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

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Abstract

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

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

1. Introduction

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

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

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

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

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

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

1.1 A systems framework

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

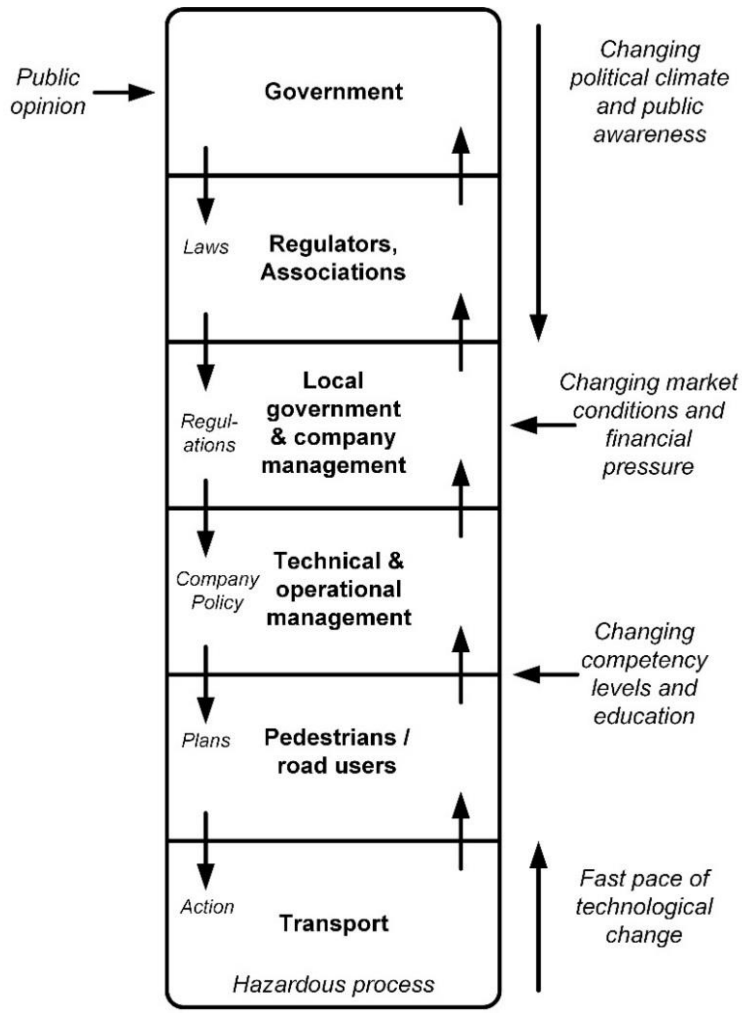


Figure 1. Rasmussen's (1997) risk management framework, adapted for pedestrian activities.

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

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

1.2 Performance variability

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

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

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

2. Method

2.1 Design

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

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

2.2 Data sources

2.2.1 Activity as imagined

Designers of the road system are not an identifiable group of individuals; in fact road system design has evolved over the last century or so, with intentions embodied in artefacts such as legislation, design codes and standards, education materials and the physical road infrastructure itself. For the purposes of this study, activity ‘as imagined’ was described based on relevant texts (e.g. laws and guidance material) that can be considered akin to work procedures which are commonly viewed as a proxy for work as imagined within organisations (e.g. Antonsen, Almklov & Fenstad, 2008; Clay-Williams, Hounsgaard & Hollnagel, 2015; Dekker, 2006).

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

2.2.2 Activity as done

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

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

Participants

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

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

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

Materials

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

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

During the walk, participants wore Imging HD video recording glasses to record the forward view. In addition, 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

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

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

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

Procedure

Participants were provided with an explanatory statement giving details of the study and instructions on how to practice providing concurrent verbal protocols by email prior to attending to participate in the study. On the day of the study, participants met the researcher near the beginning of the study route. After giving informed consent, the researcher verbally explained to participants the instructions on how to provide concurrent verbal protocols. These instructions included an explanation that the process aims to gather information about situation awareness (i.e. understanding of what is going on) and decision making during the walk. Participants were told that it is more important that they verbalise what they are thinking about or doing mentally as they walk, rather than just what they are physically doing. Further, they were told that it is important to verbalise or think aloud continuously as they walk the route and that if they need to stop thinking aloud (i.e. due to concentrating on a complex traffic situation), to re-cap their thoughts once they can do so.

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

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

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

2.2 Network development

2.2.1 Task network development

To understand tasks 'as imagined', task networks were developed using content analysis to identify task-related information within the texts (which formed the nodes in the task network) and capturing relationships representing sequences or dependencies of tasks (which were represented as links between the nodes). For example, the content of the two sentences "Always wait for the green man signal before crossing" and "Make sure all traffic is stopping before starting to cross" (VicRoads, 2011) resulted in the identification of four tasks, and their relationships (see Figure 3A). The tasks identified across the source documents were combined in a single task network.

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

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

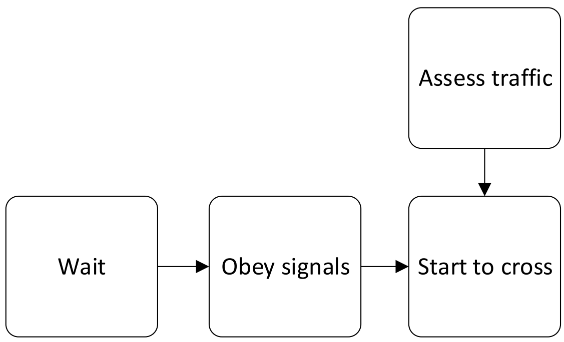
2.2.2 Information network development

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

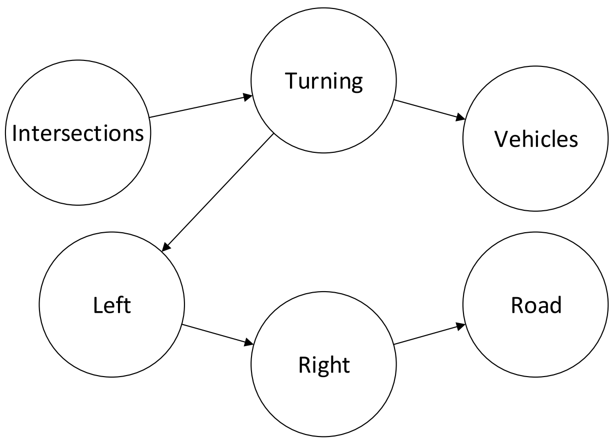
This ‘activity as imagined’ information network was generated by a single analyst, based on the information nodes identified across the source documents, and was reviewed and validated by a second analyst. Any disagreements were resolved through discussion until consensus was reached. The frequency of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

For the ‘activity as done’ information network, the larger underpinning data set (transcripts of verbal protocols) required a different validation approach. In this case, individual information networks for each encounter were initially generated by a single analyst. A second analyst then independently generated networks for 20% of encounters. Inter-rater reliability for the information networks was calculated in two ways. Firstly, the level of agreement in relation to the nodes was calculated. A percentage agreement of 80.2 was achieved in this analysis. Next, agreement in relation to the links between concepts was considered. Given that a disagreement about a node will automatically involve a disagreement associated with links associated with the node, for this analysis only links between agreed-upon nodes were considered. This resulted in a 71.7% agreement level on the links. All disagreements relating to the identification of concepts and the links between them were resolved through discussion.

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



A. Task network development



B. Information network development

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

2.2.3 Network analysis

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

2.4 Comparing activity as imagined and activity as done

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

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

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

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

3. Results and discussion

3.1 Signalised road intersections

3.1.1 Tasks at intersections

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

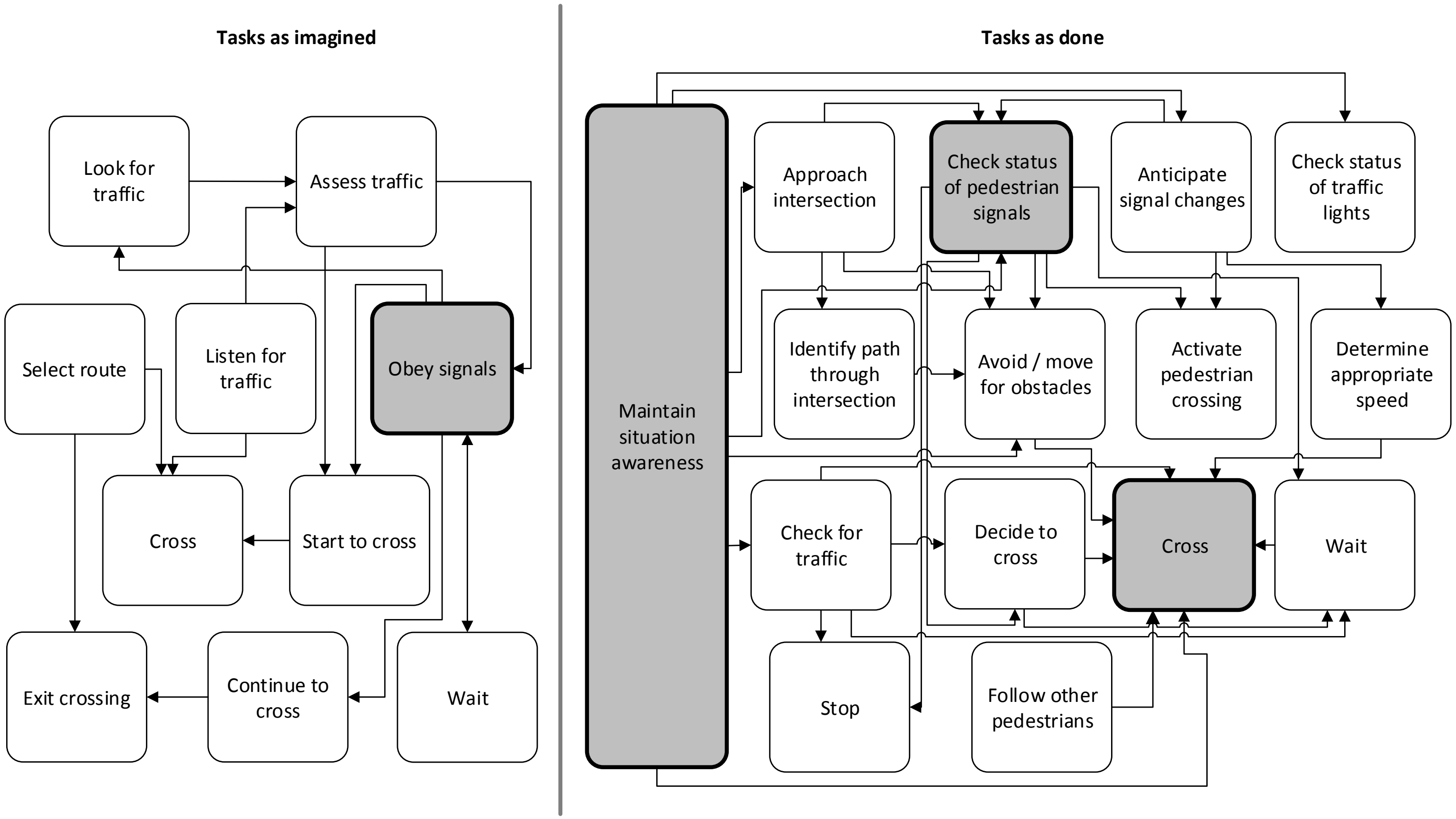


Figure 4. Tasks as imagined and as done for negotiating a signalised road intersection. Note: nodes in grey are key nodes, based on their sociometric status within the network.

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

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

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

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

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

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

3.1.2 Situation awareness at intersections

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

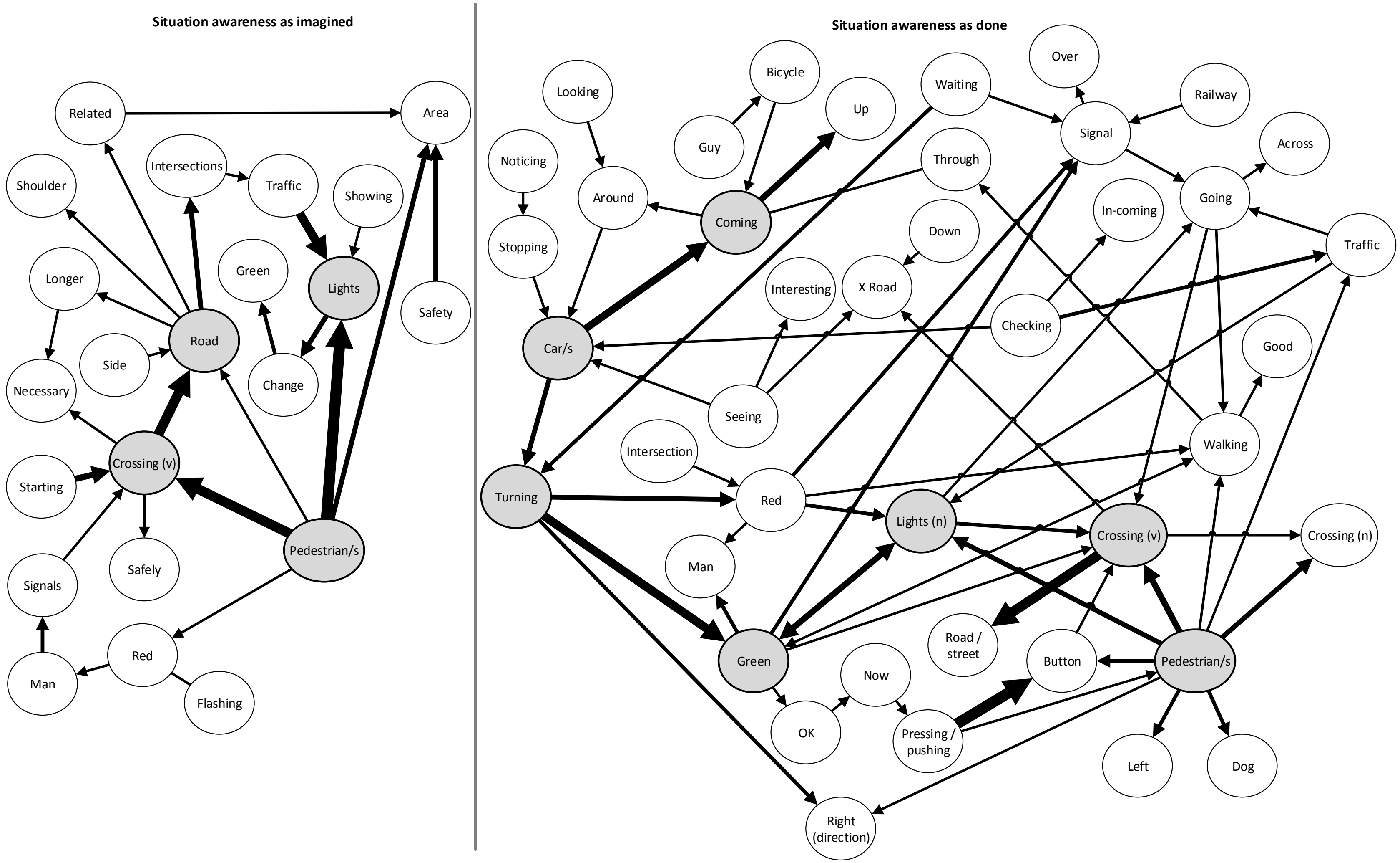


Figure 5. Information networks for pedestrians using signalised intersections. Note: (v) refers to the verb form of a word and (n) to the noun form; nodes in grey are key nodes, based on their sociometric status within the network.

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

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

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

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

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

3.1.3 Comparing activity as imagined and activity as done at intersections

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

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

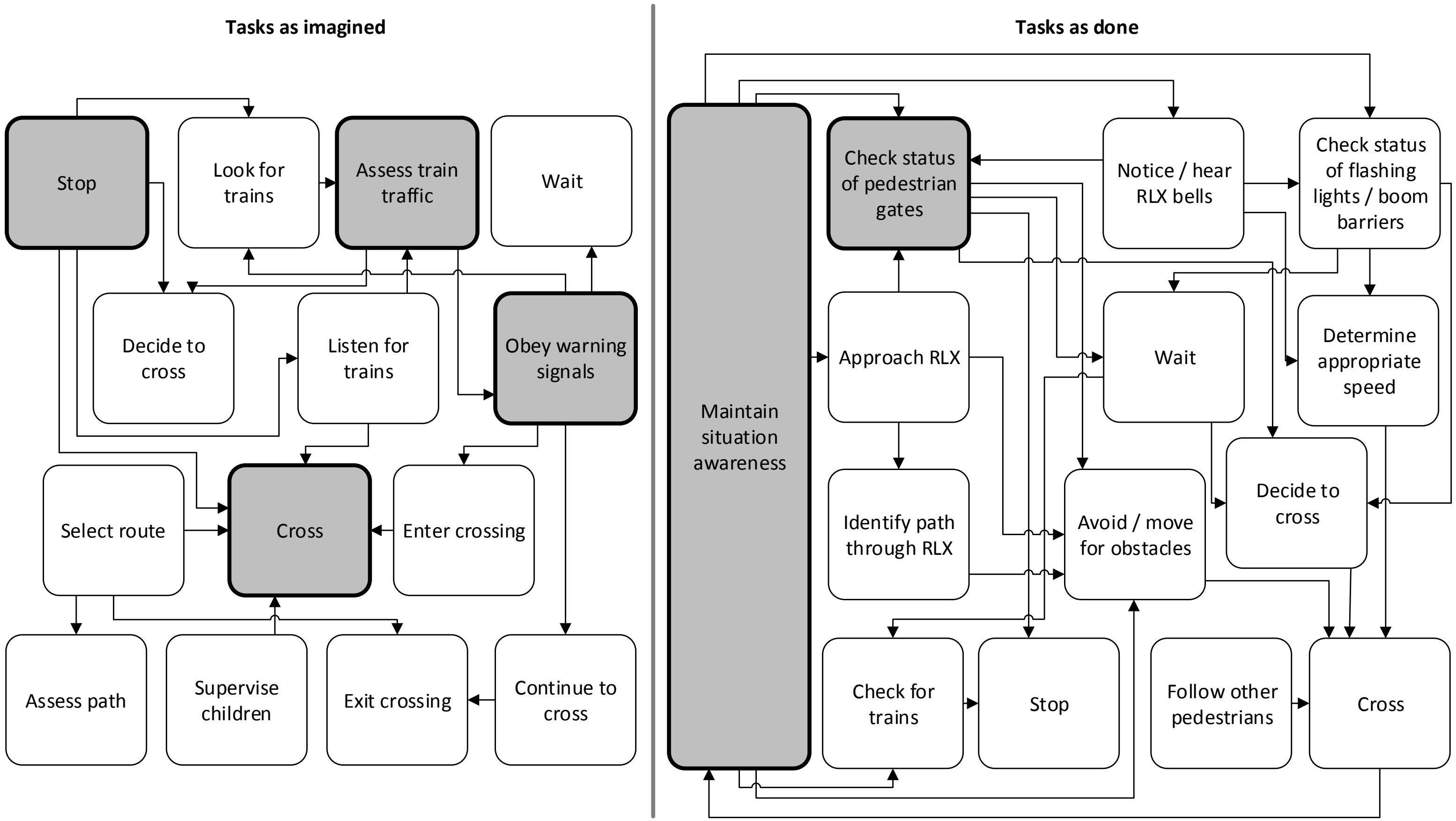
	True positive rate	**False positive rate**	**Matthews' correlation coefficient**
Task networks	0.50	0.83	-0.36
Information networks	0.54	0.82	-0.30

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

3.2 Railway level crossings

3.2.1 Tasks at railway level crossings

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.

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

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

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

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

3.2.2 Situation awareness at railway level crossings

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

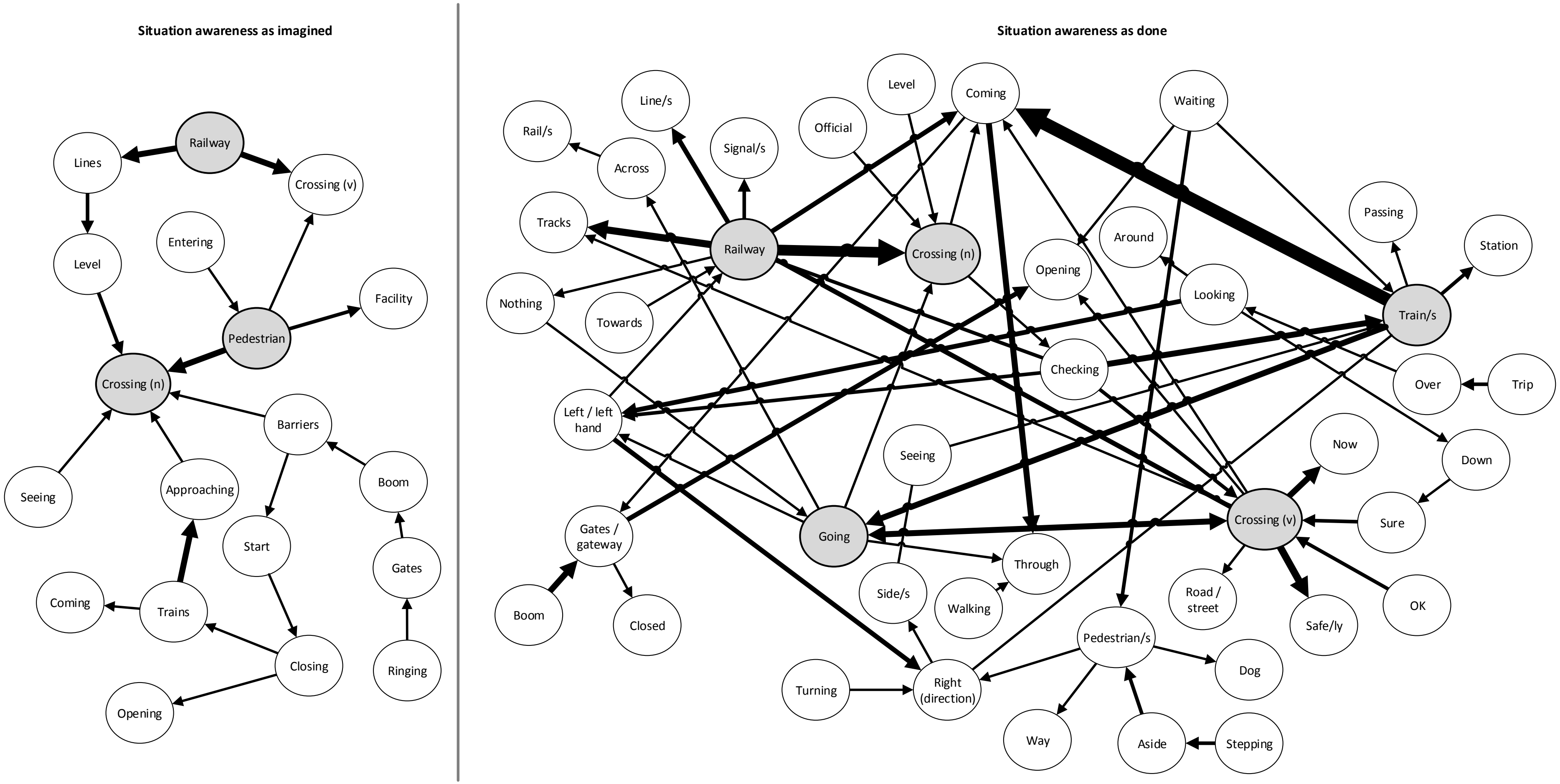


Figure 7. Information networks for pedestrian use of a railway level crossing. Note: nodes in grey are key nodes, based on their sociometric status within the network.

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

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

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

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

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

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

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

4. Conclusions

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

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

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

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

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

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

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