

1 Running head: UMPIRE DECISION-MAKING PROCESS

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

7 making of Australian football umpires

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**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.

**Keywords:**

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



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 biffa (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 (Hancock & 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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**References**

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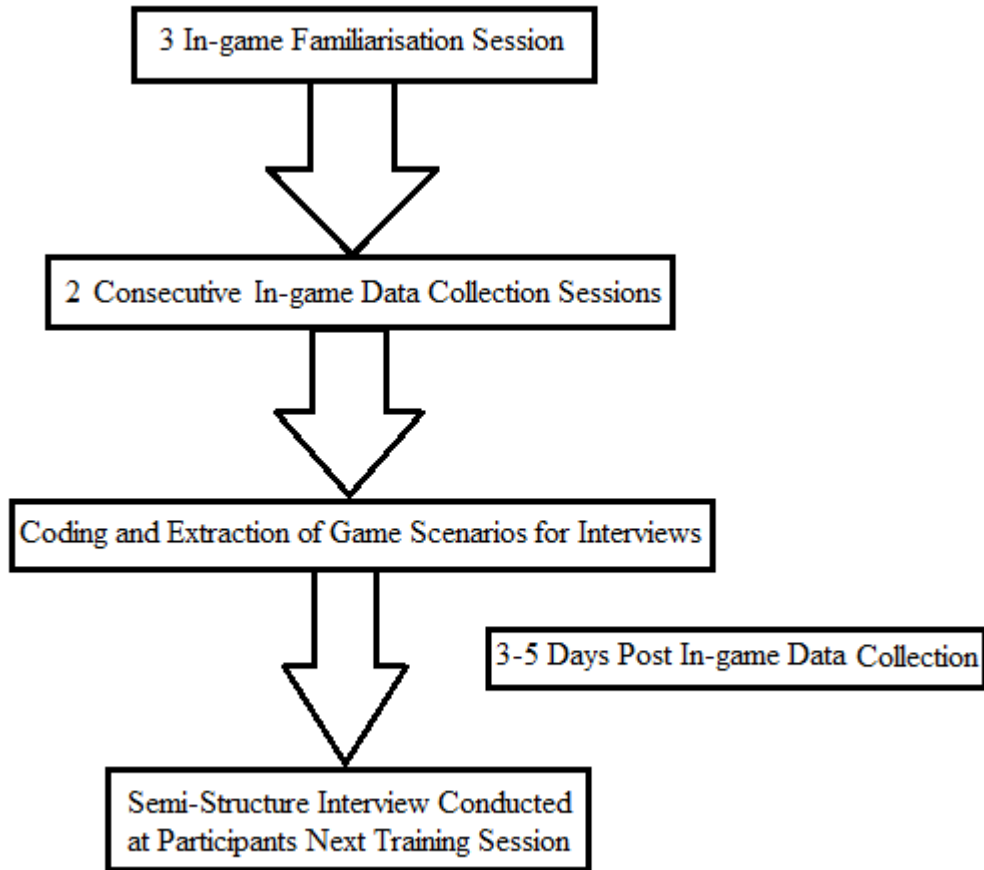
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564 *Table 1.* The definition and number of times each theme was discussed by the participants during  
 565 the data collection phase (i.e., in-game verbalisation and semi-structured interviews).

| 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   |

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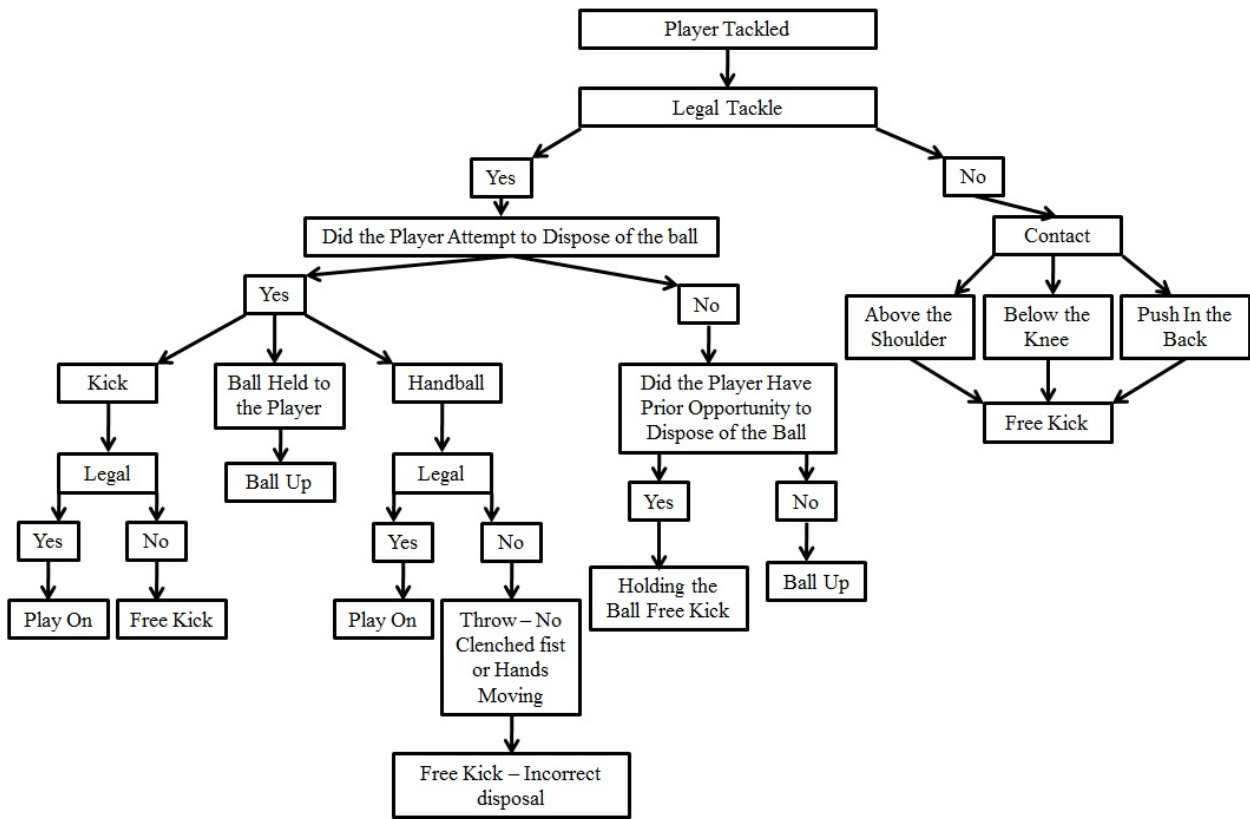
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568 *Figure 1.* Schematic of the data collection period for all participants.

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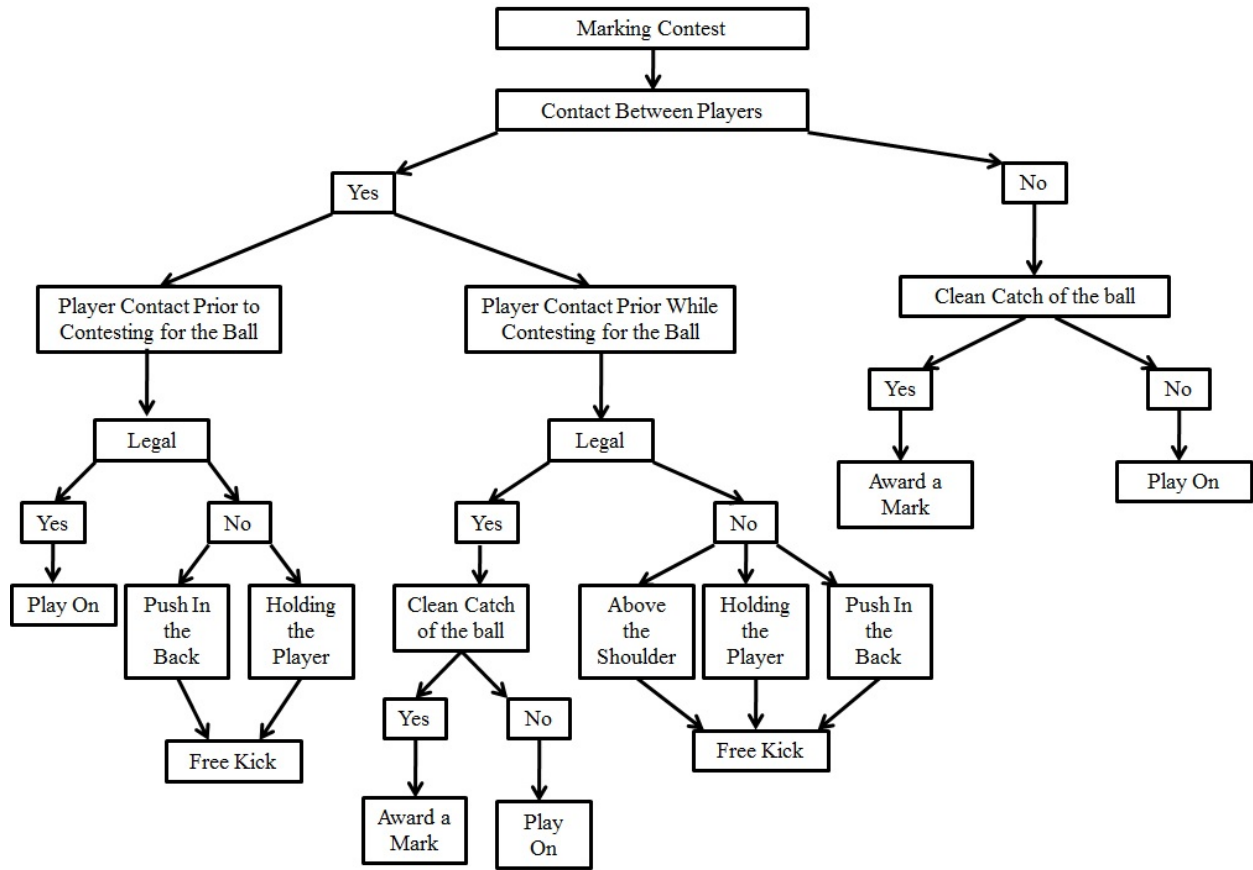
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573 *Figure 2.* Decision-making heuristic for a tackling situation.



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

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