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Walking the talk: Comparing pedestrian 'activity as imagined' with 'activity as done'

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16 **Walking the talk: Comparing pedestrian ‘activity as imagined’ with ‘activity as done’**

17 **Abstract**

18 The safety of vulnerable road users, including pedestrians, is an important issue worldwide. In line with the shift towards
19 systems thinking in transport safety, the aim of this study was to compare the normal performance of pedestrians as they
20 navigate the road system with that imagined by road system managers to gain insights into how safety management can
21 be improved for this vulnerable road user group. The Event Analysis of Systemic Teamwork framework was used to
22 compare pedestrian activity ‘as imagined’ and ‘as done’ at signalised road intersections and railway level crossings. Data
23 regarding ‘activity as imagined’ was derived from documentation review, and data on ‘activity as done’ was derived from a
24 semi-naturalistic study of ten participants. It is concluded that in both environments pedestrians exhibited more diversity
25 and variability than anticipated by system managers. Insights for improving the design of the road environment for
26 pedestrians are provided. Further, it is argued that wider changes to the processes used in the design and management of
27 road systems are needed.

28 **Keywords:** Performance variability, Pedestrian safety, Intersections, Railway level crossings, Event Analysis of Systemic
29 Teamwork, Systems thinking

30

31 **1. Introduction**

32 The benefits of active transport such as walking are well-recognised and there is increasing evidence to
33 support shifts to active transport to improve population health and reduce carbon emissions (e.g. Purcher &
34 Buehler, 2010; Rabl & de Nazelle, 2012). However, there are risks for pedestrians who, as vulnerable road
35 users, are generally more susceptible to injury in crashes than other road user groups (Australian Transport
36 Council, 2011). Between 2004 and 2008, there were 3,702 pedestrian casualties (fatalities and serious injuries)
37 in the Australian state of Victoria and, across Australia as a whole, pedestrians make up 13% of road fatalities
38 (Bureau of Infrastructure, Transport and Regional Economics, 2015). Globally, pedestrian fatalities comprise
39 22% of all road deaths (World Health Organization, 2015) and worryingly, in the United States, the number of
40 pedestrian fatalities has risen 19% from 2009 to 2014 (Retting, Rothenberg & Schwartz, 2016).

41 In Victoria, Australia, the majority of casualty-crashes occur in urban areas and over 40% of fatal accidents
42 involving pedestrians occur at intersections (Senserrick, Boufous, de Rome, Ivers, & Stevenson, 2014). While
43 collisions with pedestrians at railway level crossings are much less frequent, with 20 collisions in Victoria from

44 2004-2008 (Australian Transport Safety Bureau, 2012a), they are more likely to result in fatal outcomes. These
45 collisions are also more disruptive to the transport system resulting in lengthy train delays with associated
46 economic loss. Statistics indicate that while reductions have occurred in the number of motor vehicle-train
47 collisions at railway level crossings, this has not been reflected in the pedestrian-train collision rate (Australian
48 Transport Safety Bureau, 2012b; Metaxatos & Sriraj, 2013; Stefanova et al., 2015).

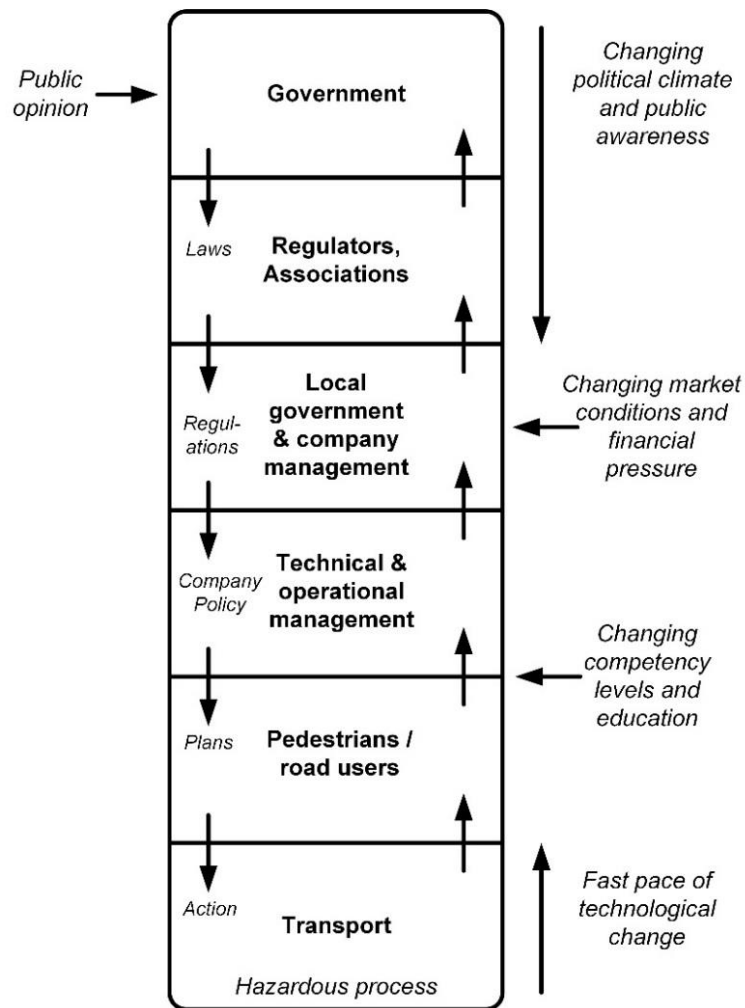
49 Poor pedestrian behaviour has been identified as an important issue for the improvement of pedestrian safety.
50 For example, a study by Freeman and Rakotonirainty (2015) into behaviour at railway level crossings found
51 that 25% of pedestrians reported deliberately violating rules, with the majority doing so because they were
52 rushing or running late. In addition, it is well-known that pedestrians regularly cross against signals at
53 intersections (e.g. Kim, Made Brunner, & Yamashita, 2008; King, Soole, & Ghafourian, 2009). It therefore
54 seems apparent that to improve safety we should focus on improving the behaviour of pedestrians, increasing
55 compliance with rules that are developed to keep them safe.

56 However, is this compliance based approach the most effective way to manage safety? In recent times there
57 has been an increase in the use of so-called systems thinking approaches to understand and enhance road
58 safety behaviours (Newnam & Goode, 2015; Newnam et al., 2017; Salmon & Lenné, 2015; Salmon et al., 2013;
59 Salmon, Read & Stevens, 2016). One of the fundamental advances provided by systems thinking centres
60 around the idea that the behaviours underpinning accidents do not necessarily have to be errors, failures or
61 violations (Salmon et al., 2017). As Dekker (2011) points out, systems thinking is about how accidents can
62 happen when no parts are broken. In his recent drift into failure model, Dekker (2011) argues that the seeds
63 for failure can be found in “normal, day-to-day processes” (pg. 99) that are shaped by goal conflicts and other
64 pressures. These normal behaviours include workarounds, improvisations, and adaptations (Dekker, 2011). In
65 the pedestrian context, we can view behaviours like jaywalking as an adaptation, undertaken where
66 pedestrians may be frustrated by waiting times and take their own decision to cross when they believe it is
67 safe to do so. Understanding why decisions and behaviours make sense to pedestrians at the time gives us a
68 different perspective on the problem, and facilitates the development of new types of interventions. Studying
69 so-called ‘normal performance’ and how it plays a role in adverse events is a critical but often overlooked
70 requirement in accident prevention research (Salmon et al., 2017).

71 Given the current paradigm shift in transport safety from an individual approach to systems thinking
72 approaches (Larsson, Dekker & Tingvall, 2010; Newnam & Goode, 2015; Salmon & Lenné, 2015), this paper
73 argues that comparing the normal performance of pedestrians as they navigate the road system with that
74 imagined by road system managers can provide insights into how safety management can be improved for this
75 vulnerable road user group.

76 1.1 A systems framework

77 A popular systems-based model of safety management is Rasmussen's (1997) risk management framework. It
78 describes how the transport system comprises hierarchical levels from government at the top, down to the
79 operating process at the bottom. At each level, decisions and actions are made by actors such as government
80 officials, regulators and transport managers that constrain the decisions and actions of those in the level
81 below. In turn, information is provided back up the hierarchy to inform those above of the effectiveness of the
82 safety constraints. This process of constraints flowing down and information flowing up the hierarchy is known
83 as vertical integration. According to Rasmussen, failures of vertical integration lead to accidents and incidents.
84 Figure 1 shows Rasmussen's framework adapted for pedestrian activities.



85

86 Figure 1. Rasmussen's (1997) risk management framework, adapted for pedestrian activities.

87 Applying the idea of vertical integration to pedestrian safety, it is important to understand the extent to which
 88 the assumptions and expectations of those at the higher levels of the system who own and manage the system
 89 flow down through the system and match the behaviour of system users (e.g. pedestrians themselves). The
 90 distinction between 'work as imagined' and 'work as done' is an important notion in the understanding of
 91 safety-critical systems (Hollnagel, 2014; Norman, 1988). How management anticipate and expect the system
 92 to be used is often very different to how it is actually used, particularly over time as practices shift and adapt
 93 to perturbations and external disturbances. In the road transport system, the managers (e.g. road authorities,
 94 government) tend to promote a normative view of road user activity. That is, they focus on how users should
 95 interact with technology and the built environment as designed regardless of context or competing goals. For
 96 example, fences and barriers may be implemented to stop pedestrians from crossing a road in a particular
 97 place, with no regard for why pedestrians want to cross there, such as desire lines between points of interest.

98 Deviations from these expectations, such as pedestrians jumping or otherwise circumventing barriers, are
99 addressed through changes to laws in an attempt to reduce variety and variability. However, to improve safety
100 in practice there is a need to understand actual user activity. This provides leverage to design to meet the
101 needs both of the users and the system managers.

102 1.2 Performance variability

103 As noted previously, accident causation theory has moved away from discussions of human error or deviations
104 from normative behaviour; instead focussing on the notion of 'human performance variability' (e.g. Dekker,
105 2014). This acknowledges that in complex systems, including road transport systems (Salmon, Read & Stevens,
106 2016), human performance must be variable and adaptive to cope with system perturbations and disturbances.
107 This view of safety emphasises that a broad spectrum of behaviour exists in any system, not only as a
108 dichotomy of compliant and non-compliant behaviour (Dekker 2006). Unless this is acknowledged by those
109 responsible for designing and managing safety critical systems, opportunities will be missed to create resilient
110 systems. For example, if we know that pedestrians have a general propensity for choosing the quickest or
111 shortest route (Agrawal, Schlossberg & Irvin, 2008) then rather than force compliance (which can be
112 expensive), we can use this understanding to design environments in which the quickest, shortest route (or
113 one that appears that way) is also the safest for example by providing signalised crossings where pedestrians
114 prefer to cross.

115 Research in the area of pedestrian behaviour and safety is beginning to move towards systems-based
116 approaches (e.g. Salmon et al., 2014; Stefanova et al., 2015; Vizzari, Manenti & Crociani, 2013) and
117 understanding variability in how pedestrians and other road users perceive and negotiate road environments
118 (e.g. Beanland, Lenné, Salmon, & Stanton, 2015; Cornelissen et al., 2013; Mulvihill, Salmon, Lenné, Beanland,
119 & Stanton, 2014; Salmon et al., 2014). These applications have provided important insights into how the
120 design of road environments influences pedestrian behaviour and safety; however, no previous research has
121 focussed specifically on the concept of 'work as imagined' versus 'work as done' in the area of road safety.
122 Given that most pedestrians cannot be considered to be undertaking work when interacting with the road
123 system, we can instead conceptualise the comparison as being between 'activity as imagined' and 'activity as
124 done'.

125 The aim of this study was to contrast the activities of pedestrians ‘as imagined’ by road system managers and
126 ‘as done’ by pedestrians, in real road environments. The analysis considers firstly pedestrian activity at
127 signalised intersections, and secondly, pedestrian activity at railway level crossings. The findings are used to
128 provide recommendations to improve the management of road environments to support positive performance
129 variability, and consequently improve pedestrian safety.

130

131 **2. Method**

132 **2.1 Design**

133 The Event Analysis of Systemic Teamwork (EAST) framework (Stanton, Salmon, Walker, Baber, & Jenkins, 2005)
134 was adopted to structure the analysis. EAST uses network-based representations of tasks, social interactions
135 and information elements to understand system functioning. For this analysis, task and information networks
136 were used. Task networks describe the activities that are performed in the system and show the relationships
137 between them through links between the nodes, while information networks represent the information that is
138 used and how different information types are linked (Stanton & Harvey, 2016). Information networks are
139 commonly used to represent situation awareness (e.g. Salmon, Lenné, Young & Walker, 2013). Thus, networks
140 were created to represent pedestrian tasks ‘as imagined’ and ‘as done’, and pedestrian situation awareness ‘as
141 imagined’ and ‘as done’. Social interaction networks were not developed in this study as the task and
142 information networks were developed solely from the perspective of pedestrians.

143 Pedestrian behaviour was analysed in two road environments where pedestrians are exposed to risk of
144 collisions with transport vehicles: at signalised intersections and at railway level crossings.

145

146 **2.2 Data sources**

147 **2.2.1 Activity as imagined**

148 Designers of the road system are not an identifiable group of individuals; in fact road system design has
149 evolved over the last century or so, with intentions embodied in artefacts such as legislation, design codes and
150 standards, education materials and the physical road infrastructure itself. For the purposes of this study,

151 activity 'as imagined' was described based on relevant texts (e.g. laws and guidance material) that can be
152 considered akin to work procedures which are commonly viewed as a proxy for work as imagined within
153 organisations (e.g. Antonsen, Almklov & Fenstad, 2008; Clay-Williams, Hounsgaard & Hollnagel, 2015; Dekker,
154 2006).

155 For intersections, rules 230 and 231 of the *Road Safety Road Rules 2009* and a fact sheet published by the road
156 agency (VicRoads, 2011) were identified as relevant texts for analysis. For railway level crossings, rule 235 of
157 the *Road Safety Road Rules 2009* (Vic) and web page text published by the responsible government authority
158 titled 'Safe use of rail pedestrian crossings' (Public Transport Victoria, 2013) were identified as relevant texts
159 for analysis.

160 **2.2.2 Activity as done**

161 To understand the actual behaviour of users at the two road environments, we employed a semi-naturalistic
162 approach to data collection. This was achieved by asking participants to walk a pre-determined route while
163 providing concurrent verbal protocols and wearing recording equipment. This enabled data to be collected
164 about the tasks being undertaken and participants' situation awareness and decision making processes.

165 Ethics approval was granted by the Monash University Human Research Ethics Committee prior to data
166 collection commencing.

167 *Participants*

168 Ten participants (4 males, 6 females) took part in the study (five at each study location). Participants were
169 aged between 19 years and 62 years ($M = 36.6$ years, $SD = 15.95$ years). Participants self-reported that they
170 walked, on average, between 15 and 90 minutes per day in urban areas ($M = 45.10$ minutes, $SD = 25.34$).

171 Participants reported how often they undertook the tasks of crossing at pedestrian crossings and railway level
172 crossings when walking in urban areas. 90% of participants 'always' or 'often' used road pedestrian crossings
173 during the daily activities and two-thirds of participants 'always' or 'often' used railway level crossings (the
174 remaining third used them 'sometimes').

175 Experience with the specific study routes traversed by the participants was mixed. 20% of participants had
176 traversed the route more than 20 times previously, 10% had walked the route between two and 10 times, 40%
177 of participants had traversed the route once previously and 30% had never previously traversed the route.

178 *Materials*

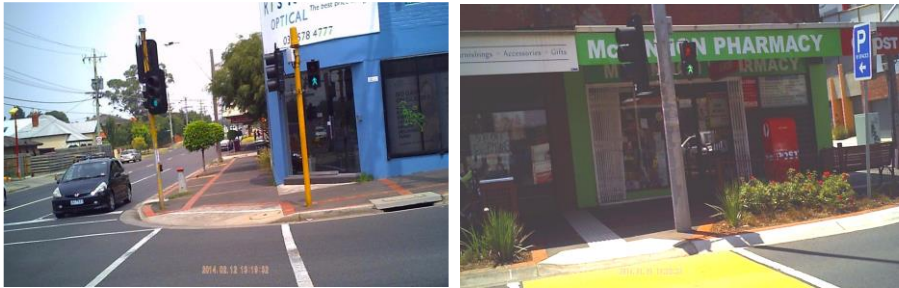
179 A questionnaire was used to collect demographic information from participants and a laptop computer was
180 used to display a video showing a pedestrians' view of traversing a footpath in an urban area. This was used by
181 the researcher to demonstrate the verbal protocol methodology and to enable participants to practice
182 providing concurrent verbal protocols. Verbal protocols are used to gain insight into the cognitive and physical
183 processes that an individual uses to perform a task (Walker, 2004). This is achieved by asking individuals to
184 'think aloud' while concurrently performing the task of interest, and then analysing a transcript of these
185 verbalisations to make 'valid inferences' from the content of discourse (Weber, 1990). The approach has been
186 used in previous semi-naturalistic studies of road user behaviour, including for understanding road user tasks
187 and situation awareness (e.g. Salmon et al., 2014, Walker, Stanton, & Salmon, 2011, Young et al. 2013). The
188 verbal protocol technique has been shown to have no impact on most driving tasks (although some vehicle
189 control tasks are improved; Salmon, Goode, Spiertz, Thomas, Grant & Clacy, 2017) and thus was not expected
190 to interfere with participants usual behaviour.

191 Two locations in the south-eastern suburbs of Melbourne, Victoria were selected for the study. Each location
192 incorporated both signalised pedestrian crossings over roads as well as signalised railway level crossings.
193 Figure 2 presents images of the approach to each of these environments. At each location, a route was
194 designed to incorporate participants crossing at least two signalised intersections and two railway level
195 crossings. The routes were designed to be relatively simple to avoid any heightened cognitive workload for
196 participants unfamiliar with the study location and took approximately 20 minutes to complete.

197 During the walk, participants wore Imaging HD video recording glasses to record the forward view. In addition,
198 participants wore a microphone and dictaphone which recorded their concurrent verbal protocols.

Location 1

Signalised intersections

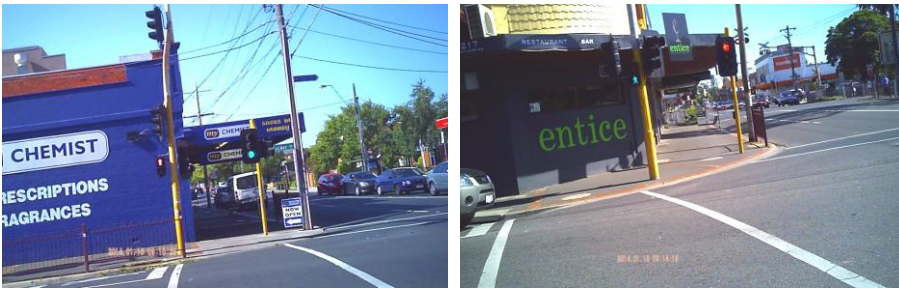


Railway level crossings



Location 2

Signalised intersections



Railway level crossings



199

200 Figure 2. Approaches to the eight road environments traversed by participants

201 The intersections on the routes were signalised. At these types of intersections road users facing a green light
202 have right of way. Pedestrians and road traffic moving in the same direction have right of way simultaneously.
203 Road traffic can turn left and right at an intersection on a green traffic light but must give way to pedestrians
204 who are crossing the road being entered. Pedestrians are provided with a visual signal showing either a
205 standing 'red man' symbol (signalling for the user to stop), or a walking 'green man' symbol (signalling for the
206 user to cross). A flashing 'red man' signal is used to indicate that the pedestrian phase is coming to an end and
207 that pedestrians currently crossing should continue to cross but that pedestrians should not begin to cross. For
208 the pedestrian lights to activate, pedestrians press a button located at the intersection. These buttons use
209 auditory and tactile feedback to assist pedestrians with visual and hearing impairments. When the red man is
210 displayed a series of beeps are provided at long intervals and when the green man is displayed a series of
211 beeps at shorter intervals occur.

212 The railway level crossings on the routes were standard 'active' crossings, designed so that approaching trains
213 have right of way over road traffic. However, whenever trains are not present, the roadway and adjacent
214 pedestrian footpath are open to allow traffic through flow. Following detection of an approaching train a range
215 of warning signals intended to indicate to pedestrians (and other road users) that they must stop for the train
216 are activated. The warnings typically include bells, automatic gates, twin red flashing lights and boom barriers
217 operating at the road crossing. The sight of the train itself can also act as a warning and the train horn is
218 generally required to be sounded as a warning prior to the train reaching the crossing. Because automatic
219 gates close across the pedestrian crossing, 'emergency exit gates' are provided to allow pedestrians to exit
220 from the crossing if they are traversing when the warnings begin to avoid becoming trapped on the crossing
221 with a train approaching.

222 *Procedure*

223 Participants were provided with an explanatory statement giving details of the study and instructions on how
224 to practice providing concurrent verbal protocols by email prior to attending to participate in the study. On the
225 day of the study, participants met the researcher near the beginning of the study route. After giving informed
226 consent, the researcher verbally explained to participants the instructions on how to provide concurrent
227 verbal protocols. These instructions included an explanation that the process aims to gather information about
228 situation awareness (i.e. understanding of what is going on) and decision making during the walk. Participants

229 were told that it is more important that they verbalise what they are thinking about or doing mentally as they
230 walk, rather than just what they are physically doing. Further, they were told that it is important to verbalise or
231 think aloud continuously as they walk the route and that if they need to stop thinking aloud (i.e. due to
232 concentrating on a complex traffic situation), to re-cap their thoughts once they can do so.

233 Next, participants were given a short demonstration of providing concurrent verbal protocols by the
234 researcher followed by a practice session in which they watched a video recording, taken from a pedestrians'
235 perspective, of walking in an urban environment. During the practice, the researcher provided feedback to the
236 participant regarding the quality of their verbal protocols until they were able to provide protocols of sufficient
237 quality for the study. For example, if a participant stated "I am looking down at the pavement" during the
238 practice, the researcher would prompt them to verbalise what they are thinking about in relation to that
239 action and what information from the environment they were using, such as, "I am checking the pavement to
240 make sure that I am not going to slip as the surface is muddy".

241 Participants were then shown a map of the walking route that they were to take and asked to memorise it.
242 When participants indicated that they were confident in undertaking the verbal protocol procedure and that
243 they understood the route to take the recording equipment was fitted and activated. Participants then
244 negotiated the study route alone whilst providing a continuous concurrent verbal protocol. They then met the
245 researcher back at the initial location and were debriefed.

246 The audio recordings were downloaded from the dictaphone and transcribed verbatim in Microsoft Word. The
247 verbal protocols provided by participants relating to the two signalised intersections and two railway level
248 crossings were extracted from the overall dataset.

249 **2.2 Network development**

250 **2.2.1 Task network development**

251 To understand tasks 'as imagined', task networks were developed using content analysis to identify task-
252 related information within the texts (which formed the nodes in the task network) and capturing relationships
253 representing sequences or dependencies of tasks (which were represented as links between the nodes). For
254 example, the content of the two sentences "Always wait for the green man signal before crossing" and "Make
255 sure all traffic is stopping before starting to cross" (VicRoads, 2011) resulted in the identification of four tasks,

256 and their relationships (see Figure 3A). The tasks identified across the source documents were combined in a
257 single task network.

258 To understand tasks 'as done', overall task networks for each type of encounter were created from reviewing
259 the audio and video recordings taken during the study, across all participants. For example, the task node of
260 'approach intersection' was underpinned by statements such as "Coming up to the pedestrian crossing",
261 "Coming up to the traffic lights..." and "Come up to the crossing". It was also supported by the video footage of
262 the participant walking towards the intersection.

263 The task networks were generated by a single analyst and reviewed and validated by a second analyst. Any
264 disagreements were resolved through discussion until consensus was reached.

265 **2.2.2 Information network development**

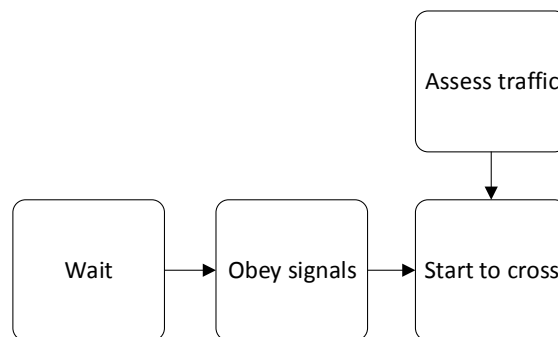
266 Information networks, showing the concepts that comprise pedestrian situation awareness 'as imagined', were
267 created by identifying concepts within the texts that related to information which the road user would be
268 expected to use when encountering the road environments. These concepts become the nodes in the
269 network. The links within the networks reflect the relative position of the concept within the text. That is,
270 concepts positioned adjacent to one another in text were linked. For example, the sentence "At intersections
271 always look out for turning vehicles. Check for vehicles turning right and left into the road being crossed"
272 (VicRoads, 2010) resulted in the identification of 6 information nodes and the relationships between them (see
273 Figure 3B).

274 This 'activity as imagined' information network was generated by a single analyst, based on the information
275 nodes identified across the source documents, and was reviewed and validated by a second analyst. Any
276 disagreements were resolved through discussion until consensus was reached. The frequency of the co-
277 occurrence of concepts in the text was tallied and the frequencies noted on the links between nodes,
278 represented by the thickness of the line widths.

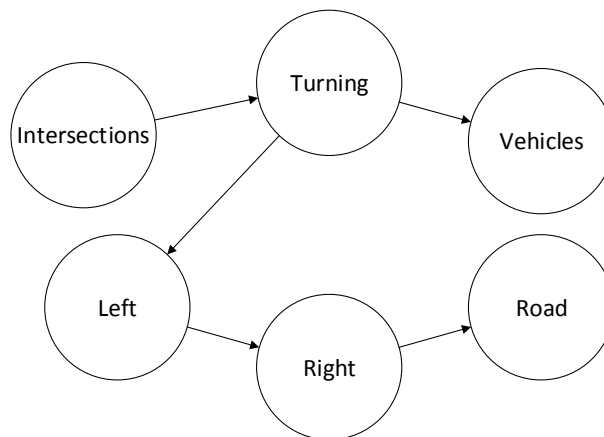
279 For the 'activity as done' information network, the larger underpinning data set (transcripts of verbal
280 protocols) required a different validation approach. In this case, individual information networks for each
281 encounter were initially generated by a single analyst. A second analyst then independently generated
282 networks for 20% of encounters. Inter-rater reliability for the information networks was calculated in two

283 ways. Firstly, the level of agreement in relation to the nodes was calculated. A percentage agreement of 80.2
284 was achieved in this analysis. Next, agreement in relation to the links between concepts was considered. Given
285 that a disagreement about a node will automatically involve a disagreement associated with links associated
286 with the node, for this analysis only links between agreed-upon nodes were considered. This resulted in a
287 71.7% agreement level on the links. All disagreements relating to the identification of concepts and the links
288 between them were resolved through discussion.

289 Because of the application of the rule to link nodes that are adjacent in the text, a second rule was applied in
290 the development of the information networks to ensure that they were an appropriate reflection of the data.
291 This rule was to delete all idiosyncratic links between nodes (i.e. links that occurred only once in the dataset) in
292 the full information networks, as well as orphaned nodes created by the link deletions. For example, in the
293 'activity as done' network one participant statement had referred to a "frightening dog", leading to these two
294 nodes being linked. As this pair of nodes only co-occurred once, the link was deleted. Then the node
295 'frightening' was deleted as it did not have any additional links to other nodes. The node 'dog' remained, as it
296 did have links to other nodes in the network.



A. Task network development



B. Information network development

297

298 Figure 3. Examples of initial generation of task and information networks

299 **2.2.3 Network analysis**

300 Network analysis metrics are used in EAST to provide quantitative measures of the structure of networks and
301 the properties of nodes within networks. In this study, analysis software, AGNA version 2.1 (Benta, 2005) was
302 used to calculate the sociometric status of nodes within the networks. Sociometric status can be used to
303 identify key nodes within a network. Sociometric status is calculated based on the number of links received
304 and emitted by a node relative to the number of nodes in the network. Key nodes are defined as nodes which
305 have a higher sociometric status score than the sum of the mean sociometric status score plus the standard
306 deviation sociometric status score for all nodes in the network (Houghton et al, 2006). These key nodes can be
307 considered to have a high influence on the whole network, relative to other nodes.

308 **2.4 Comparing activity as imagined and activity as done**

309 Matthews' correlation coefficient was used to compare activity as imagined (predicted performance) with
310 activity as done (observed performance). The coefficient is interpreted in a similar manner to Pearson's
311 correlation coefficient. A correlation of 1 indicates perfect agreement, 0 is expected for a prediction no better
312 than random, and a correlation of -1 indicates total disagreement between prediction and observation
313 (Matthews, 1975).

314 The analysis involved comparing the nodes in the networks describing actual activity with the nodes in the
315 networks describing activity as imagined. The number of true positives, true negatives, false positives and false
316 negatives were identified and used to calculate rates of true positives and false positives, as well as Matthews'
317 correlation coefficient. The following definitions were used:

- 318 • True positives. Nodes that were present in the both the activity as imagined networks and the
319 networks describing activity as done.
- 320 • False positives. Nodes that were present in the activity as imagined network only.
- 321 • False negatives. Nodes that were present in the activity as done network only.
- 322 • True negatives. Nodes that were correctly rejected from the activity as done networks. These were
323 determined by reviewing the activity as imagined networks developed for the other road
324 environment. For example, when identifying true negatives for the *railway level crossing* activity as

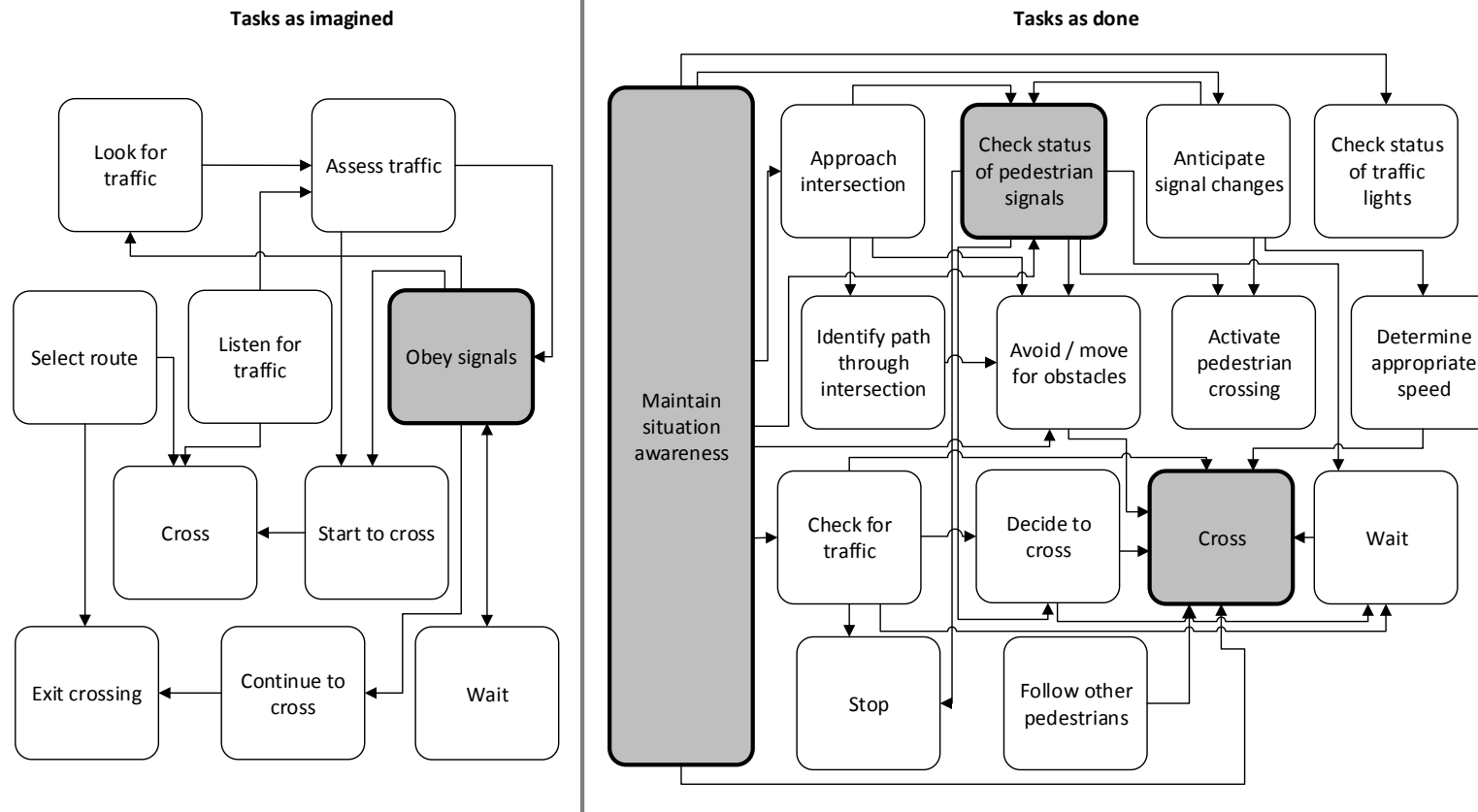
325 done task network, the task of 'check status of traffic lights' from the activity as imagined *intersection*
326 task network was designated a true negative as it is not a task that is able to undertaken by
327 pedestrians in that context.

328 **3. Results and discussion**

329 **3.1 Signalised road intersections**

330 **3.1.1 Tasks at intersections**

331 The task networks generated for crossing intersections are shown in Figure 4. On the left hand side is the task
332 network for tasks as imagined and on the right hand side is the task network representing tasks as done. A
333 total of 10 tasks were identified for the tasks as imagined network, while 15 tasks were identified for the tasks
334 as done network.



335

336 Figure 4. Tasks as imagined and as done for negotiating a signalised road intersection. Note: nodes in grey are key nodes, based on their sociometric status within the

337 network.

338 For the tasks as imagined network, a mean sociometric status was found of 0.33, and standard deviation (SD)
339 of 0.14. Therefore any nodes with a status above 0.47 were designated as key nodes. There was only one key
340 node 'Obey signals' (status = 0.66) in this network. It is perhaps not surprising this was a key node given that
341 compliance with signals is a focus of the road rules.

342 For the tasks as done network, a mean sociometric status was found of 0.27 (SD = 0.14). Therefore any nodes
343 with a status above 0.41 were designated as key nodes. These nodes were 'Maintain situation awareness'
344 (status = 0.50), 'Cross' (status = 0.50) and 'Check status of pedestrian signals' (status = 0.43).

345 The task of maintaining situation awareness was unique to the as done network and referred to a continual
346 process carried out by pedestrians as they approached and traversed the intersection. It involved maintaining
347 awareness of aspects of the environment such as the position and intentions of other road users such as
348 cyclists and other pedestrians, as well as non-task related aspects within the environment such as looking at
349 shops, or a general interest in what other road users are doing. These other aspects are interesting as it
350 demonstrates that pedestrians have multiple overlapping goals that need to be understood and considered in
351 design.

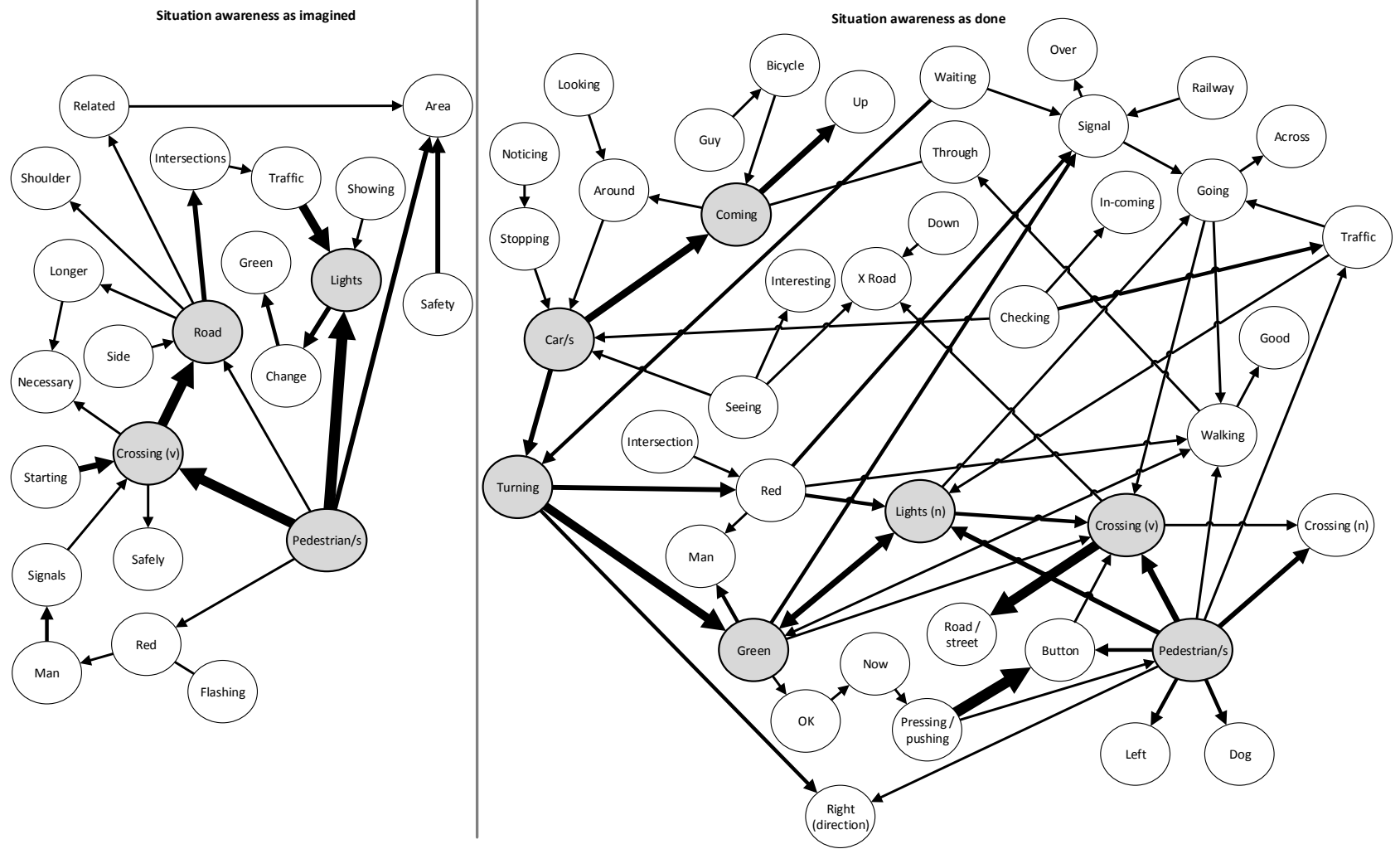
352 The task of crossing the intersection was present in both networks, but was more prominent in the as done
353 network, suggesting it may hold more significance or priority in real world situations. Finally, the importance of
354 the pedestrian signals in influencing pedestrian behaviour was highlighted in both networks.

355 Other tasks that were not key nodes but that were unique to the actual network were 'Anticipate signal
356 changes' and 'Avoid / move for obstacles'. The former task describes when pedestrians check traffic lights and
357 pedestrian signals facing different approaches to the intersection, using their knowledge of signal sequences
358 (either generally, or at the particular intersection) to anticipate when they will receive the signal to proceed.
359 Pedestrians might use information such as the length of time on approach they have seen the traffic lights at
360 stop to decide whether to speed up their pace to press the button ('activate pedestrian crossing') in time for it
361 to have an effect on the light sequence, instead of waiting for another light cycle before they will be provided
362 with the green man signal. That this task was omitted from the as tasks as imagined network again suggests a
363 lack of consideration by designers of goal driven behaviour; i.e. that pedestrians are not passive responders to
364 the environment but are actively seeking to achieve their own goals.

365 The task 'Avoid / move for obstacles' represented occasions when pedestrians moved to make space for other
366 pedestrians, as well as changing their course or showing concern to avoid other objects such as poles, pets,
367 etc. While considerations around pedestrian movements and crowds are taken into account in engineering
368 design, it is questionable the extent to which unusual circumstances (such as people walking with dogs, or
369 people taking different paths to maximise shelter during inclement weather) are taken into account in design
370 of pedestrian environments.

371 **3.1.2 Situation awareness at intersections**

372 The information networks for signalised intersections are shown in Figure 5. A total of 23 information concepts
373 are present in the as imagined network, while 42 information concepts are present in the as done network.



374

375 Figure 5. Information networks for pedestrians using signalised intersections. Note: (v) refers to the verb form of a word and (n) to the noun form; nodes in grey are key

376 nodes, based on their sociometric status within the network.

377 For the situation awareness as imagined network, a mean sociometric status was found of 0.39 (SD = 0.37).
 378 Therefore, nodes with a status above 0.76 were designated as key nodes. For the situation awareness as done
 379 network, the mean sociometric status was calculated at 0.21 (SD = 0.20). Therefore, nodes with a status above
 380 0.41 were designated as key nodes.

381 The key nodes within these networks are shown in Table 1. There was some consistency between the
 382 networks with the concepts of 'Pedestrian/s', 'Crossing (v)' and 'Lights' being prominent within both networks.
 383 However, the prominence of the additional information elements 'Green', 'Turning' and 'Cars' within the as
 384 done network suggests that pedestrians using intersections are not only using the traffic lights to make
 385 decisions, but are also looking for confirmation that it is safe to cross.

386 Table 1. Key nodes within the signalised intersection information networks

'As imagined' network node	Sociometric status	'As done' network node	Sociometric status
Crossing (v)	1.29	Green	0.76
Pedestrian/s	1.19	Pedestrian/s	0.73
Lights	1.05	Crossing (v)	0.63
Road	1.05	Lights	0.59
-	-	Turning	0.51
-	-	Cars	0.44
-	-	Coming	0.41

387
 388 In addition to considering what is in the networks, it is interesting to note what is absent. Across both situation
 389 awareness networks there was no mention of audible signals or traffic sounds (i.e. no concepts associated with
 390 listening, hearing, sound or noise). However, there were examples where the audible tones were important for
 391 decision making. For example, from the audio and video recordings of actual use of intersections one
 392 participant appeared to respond to the audible tone to proceed from an adjacent pedestrian crossing and
 393 began to step out onto the crossing against a red man display before noticing the traffic begin to move at
 394 which point he stepped back. His verbal protocol at the time this occurred was 'I thought it was mine but
 395 before I walked (*on the road*) though I noticed it was not mine so I stopped immediately'.

396 Further, while the information elements of 'Red' and 'Green' are found in the as done network linked to the
 397 'Man' and 'Lights', there is no mention of the red man signal when it is flashing even though the majority of
 398 participants encountered the situation where the red man signal began to flash while they were crossing. This
 399 raises the question as to whether this signal is meaningful for pedestrians or is simply treated as either green
 400 or red.

401 **3.1.3 Comparing activity as imagined and activity as done at intersections**

402 Matthews' correlation coefficient was calculated for the task and information networks (Table 2). The findings
 403 were similar across both types of networks with moderate true positive rates at around 50% and high false
 404 positive rates at around 80%. The correlation coefficients emphasise the low to moderate negative correlation
 405 between the networks.

406 Table 2. Comparing task and information networks as imagined and as done for intersections

	True positive rate	False positive rate	Matthews' correlation coefficient
Task networks	0.50	0.83	-0.36
Information networks	0.54	0.82	-0.30

407

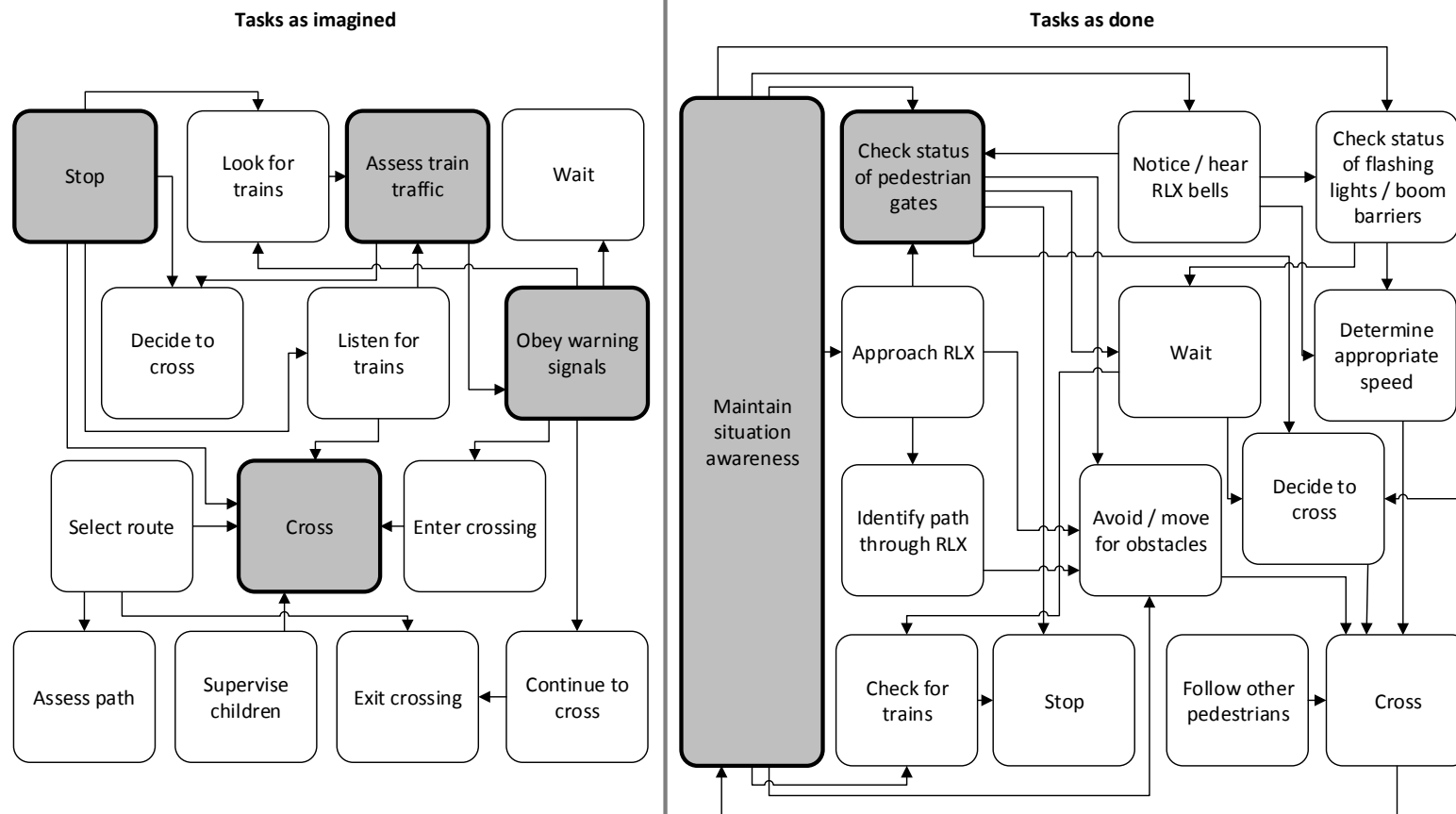
408 Some key insights were identified from the intersection analysis overall. Firstly, the analysis shows that it is
 409 intended that pedestrians will take a conservative and somewhat simplistic approach by obeying the traffic
 410 signals, with some additional tasks such as double checking by looking and listening to traffic. In practice, it
 411 appears that pedestrians pay attention to a wide range of information in the environment and are concerned
 412 with what they need to achieve to cross the road efficiently. For example, pedestrians frequently focused on
 413 concepts associated with the lights turning green. While concepts associated with safety and with checking for
 414 hazards (such as turning traffic) were identified, there was no explicit reference to safety in the as done
 415 intersection networks. This suggests that pedestrians may not consciously be thinking about safety when using
 416 intersections. These findings suggest there may be a failure of road system managers to fully appreciate the
 417 multiple goals of pedestrians. For example, a pedestrian frustrated by waiting may choose to cross against a
 418 red signal. The need for consideration of the range of goals and social norms that might be driving pedestrian
 419 behaviour is an important implication of these findings. Potentially, crossing compliance could be improved by

420 changing traffic cycles to reduce pedestrian waiting times, or by ensuring that pedestrian footpaths and
421 crossings follow the shortest route to desirable destinations.

422 **3.2 Railway level crossings**

423 **3.2.1 Tasks at railway level crossings**

424 The task networks developed for pedestrian activity at railway level crossings are shown in Figure 6.



425

426 Figure 6. Tasks as imagined and as done for negotiating a railway level crossing. Note: nodes in grey are key nodes, based on their sociometric status within the network.

427 In both networks, 14 tasks were identified. However, there were a number of differences in content of the
428 tasks identified.

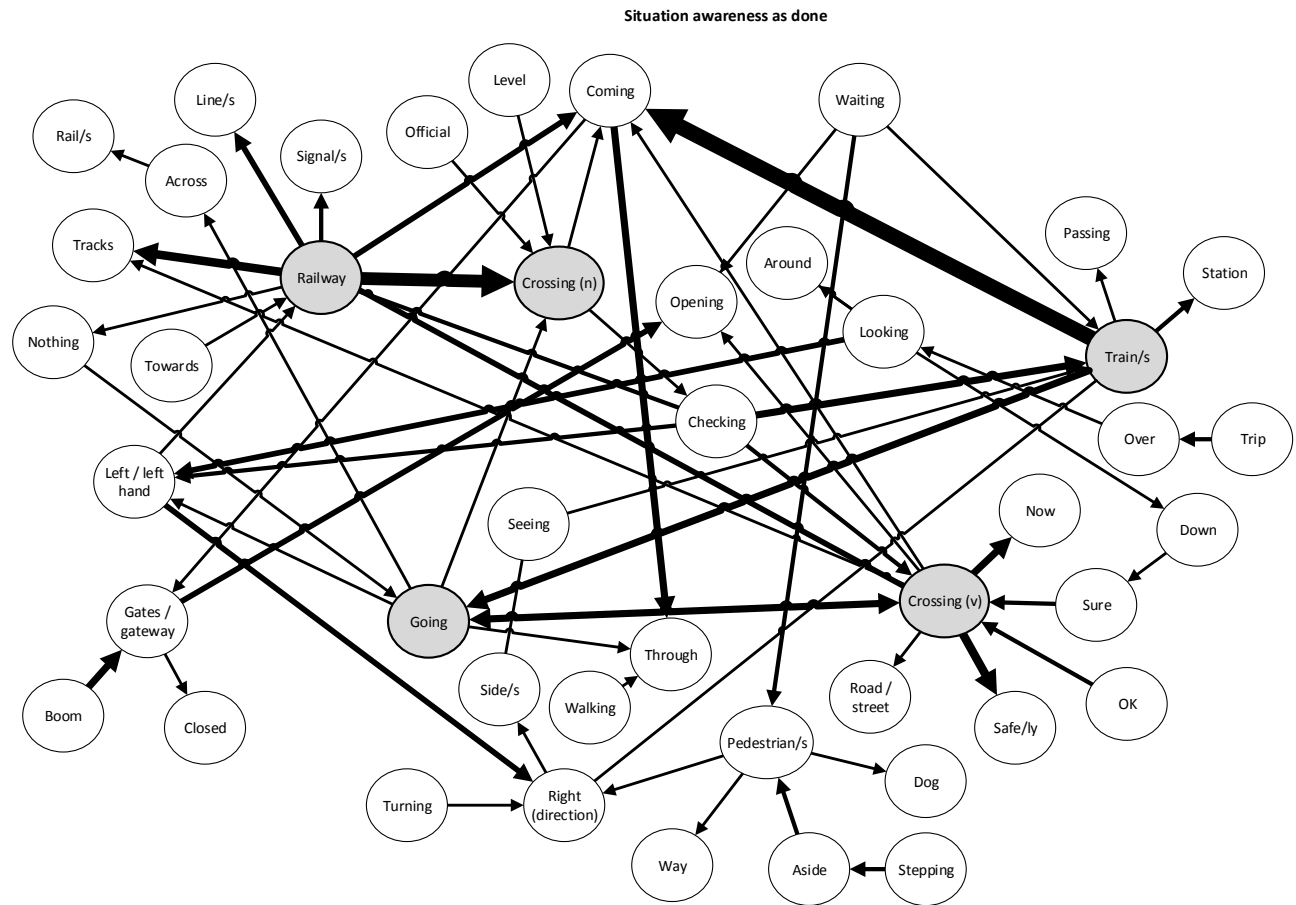
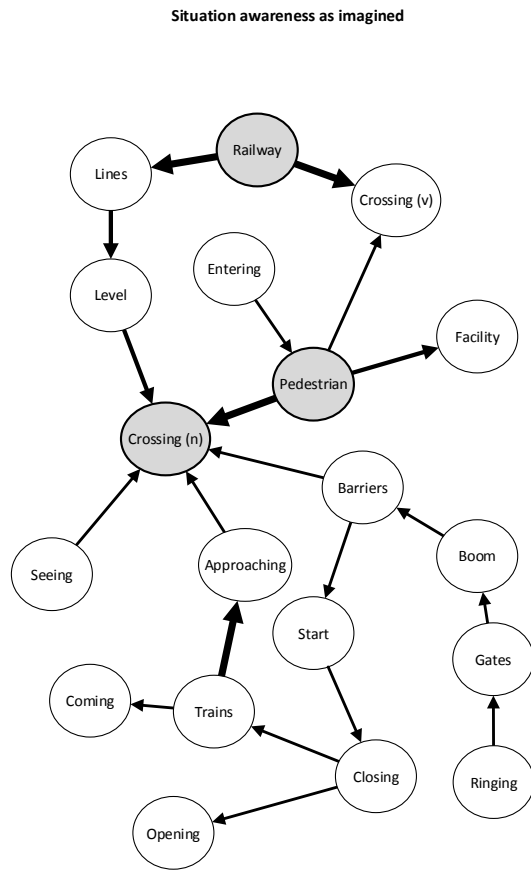
429 For the tasks as imagined network, a mean sociometric status was found of 0.20 (SD = 0.10). Therefore any
430 nodes with a status above 0.30 were designated as key nodes. The key nodes for the tasks as imagined were
431 'Obey warning signals' (status = 0.38), 'Stop' (status = 0.31), 'Assess train traffic' (0.31) and 'Cross' (0.31).

432 For the tasks as done network, a mean sociometric status was found of 0.31 (SD = 0.13). Therefore any nodes
433 with a status above 0.43 were designated as key nodes. The key nodes identified were 'Maintain situation
434 awareness' (status = 0.54) and 'Check status of pedestrian gates' (status = 0.54). While the task of maintaining
435 situation awareness included the status of the railway crossing warnings, as well as the position of trains and
436 other road users, it is interesting that in the as done task network there is a focus on the pedestrian gates that
437 was not found in the as imagined network. The gates, as opposed to the warning signals, may be more salient
438 to pedestrians operating in the real world as they are a physical barrier that ostensibly prohibits pedestrians
439 from moving into the crossing.

440 An additional task unique to the actual network (although not a key node) was 'Follow other pedestrians'.
441 Potentially this task was not present in the as imagined task network because road system managers would
442 want to discourage reliance on others for decision making about whether to cross the tracks. However, using
443 the behaviour of others as a cue is a natural human tendency. Similarly, the task of 'Determine appropriate
444 speed' was found only in the as done network and could include actions such as running to get through the
445 crossing prior to the gates closing. Finally, as with the task networks for intersections, the as imagined network
446 did not include any direct reference to avoiding obstacles on the path however this task was undertaken by
447 pedestrians in the study (task of 'avoid / move for obstacles'). This task particularly related to avoiding
448 stepping or tripping on the train tracks or bitumen around the tracks which can become loose where it meets
449 the rails. For example, a participant stated while they were crossing that they were 'making sure I don't step
450 on the train tracks'.

451 **3.2.2 Situation awareness at railway level crossings**

452 The information networks for railway level crossing are shown in Figure 7.



453

454 Figure 7. Information networks for pedestrian use of a railway level crossing. Note: nodes in grey are key nodes, based on their sociometric status within the network.

455

456 For the as imagined network, a mean sociometric status was found of 0.31 (SD = 0.20). Therefore any nodes
 457 with a status above 0.51 were designated as key nodes. For the as done network, the mean sociometric status
 458 was 0.18 (SD = 0.19). Therefore, nodes with a status above 0.37 were designated as key nodes.

459 The key nodes within these networks are shown in Table 3. It can be seen that the concepts of the 'Crossing
 460 (n)' itself, and 'Railway' are prominent within both the system design and actual networks. However, the
 461 presence of the concepts 'Crossing (v)' as a verb and 'Going' in the actual network suggest pedestrians are
 462 focussed on actions and getting through the crossing. Furthermore, the concept of 'Train' was a key node only
 463 in the actual network, suggesting that pedestrians are concerned with identifying the presence of a train.

464 Table 3. Key nodes within the railway crossing information networks

'As imagined' network node	Sociometric status	'As done' network node	Sociometric status
Crossing (n)	0.78	Crossing (v)	0.89
Pedestrian	0.67	Railway	0.89
Railway	0.56	Train/s	0.48
-	-	Going	0.45
-	-	Crossing (n)	0.43

465

466 3.2.3 Comparing activity as imagined and activity as done at railway level crossings

467 From Table 4 it can be seen that, similar to intersections, there was a low to moderate inverse correlation
 468 between the task and information networks as imagined and as done. The true positive rates were moderate
 469 at around 50% and the false positive rates were high at around 70-90%. For the information networks the lack
 470 of consistency was particularly pronounced, with a moderate inverse relationship evident between what
 471 information elements are expected to be used and those actually used by pedestrians.

472 Table 4. Comparing task and information networks as imagined and as done for railway level crossings

	True positive rate	False positive rate	Matthews' correlation coefficient
Task networks	0.44	0.77	-0.33
Information networks	0.50	0.93	-0.53

473 In relation to railway level crossings it appears that the design intention is for pedestrians to obey warnings
474 while in practice it appears that pedestrians were most concerned about whether or not a train was
475 approaching, as well as the status of pedestrian gates. The focus on the train echoes previous research (e.g.
476 Beanland, Lenné, Salmon, & Stanton, 2015; Mulvihill, Salmon, Lenné, Beanland, & Stanton, 2014) that has
477 highlighted the importance of the train in pedestrian decision-making at level crossings. Pedestrians also
478 frequently mentioned the acts of crossing and going, suggesting that they were primarily focussed on getting
479 across the crossing. While gates and barriers remain an important safety measure, designers might focus on
480 ensuring that their operation is seen as legitimate (e.g. avoiding unnecessarily long warning times such as
481 when trains are stopped at adjacent stations).

482 **4. Conclusions**

483 This analysis has suggested a gulf exists between pedestrian activity 'as imagined' and 'as done' within the
484 road system. In short, pedestrians in our study demonstrated considerably more variability in the tasks they
485 undertake and the information they use in making decisions than expected by system managers.

486 It is acknowledged that the data collected, based on only 10 participants, may not have captured the range of
487 decisions and behaviours undertaken by pedestrians. For example, no participants crossed the road when the
488 red man signal was showing or crossed a railway level crossing when the pedestrian gates were closed,
489 potentially due to their knowledge of participating in a research study. Therefore, the networks obtained may
490 be focussed on 'safe' or 'compliant' decision making. Nonetheless the findings are clear that even pedestrians
491 operating under research conditions and assumedly displaying tendencies toward social desirability do not
492 operate in the way expected by designers. Further research could focus on gaining a larger sample size and
493 developing networks for all decisions made by pedestrian in these environments. This would likely uncover
494 even more diversity. Further research should also consider different road environments at which pedestrians
495 are at risk (e.g. unsignalised intersections) and could consider the impact of familiarity with the road
496 environment on pedestrian tasks and situation awareness. In addition, given the limitations of the use of
497 naturalistic data alone, further research could also extend these findings through interviews with pedestrians
498 or through review of accident investigation findings.

499 Overall, the findings suggest a failure in vertical integration may be present, which leaves the system
500 vulnerable to accidents. It is argued that to make additional safety gains in this context, we need more than
501 evolutionary changes to components (such as changes to road rules or infrastructure) but revolutionary
502 change in the way that roads are designed and managed.

503 Work as imagined versus work as done is an important contemporary question for safety scientists. The
504 findings of this study support the notion that system managers tend to have a normative view of activity
505 within the system whereas in practice the performance variability of system components means that the
506 situation is more complex. Whilst this is a well-known issue in areas such as product design (e.g. Norman,
507 1998) it has not previously been reported in the road context. This raises questions about the extent to which
508 road system managers understand the performance variability of pedestrians operating in urban road
509 environments. It also suggests that attempts to constrain pedestrian behaviour through design may not be
510 working optimally – there remains a latitude for behaviour beyond what is preferred. Finally, it brings into
511 question the capacity for road environments to cope with the variability of user behaviour.

512 The differences between the expectations of road system managers and the real world experiences of
513 pedestrians suggests that benefits could be gained by changing the way road system design is undertaken. It is
514 proposed that data on actual system use should feed into on-going re-design processes that enable the initial
515 assumptions to be challenged and new interventions put in place. Such processes can be used to manage
516 performance variability, rather than continuing to focus on constraining variability. This would support the
517 adaptive capacity and resilience of the road system; allowing it to adapt and evolve in response to changing
518 environmental conditions such as increasing congestion, an ageing population, increasing use of personal
519 technologies and the introduction of autonomous vehicles who will interact with pedestrians. The process of
520 re-design could also adopt modelling approaches to explore the possibilities for behaviour within the
521 parameters of the design. Formative human factors analysis methods such as Cognitive Work Analysis provide
522 this capability and could potentially be adopted in further research and practice (e.g. Read et al., 2017). To
523 achieve this we need a shift in the philosophies underpinning road safety management from the ‘old view’ of
524 human error (Dekker, 2014) to valuing humans as adaptive decision makers whose decisions and actions keep
525 systems safe.

526 In particular, it is vital that processes are put in place to gather information about pedestrian activity in the
527 real world and to share this across the road system so that it can be used to continually work to close the gap
528 between activity as imagined and done.

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