Verbalisation, Performance

35 **Exploration of the perceptual-cognitive processes that contribute to in-game decision-**

36 **making of Australian football umpires**

37 Currently, there is an extensive body of sport-based research that indicates perceptual-

38 cognitive skills, such as pattern recognition (Berry, Abernethy, & Côté, 2008; Farrow, McCrae,

39 Gross, & Abernethy, 2010) and anticipation (Farrow et al., 2010; Savelsbergh, Williams, Kamp,

40 & Ward, 2002), provide a domain-specific advantage for expert sport performers. These

41 perceptual-cognitive processes are associated with the execution of fast and accurate decisions,

42 which is a necessity for sports officials involved in high tempo ball sports. Researchers have

43 attempted to isolate and understand the decision-making skill of sports officials using a number

44 of research paradigms. Findings indicate an expertise effect for decision-making performance

45 between skilled and less skilled umpires (Catteeuw, Helsen, Gilis, & Wagemans, 2009; Larkin,

46 Berry, Dawson, & Lay, 2011; Larkin, Mesagno, Berry, & Spittle, 2014); psychological aspects

47 of perceptual-cognitive performance (e.g., MacMahon et al., 2015); and the potential impact of

48 physical exertion (Larkin, O'Brien, et al., 2014; Paradis, Larkin, & O'Connor, 2015) and

49 environmental conditions (Taylor et al., 2014; Watkins et al., 2014) on decision-making

50 performance. Despite the empirical evidence now available from these studies, there is limited

51 knowledge of the processes underlying decision-making of sport officials.

52 In an attempt to understand skilled referee performance, Mascarenhas, Collins and

53 Mortimer (2005) identified five themes that informed the development of their Cornerstones

54 Model of Refereeing Performance including: (i) knowledge and application of the law; (ii)

55 physical fitness, positioning and mechanics; (iii) personality and game management; (iv)

56 contextual judgement; and (v) psychological characteristics of excellence. While all themes are

57 potentially relevant to in-game decision-making, specifically the theme knowledge and

58 application of the law can be identified as directly relevant to in-game decision-making, and was

59 defined as "the underpinning knowledge of the law that allows referees to accurately interpret

60   dynamic situations and penalise accordingly" (Mascarenhas et al., 2005, p. 368). Mascarenhas et

61   al. identified several important sub-themes under the knowledge and application of the law

62   theme that included decision-making timing and consistency, and decision-making clarity. While

63   the cornerstones model provides a description of the factors that may contribute to performance,

64   the model does not indicate how these factors interact to inform the decision-making process.

65   Therefore, to develop a greater understanding of the underlying cognitions for decision-making

66   performance, MacMahon and McPherson (2009) suggested experimental designs should include

67   verbalisation methods, such as interviews or verbalisation of events, to better inform the

68   decision-making process.

69   Despite verbalisation techniques providing an understanding of the cognitive processes that

70   contribute to problem solving (Kuusela & Paul, 2000), this methodology has been afforded little

71   research attention in order to understand factors that contribute to the decision-making process of

72   sports officials. One investigation (Lane, Nevill, Ahmad, & Balmer, 2006) used retrospective

73   verbalisation to explore the factors that five experienced soccer referees perceived to influence

74   decision-making. Identified themes included crowd factors, decision accuracy and errors,

75   experience, regulations, and opinions as themes. For example, the referees strived for accurate

76   decision; however, in relation to decision accuracy they were accepting that human error can

77   influence decision-making accuracy with logical reasons for inaccurate decisions being the speed

78   of the game, or not being in the correct position to view the incident. Despite identifying some of

79   the themes associated with decision-making, the investigation did not describe the underlying

80   cognitive processes associated with in-game decision-making. Extending this research, Hancock

81   and Ste-Maire (2014) used a stimulated recall technique to explore the strategies used by elite,

82   intermediate and novice ice hockey referees when making a decision. Participants viewed

83   footage from a head camera of a game they had refereed and were asked a series of questions

84   relating to their decision-making strategies. Results demonstrated an expertise effect with elite

85 referees demonstrating more refined knowledge structures. Further, strategies influencing in-

86 game decisions such as game context, anticipating game flow and prioritising the certain

87 decision-making situations were also identified.

88   While the current research exploring sports officials decision-making have identified

89 numerous external factors that may influence the decision-making process, there has been

90 limited exploration of the underlying processes associated with in-game decision-making.

91 Therefore, this study aims to investigate the strategies associated with in-game decision-making

92 of Australian football umpires. Further, the investigation attempts to describe the underlying

93 processes associated with in-game decision-making, to potentially inform the creation of

94 Australian football umpire specific decision-making heuristics.

95   **Method**

96 **Participants**

97   Three male Australian football umpires, who were previously involved in training camps at

98 an elite level and currently officiating in a regional Australian football Division 1 competition

99 volunteered to participate in the study. Participant 1 (i.e., P1) was 30 years old and had umpired

100 170 senior Australian football Division 1 games. Participant 2 (i.e., P2) had umpired 350 senior

101 Australian football games and was 32 years old. Participant 3 (i.e., P3) was 39 years old and had

102 umpired a total of 400 senior Australian football Division 1 games. While there is a disparity in

103 the number of games each participant had umpired, following consultation with umpire coaches

104 with regards to current in-game decision-making performance, all participants were considered

105 to be of the same current performance level. Ethics approval was granted by the University

106 Human Research Ethics Committee, and participants provided approved consent prior to the

107 commencement of the study.

108   **Procedure**

109   **In-Game Verbalisation.** During two competitive in-season games, which were separated

110   by 7 days, participants were instructed to 'think out loud' and provide a "running commentary"

111   of the in-game information they were perceiving and the processes by which they made a

112   decision. This process was believed to provide an explicit representation of the cognitive

113   processes associated with in-game decision-making. In-game verbal information was recorded

114   using an Olympus DS-5000 digital voice recorder, which was attached to the upper back of the

115   participant using a commercially available elastic harness that is used for player tracking devices.

116   A lapel microphone was used to capture verbal information and was attached to the shirt lapel. In

117   addition, video footage was recorded using two digital video cameras positioned in an elevated

118   central position on the boundary line. The first camera tracked the movement of the ball

119   providing vision of player contests, body contact, infringements and general game-play similar to

120   television broadcast view (i.e., the immediate vicinity of the ball). The second camera tracked the

121   movements and actions of the participating umpire. After video recording, the video footage was

122   coupled with the audio recording with the verbal reports transcribed verbatim.

123   To ensure the participants were comfortable and competent at verbalising their thought

124   processes during the game, participants completed three in-game verbalisation familiarisation

125   sessions, whereby they were asked to verbalise their cognitive processes. Following the

126   familiarisation sessions the footage was reviewed and any further questions from the participants

127   were answered.

128   **Semi-Structured Interviews**. To further ascertain the participant's decision-making

129   process, individual semi-structured interviews were conducted, using the stimulated recall

130   technique. The stimulated recall technique is an introspective procedure, whereby video recorded

131   information showing the actions and behaviour of the participant is replayed to stimulate recall

132   of cognitive processes (Lyle, 2003).

133   During the semi-structured interviews, which ranged from 26 to 39 minutes in duration,

134   video footage from the two recorded games was shown to aid accurate recall of information

135   (Côté, Ericsson, & Law, 2005). During the interview, which occurred at the participants first

136   available training session following the second recorded game (i.e., three to five days after; see

137   Figure 1), participants viewed eight short video clips (coupled with in-game verbalisation audio)

138   and were asked to recall and verbalise their cognitive processes of the in-game incidents

139   presented. The video clips were used as a primer to prompt decision-making processes and

140   negate any disparity with the timing of the retrospective recall. The video clips presented

141   situations where the participant was the controlling umpire for the passage of play and contained

142   six incidents that resulted in a free kick, and two incidents where the participant did not award a

143   free kick. Following the initial recall, the video was replayed and paused at specific time points

144   (i.e., just prior to or following the incident) and a series of open-ended questions were asked. The

145   open-ended questions were focused on understanding the cognitive processes and identifying

146   decision-making information used by the participant (e.g., can you describe the information that

147   led you to this decision? Explain how you came to this conclusion in the passage of play rather

148   than a different outcome?). This same sequence of questions was repeated for the remaining

149   seven clips.

150   **<<<INSERT FIGURE 1 HERE>>>**

151   After the eight clips had been considered and discussed, participants were presented with

152   two standardised game-play situations from a game where none of the participants were

153   involved. The participants watched the standardised footage until they were familiar with the

154   game-play situation and were asked to concurrently verbalise their thought processes. Akin to the

155   earlier clips, the same series of open-ended questions that focused on cognitive processes and

156   critical information were asked. Following the interview, verbal recordings were transcribed

157   verbatim.

158 **Data Analysis**

159   Data from the in-game verbal reports and semi-structured interviews were combined and

160 analysed using content analysis, incorporating grounded theory (Glaser & Strauss, 1967).

161 Content analysis is defined as "objective, systematic and quantitative description of the manifest

162 content of communication" (Berelson, 1952, p. 19), whereby the process is to explore the text for

163 themes rather than observation-based notes (Patton, 2002). The grounded theory approach

164 requires the researcher to become immersed in the data, so meanings can be identified, with

165 specific observations leading towards general patterns and themes (Glaser & Strauss, 1967).

166 Therefore, the focus of the analysis will be on the manifest meaning, and not the connotative

167 meaning (or latent content) of the verbal report (Riffe, Lacy, & Fico, 1998).

168   To ensure the data were trustworthy, two methods were implemented. Initially, the first

169 author concurrently listened to the audio recording and read the transcripts, which ensured no

170 errors were included in the transcripts. Second, member checking was implemented, with all

171 participants confirming the information within the transcripts were accurate, and any identified

172 errors were corrected.

173   Following data checking, the first and second author separately read the transcripts until

174 they were familiar with the content. A cross-case analysis of the qualitative data (concurrent in-

175 game verbalisation and interview verbalisation data) was conducted with an integrated approach

176 of the results presented from the three individual cases (Creswell, 2007). As the aims of the study

177 were to identify the decision-making processes of the participants, only comments relating to

178 decision-making and game management were coded and used for analysis. As a result,

179 comments relating to physical fitness or general non game-specific conversations were not coded

180 or assessed in the analysis (e.g., "are you feeling tired" & "did you hear that spectator").

181 Therefore, coding of all the in-game transcripts identified 670 comments, with a further 460

182 comments coded from the semi-structured interviews for analysis. Raw data (i.e., meaningful

183   quotes) were separately coded by two authors. This process led to an initial identification of nine

184   themes considered important to understand the processes associated with Australian football

185   umpires' decision-making. After the raw data were analysed, the first and second author

186   discussed and operationally defined each theme. As a result, some themes were combined within

187   more broad groupings based on belongingness. Three themes emerged from the analysis

188   including (i) knowledge of game-play, (ii) player intention during game-play, and (iii) decision

189   evaluation (see Table 1 for operational definitions).

190   **<<< INSERT TABLE 1 HERE >>>**

191   To assess the trustworthiness of the data both, inter-coder and intra-coder agreement were

192   assessed. To assess inter-coder agreement an independent assistant and the first author coded all

193   transcripts. The percentage of agreement was then determined using Cohen's Kappa, with an

194   inter-coder agreement of 85% indicating a high level of agreement (Riffe et al., 1998). Intra-

195   coder agreement was established by the independent assistant coding the transcripts on two

196   separate occasions, 14 days apart, as this time interval is likely to determine random differences

197   in the coding rather than changes in behaviour or ability (Pedhazur & Pedhazur-Schmelkin,

198   1991). An intra-rater agreement of 89% was reached indicating a high level of agreement (Riffe

199   et al., 1998).

200   **Results and Discussion**

201   Analysis of both the in-game and interview data revealed two types of verbal data: internal

202   (i.e., self-cognitions or personal thoughts that umpires verbalized during the game), and external

203   dialogue (i.e., verbalized inter-personal communication between the umpires and the players),

204   which will be discussed. Analysis of the verbal reports identified three salient themes including

205   (i) knowledge of game-play, (ii) player intention during game-play, and (iii) decision evaluation.

206   **Knowledge of Game-Play**. The "internal" theme of knowledge of game-play was defined

207   as self-directed verbal communication that demonstrated knowledge of future player actions

208   and/or game-play. Investigators have shown skilled performers use visual information early in an

209   action sequence to predict the next act of play (Abernethy & Russell, 1987; Larkin, et al., 2011),

210   which is an important skill in Australian football, as umpires need to perceive the action

211   sequence to assist in positioning themselves appropriately to view the next ball contest (Larkin et

212   al., 2011). Participant 1 (i.e., P1) demonstrated knowledge of game-play by anticipating potential

213   infringements, "The ball is coming forward, and could be hands in the back (pause). Nah

214   nothing, play on." In this example, P1 recognised early in the action sequence that a push in the

215   back infringement was a likely outcome, but delayed his decision (as indicated by the pause)

216   until contact had occurred. Anticipating but delaying judgement until contact is made is

217   important, particularly as Australian football umpires are instructed to watch the whole incident

218   before making a decision, because it may allow them more time to consider whether the decision

219   is correct. In another situation where two players contested the ball on the ground, P1 stated what

220   infringement was likely, "I'm watching for high contact on him (high tackle infringement)

221   (pause). Fair tackle play on". Again, after perceiving the information P1 paused, again viewing

222   the whole incident prior to making an informed decision to allow the play to continue without an

223   infringement being called. Both of these examples demonstrate P1's ability to assess the game

224   scenario and generate possible decision outcomes based on advance cue information. The ability

225   to use advance cue information has been shown to be an attribute of skilled decision-making

226   performance in athletes and gymnastic judges (Ste-Marie, 1999; Vaeyens, Lenoir, Williams, &

227   Philippaerts, 2007).

228   Participant 2 (i.e., P2) provided an example of knowledge of game-play through his player

229   management skills near the conclusion of a game where one goal (6 points) separated the two

230   teams. The game became tense with players committing several infringements to either gain an

231   advantage or prevent the opposition from scoring as P2 stated, "A few players getting edgy; as

232   the game gets close, they start to lose the plot. I have to watch play behind the ball more." This

233   illustrates P2's knowledge and understanding of how players become more nervous and tense

234   (i.e., edgy) during the final stages of a close game, with the potential for players to act erratically

235   (i.e., lose the plot). P2 recognises this change in the player's mannerisms and identifies the

236   increased likelihood of player contact infringements. Consequently, knowledge of game context

237   altered P2's game management style as he consciously shifted his attention to potentially illegal

238   off the ball player confrontations. Similarly, Participant 3 (i.e., P3) monitored player behaviour

239   by stating,

240   I'm just pre-empting; Player 1 came through with a lifted elbow (near head height of an

241   opposition player), if an opposition player seen that they may hit him... Its player

242   management, less likely for biffo (i.e., the player's engaging in physical confrontation) if

243   the players think we're onto it.

244   Even though the player did not commit an infringement, P3 identified that the action may have

245   further consequences on the game (such as opposition players retaliating). Thus, both P2 and P3

246   illustrated a sound understanding of player behaviour and were proactive in managing these

247   incidents as a duty of care to the players (Gabbe & Finch, 2000).

248   In the Cornerstones Model for Refereeing Performance, Mascarenhas et al. (2005)

249   identified the importance of an umpire being able to "alter his or her style of refereeing to suit

250   the particular nuances of the game" (p. 386). Based on this description, umpires should

251   understand the way the game is played to effectively manage the game environment and alter

252   their umpiring style based on the game context. The participants demonstrated the ability to alter

253   their personal umpiring style based on changes within the game environment, such as game

254   context (time and score) or player changes (personal performance changes), which exhibits an

255   experienced level of performance (Ward & Williams, 2003).

256   **Player Intention during Game-Play**. The theme player intention during game-play has

257   been defined as the interpretation of a player's objective during game-play (e.g., body

258   movements or actions) that guided an infringement-based decision. P1 used his interpretation of

259   a player's objective to inform his decision when two players contested for a mark. In the

260   "marking" situation, the defending player had two teammates within close vicinity of the contest

261   who could potentially gain possession of the ball and clear it from the defensive end of the

262   ground. Participant 1 provided his interpretation of the situation, by suggesting,

263   This player (attacking player) is going for the ball, this bloke (defending player) is thinking

264   I am just not fit enough so I am going to take him out of it (the contest for the ball),

265   because I have got two team mates who are going to take over (gain possession of the ball)

266   and try and get that ball out (of defence).

267   Participant 1 interpreted that the defending player's objective was to illegally impede the

268   opposition player (e.g., "I am just not fit enough so I am going to take him out of it") by either

269   holding or pushing the opposition player away from the contest for the ball to ensure his

270   teammate gained possession.

271   Participant 3 used his interpretation of a player's intention when two players contested for

272   a ball during a marking contest. Participant 3 described his interpretation of the marking contest,

273   and why he penalised the player for a holding the man infringement when he stated, "The players

274   intention was to hold up the other player and get him out of the (marking) contest (holding the

275   man infringement)... the intention has got to be the ball for both players." In this scenario,

276   Participant 3 interpreted the intention of the player as illegally attempting to obtain possession of

277   the ball and used this judgement to inform the final decision.

278   Participant 2 provided an example of this theme when he viewed a clip of a player on the

279   ground in possession of the ball. The player dived on the ball and dragged it underneath himself,

280   which according to the rules, is penalised for the infringement "holding the ball" if he does not

281   immediately knock the ball clear, or correctly dispose of the ball. P2 explains his justification for

282   the decision by stating:

283   His first objective was to dive on the ball and drag the ball in, and once he has done that he

284   has lost all right to be over the ball... he has made no attempt (to dispose of the ball), so

285   holding the ball (infringement).

286 Participant 2 interpreted the player's actions and used this information to inform his final

287 decision, to penalise the player for holding the ball.

288   The player intention during game-play theme identifies a component of an Australian

289 football umpire's decision-making process that has not been considered within the extant

290 literature. The interpretation of player's intentions may also be used for the officiating of other

291 sports. For example, in soccer, the offside rule indicates that assistant referees must consider the

292 intentions of the player when making a decision. The rule states that a player is in an offside

293 position if they are closer to their opponent's goal line, than both the ball and second last

294 defender, and if, in the referee's opinion, they are actively involved in the game-play (Fédération

295 Internationale de Football Association, 2013). As the offside rule requires assistant referees to

296 interpret whether the player intended to be actively involved in the game-play, there is potential

297 for the subjective interpretation of the player's actions to contribute to decision-making errors.

298 Researchers have found that incorrect offside decisions were commonly due to errors in assistant

299 referees' positioning (Helsen, Gilis, & Weston, 2006; Oudejans et al., 2000), however no

300 investigations have considered whether the official's interpretation of a player's intention

301 contributes to decision-making errors.

302   **Decision Evaluation**. Decision evaluation was defined as the procedure that contributed to

303 a decision outcome. It was apparent that a key stage of P1's decision-making process was the

304 elimination of possible decision outcomes prior to the final decision. A situation where this was

305 evident included a holding the ball decision, in which P1 stated,

306   With a holding the ball decision you have got to eliminate all the other free kicks first. The

307   first thing is, is the tackle legal? Was it too high? No. Next step, was it too low? No.

308   Eliminate all those outside pieces and then you go 'has he had prior opportunity (to dispose

309   of the ball)?' Yes. Did he have a chance to get rid of it (the ball)? Yes, gone (holding the

310   ball infringement).

311   This example illustrates the explicit cognitive steps P1 undertook when interpreting a possible

312   holding the ball infringement. Prior to the final infringement decision, P1 eliminated all other

313   possible infringements, such as an illegal tackle (i.e., too high, too low). Participant 1 then

314   determined whether the player with the ball had prior opportunity or reasonable time to legally

315   dispose of the ball before being tackled. In this instance P1 deemed the player to be tackled

316   legally and have prior opportunity to legally dispose of the ball. Therefore, P1's final decision

317   for this situation was a free kick for a holding the ball infringement.

318   Participant 2 also used an elimination process in the same way during tackle situations:

319   "Player 1 has got the ball, he has had prior opportunity (to dispose of the ball), he was tackled

320   legally, and he has got the ball away (legally disposed of the ball), instantaneously. So play on."

321   This example indicates that P2 explicitly processed one aspect of the incident (i.e., prior

322   opportunity) before processing the next (i.e., legal tackle) and that both players conform to the

323   rules (i.e., legal tackle, legally disposes of the ball), therefore the elimination process stops and

324   play on is indicated (no infringement).

325   Participant 3 also described the elimination process of a tackle situation: "If he doesn't get

326   taken high, is it a correct tackle? Did he fall into his back? No. You got to eliminate." This

327   example explicitly indicates that Participant 3 used a cognitive elimination process to determine

328   the final decision in player contact situations.

329   Sporting officials' decision-making has been assessed (or trained) via several perceptual-

330   cognitive video-based tools (Catteeuw et al., 2009; Larkin et al., 2011; Schweizer, Plessner,

331   Kahlert, & Brand, 2011), however, these investigations have not reported the cognitive process

332   when making a decision. To provide an understanding of the demands of sport-based decision-

333   making on athletes, Farrow and Raab (2008) presented the Decision-Making in Sport Model.

334   The model identifies seven key decision-making stages that an athlete sequentially moves

335   through in order to make a decision about in-game decisions. Within the model, the stage where

336   athletes generate and consider possible decision outcomes has been identified as a key process

337   within the decision-making process of sport performers. The Decision-Making in Sport Model

338   states that skilled athletes consider possible decision options and then rank these options to form

339   the final decision. This may be an appropriate method for athletes who make movement or

340   tactical decisions, however, this model may not sufficiently explain the decision-making process

341   of an umpire, whereby based on participants in the current study, a decision outcome may be

342   selected following an elimination process. Tversky (1972) stated that any decision is subject to a

343   sequential elimination process, whereby each decision outcome is the result of an elimination

344   process of multiple sub-decisions. A sub-decision is considered and if eliminated the next sub-

345   decision is considered. This process of sub-decision elimination or selection continues until the

346   final sub-decision is accepted. Both P1 and P2 indicated that they considered and eliminated

347   multiple sub-decisions prior to the final decision outcome for each player contact incident.

348   Existing sport-based decision-making models are limited in this context as they are not umpire

349   specific, but focus on the decision-making process of athletes generally. Furthermore, the umpire

350   specific model does not provide an indication of the specific decision-making processes

351   (Mascarenhas et al., 2005). For these reasons, further research with a greater number of umpires

352   may guide the development of an umpire specific decision-making model.

353   The elimination process used by the participants within this study highlighted the

354   complexities associated with the decision-making process in Australian football. This is akin to

355   other sports (e.g., soccer), where umpire decision-making has been identified as a complex

356   process (Ollis, Macpherson, & Collins, 2006). Based on this qualitative analysis, and Australian

357   football rules, two decision-making heuristics illustrating the elimination process for two

358   different scenarios were developed. Figure 2 illustrates the elimination process for a tackle

359   situation, and Figure 3 identifies the elimination process for a marking contest.

360   **<<<INSERT FIGURE 2 HERE>>>**

361   **<<<INSERT FIGURE 3 HERE>>>**

362   Comparison of the two decision-making heuristics highlights that one of the challenges

363   associated with understanding the decision-making process in Australian football is that the

364   elimination process is situation specific. The Decision-Making in Sport Model (Farrow & Raab,

365   2008) indicates that for each decision the decision-making process is consistent, however, the

366   current results indicated that there may not be a consistent process for every in-game decision

367   because of the variation among in-game situations. Both Figure 2 and 3 illustrate a similar

368   elimination process for each decision, however the number of options and the potential cognitive

369   load associated with the specific game situation (e.g., tackle, mark) is potentially different.

370   Therefore, there must be consideration of the different decision-making processes that occur

371   during different game situations to adequately describe the in-game decision-making process of

372   Australian football umpires.

373   While this study is an important step in understanding the decision-making process of

374   Australian football umpires, as the heuristics are based on the processes of three umpires, further

375   investigations are needed to ensure all possible options are included in the heuristics. A research

376   study with a greater number of umpires would also enable decision-making heuristics to be

377   developed for all scenarios in Australian football. As indicated by Plessner and Haar (2006),

378   there are several sub-tasks within a decision-making situation which may contribute to a correct

379   or incorrect decision. By identifying the steps within the decision-making process for different

380   infringement situations, it may be possible to identify potential issues within the decision-making

381   process. Therefore, the development of further heuristics for each in-game scenario may provide

382   a reference for identifying specific areas of decision-making mistakes and potentially inform

383   umpire decision-making training programs.

384   **Conclusions**

385   This study makes a significant contribution to the perceptual-cognitive literature as it is the

386   first attempt to explore the cognitive processes that contribute to the decision-making processes

387   of Australian football umpires. Decision-making skills are fundamental to the umpiring process

388   in all sports (Helsen & Bultynck, 2004), however there has been minimal investigation of the

389   processes that contribute to the in-game decision-making of umpires. The current exploratory

390   study identified three themes that related to both the in-game decision-making process (i.e.,

391   decision evaluation, player intention during game-play) and in-game umpire performance (i.e.,

392   knowledge of game-play) providing initial evidence of the potential factors that may contribute

393   to and/or affect the in-game decision-making process of Australian football umpires. These

394   findings have led to the preliminary development of decision-making heuristics that may provide

395   a better understanding of the decision-making process of Australian football umpires than current

396   sport-based decision-making models (e.g., Farrow & Raab, 2008). Further pursuit of the factors

397   that significantly impact the in-game decision-making process of Australian football umpires is

398   needed to potentially inform future Australian football umpire decision-making training

399   programs.

400   While this study provides an understanding of the decision-making process of Australian

401   football umpires, the findings should however, be considered in respect to methodological

402   limitations. As the current investigation used stimulated recall and concurrent verbalisation

403   methods to provide a description of the conscious in-game decision-making processes, cognitive

404   processes unavailable to conscious awareness (i.e., implicit cognitions) during in-game decision-

405   making may not have been identified during the interviews. Therefore, future investigations may

406   use standardised decision-making situations and more sophisticated technologies, such as eye

407 tracking (Hancok & Ste-Marie, 2013) or option generation techniques (Raab & Johnson, 2007),

408 to provide information about subconscious visual search patterns and the generation of decision

409 options and the associated impact on the decision-making process. This type of research will

410 further develop the understanding of umpire decision-making performance presented here. In

411 addition, the study is limited by the level of expertise of the participants. Due to the within game

412 data collection methods we were unable to recruit elite level performers. While we were able to

413 recruit participants who have been identified by elite level coaches and participated in elite level

414 training programs, researchers should consider the exploring the decision-making processes of

415 elite level umpires. This may provide information indicate different decision-making processing

416 strategies which may inform umpire decision-making training programs. Finally, the current

417 investigation did not collect data relating to the physiological performance of the participants

418 during the game. While previous investigations have indicated that physiological capacity does

419 not influence decision-making performance (Larkin et al., 2014; Paradis et al., 2015), future

420 investigations should consider whether how physiological capacity may influences the in-game

421 decision-making processes of umpires.

422 From a practical perspective, based on the findings associated with umpire decision-

423 making performance, a key component of in-game decision-making was the process of

424 interpreting a player's objective or intent during a game action. This process, however, may

425 contribute to inconsistent decision-making outcomes between umpires because each umpire may

426 interpret the intention of the player differently. Therefore, umpire coaches may contemplate the

427 introduction of novel training activities, such as video-based training, to assist the development

428 of skills associated with the interpretation of player's intention during game actions.

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432

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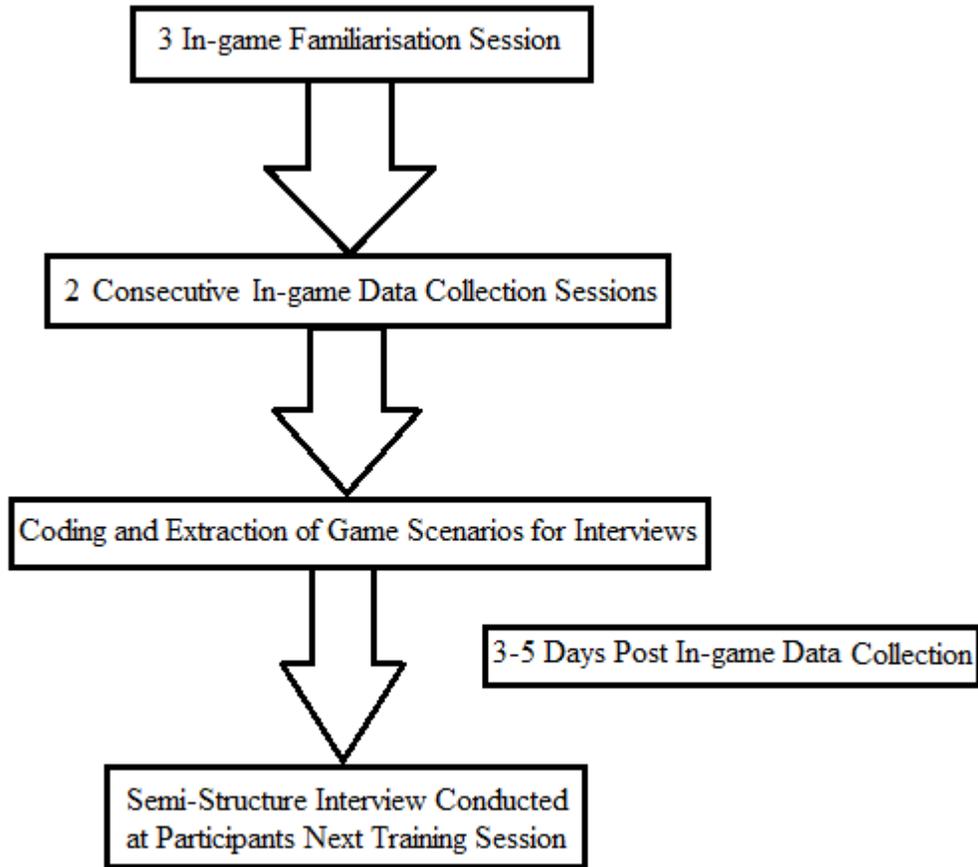529   perspective. *Psychology of Sport & Exercise*, *7*(6), 555-575.

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564   *Table 1*. The definition and number of times each theme was discussed by the participants during

565   the data collection phase (i.e., in-game verbalisation and semi-structured interviews).

Theme Name	Number	Definition
Knowledge of Game-Play	46	Self-directed communication that demonstrated knowledge of future player actions and/or game-play.
Player Intention during game play	88	The interpretation of a player's objective during game-play (e.g., body movements or actions) that guided an infringement-based decision
Decision evaluation	181	The procedure that contributed to a decision outcome

566

3 In-game Familiarisation Session

2 Consecutive In-game Data Collection Sessions

Coding and Extraction of Game Scenarios for Interviews

3-5 Days Post In-game Data Collection

Semi-Structure Interview Conducted at Participants Next Training Session
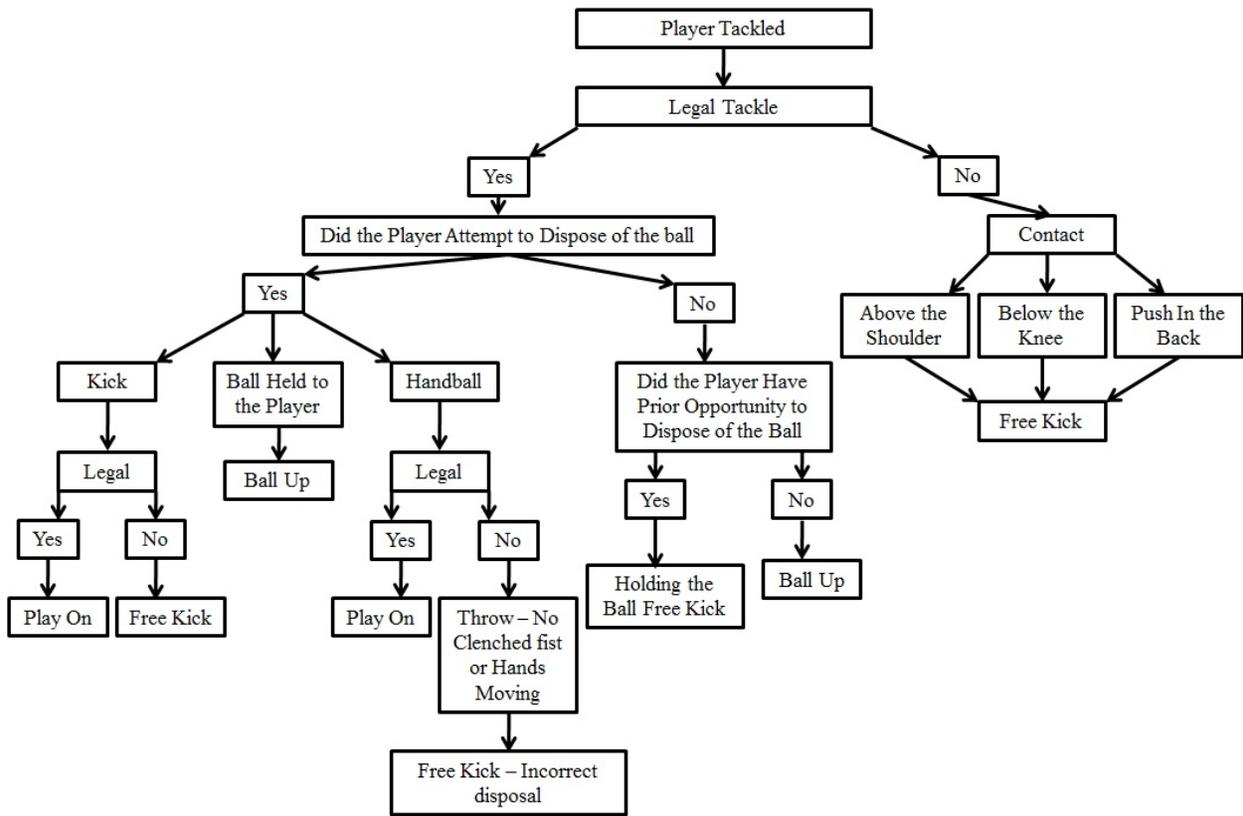
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568   *Figure 1*. Schematic of the data collection period for all participants.
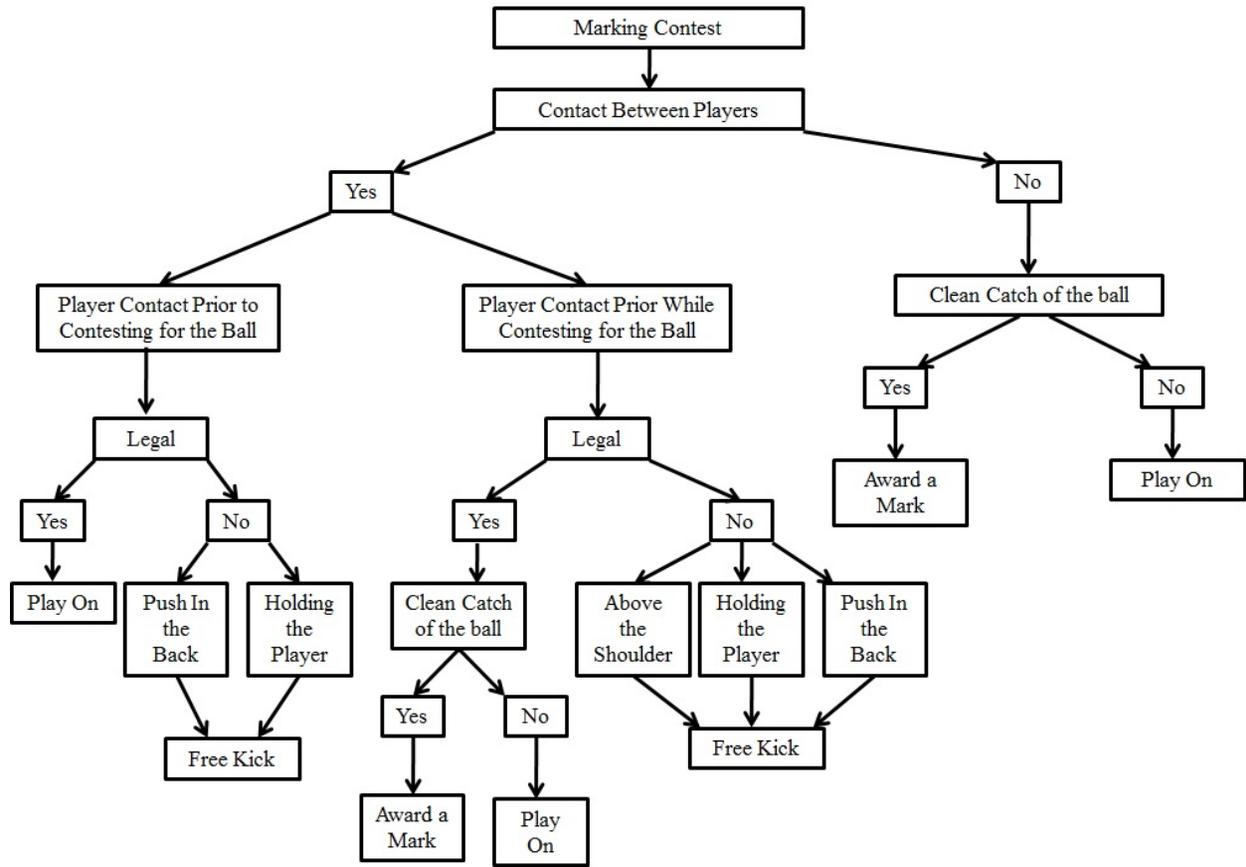
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573   *Figure 2*. Decision-making heuristic for a tackling situation.

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575   *Figure 3*. Decision-making heuristic for a marking contest.

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