Prevalence and dynamics of distracted pedestrian behaviour at railway level crossings: Emerging issues

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Abstract

Increases in pedestrian collisions in recent years has led to several studies investigating the effects of distraction on pedestrian behaviour at road intersections. Despite the fact that the recent investigations of fatal pedestrian crashes at railway crossings identified distraction as a contributing factor, research has currently failed to recognise pedestrian distraction as an emerging issue at railway level crossing. As a mitigation strategy, the rail industry is trialling innovative interventions to regain the attention of distracted pedestrians. Such interventions were found effective in attracting pedestrian attention and were well accepted. However, it is essential to understand distraction prevalence at railway crossings to evaluate whether such countermeasures provide positive cost-benefit ratios. The current study aims to gauge the prevalence of distraction at urban level crossings. We conducted field observations at a railway crossing in Brisbane, Australia and its adjacent road intersection. The behaviour of users (N=585) was video recorded during daytime. The video recordings were coded to estimate the prevalence of distraction behaviour that road users engaged in, factors that affected these proportions, and dynamic changes in behaviour. Compliance with signals was also analysed. We found that distraction, from talking to visually looking at the mobile screen, was widespread (41.9%) at the observed site and was affected by age. Highly distractive tasks were found less prevalent at the railway crossing (3%) but pedestrians engaged for longer on such tasks at railway crossing. While most non-compliances occurred for attentive pedestrians and are likely to be intentional, non-compliances by distracted pedestrians were also observed, highlighting that distraction can lead to unsafe decisions, or lack or decisions that result in unsafe behaviours. Finaly, distraction was found as a dynamic phenomenon; some pedestrians stopped their distraction once they reached the crossing; others engaged in more distractive tasks once they were on the road or crossing. Research is needed to understand Our study shows that pedestrian distraction is also a prevalent issue for railway crossings and that further research is needed to further understand and mitigate this changing behaviour.

Keywords

Safety; Road; Rail; Distraction; Mobile devices; Vulnerable Road Users

1. Introduction

Engaging with technology while walking is the most commonly reported aberrant pedestrian behaviour before non-compliance with road rules (O'Hern, Stephens, Estgfaeller, Moore, & Koppel, 2020). Although observations of pedestrians at crosswalks indicate the majority of pedestrians do not engage in technological distraction when crossing (Aghabayk, Esmailpour, Jafari, & Shiwakoti, 2021), and frequency of occurrences with phone use are reported as rare or occasional (O'Hern et al., 2020), distraction negatively affects the safety of pedestrians' behaviour (Lin & Huang, 2017; Pešić, Antić, Glavic, & Milenković, 2016). Indeed, a survey of road trauma patients identified distraction as a contributing factor, with 16.5% of injured pedestrians reporting distraction was involved in their crash (Le, Figueroa, Anderson, Lotfipour, & Barrios, 2019).

In recent years, numerous studies (e.g., Aghabayk et al., 2021; Gitelman, Levi, Carmel, Korchatov, & Hakkert, 2019; Horberry, Osborne, & Young, 2019) have been conducted on pedestrian distraction at road intersections worldwide, yet little information is available on pedestrian distraction at railway level crossings. This is despite research suggesting that distraction and inattention become more prevalent at railway crossings as the use of mobile phones and headsets is more pervasive in rail settings (Goodman, 2018; Larue, Naweed, & Rodwell, 2018). It is highlighted by the growing concern that the rail industry has on pedestrian distraction at such intersections. Such concern was raised by recent collision investigations, which identified the distraction from a mobile device as a contributing factor in the UK (Rail Accident Investigation Branch, 2009, 2010, 2013) and in New Zealand (Transport Accident Investigation Commission, 2011, 2016). It resulted in the trial of new in-ground illuminated lights and audio messages at railway level crossings in New Zealand (Hirsch, Mackie, & Cook, 2017). Such interventions are likely to be effective (Larue, Watling, Black, & Wood, 2021) and accepted by road users (Larue & Watling, 2021).

Research has not yet attempted to link distraction and risky behaviour at railway crossings. It has to be noted that a recent observational study of vulnerable road users (pedestrians and bicyclists) interacting with activated level crossings did not find a link between distraction and non-compliance with the signal (Russo, James, Erdmann, & Smaglik, 2020). However, such findings align with some studies conducted at road intersections (Baswail, Allinson, Goddard, & Pfeffer, 2019; Horberry et al., 2019; H. Zhang, Zhang, Chen, & Wei, 2019). Despite a lack of association between being distracted and crossing on red, these studies found an association between being distracted and not checking for traffic. Such effects might be particularly risky at unsignalized intersections and passively protected railway crossings. Given the current increase in incidents at railway crossings involving distracted pedestrians, it is crucial to study distraction railway level crossings to understand whether distraction behaviour and effects are different at such crossings. A first step is to estimate the prevalence of distraction as an issue at railway crossings, and this is the aim of this study.

2. Background

2.1 Distraction types

Several different behaviours have been identified as "pedestrian distraction" in the literature. However, there is little uniformity across studies. Identified distractions relate primarily to the use of mobile devices. Other types of distractions were also identified and included talking to others (Y. Zhang, Qiao, & Fricker, 2020), eating and manoeuvring luggage (Aghabayk et al., 2021).

Despite the lack of uniformity, distractions with mobile devices can be categorised into four main types. The first type consists of pedestrians holding a phone in their hand (Baswail et al., 2019; Vollrath, Huemer, & Nicolai, 2019). The second type involves looking at or interacting with the device and has been often referred to as hand-held phone use (Horberry, Osborne, & Young, 2019; Schneider & Bengler, 2020; Zhou et al., 2019). This type of interaction has also been recently observed with the use of smartwatches (Schneider & Li, 2020; Y. Zhang et al., 2020). Interactions include texting (Sheykhfard & Haghighi, 2020), emailing (Léger et al., 2020), swiping (Aghabayk et al., 2021; Feld & Plummer, 2019; Fobian et al., 2020; Léger et al., 2020; Saenz, Sun, Wu, Zhou, & Yu, 2020; Y. Zhang et al., 2020; Zhou et al., 2019), browsing (Ropaka, Nikolaou, & Yannis, 2020; Schneider & Bengler, 2020; Schneider & Li, 2020; Vollrath et al., 2019), reading a document, and playing a game (Léger et al., 2020).

The third types relate to the mobile device as a phone and listening to music through headphones, respectively. The third type has been referred to as speaking into the phone (Sheykhfard & Haghighi, 2020), phone calls (Léger et al., 2020; Russo et al., 2020), holding device to ear (Piazza et al., 2020; Sheykhfard & Haghighi, 2020), or speaking with visible headphones (Saenz et al., 2020) in the literature. The fourth and final type of use is listening to music through headphones (Horberry et al., 2019; Schneider & Bengler, 2020; Sheykhfard & Haghighi, 2020; Y. Zhang et al., 2020; Zhou et al., 2019). Such use can also require looking at (Schneider & Li, 2020; Zhou et al., 2019) or manipulating the phone (Schneider & Li, 2020).

2.2 Age and distraction behaviour

Research has found that distraction from an electronic device increases pedestrians' likelihood of violating a traffic signal (Mukherjee & Mitra, 2020). Pedestrians observed crossing while using a mobile phone, particularly when watching the phone screen, had a greater likelihood of being involved in a conflict at the crossing (H. Zhang et al., 2019). Adolescent children (aged 14-17) were more likely to be engaged in distracting behaviour (14%) than younger aged children (i.e., 9-13). However, child distraction engagement was lower than adult distraction, with 21% of adults observed talking on a mobile phone when crossing.

The laboratory study by Feld and Plummer (2019) showed that different distracting tasks impair in different ways visual scanning behaviour. While not distracted, participants' gaze was directed equally to the far walking path and surrounding environment. When engaged in a dual-task letter fluency, participants had more gaze fixations on areas unrelated to their walking task. When texting on the phone, their gaze was focused predominantly on the phone. This study suggests that while walking, young adults prioritise a distractive task over situational awareness (Feld & Plummer, 2019). In a laboratory study, engaging in distractive tasks reduced performance on a pedestrian monitoring task compared with the control scenario (Léger et al., 2020). Playing a game on a mobile device was found worse than engaging in other distracting behaviours such as writing an email or group texting (Léger et al., 2020). Those distracted by texting/web-surfing had longer crossing times, increased exposure to vehicle traffic, and are more likely to collide with other pedestrians (Ropaka et al., 2020). Overall, distracted pedestrians are more likely to experience a critical event, such as being nearly hit a vehicle and other events such as almost hitting another pedestrian, not performing head checking actions, or crossing at the wrong place or at the wrong time (Horberry et al., 2019).

2.3 Prevalence

Field observations suggest that pedestrian distraction at road intersection ranges between 15 and 45%. These prevalence levels are relevant to a wide range of high-income countries. Indeed, distraction prevalence at intersections was 31% in a study conducted in the UK (Baswail et al., 2019), 23% in Germany (Vollrath et al., 2019), 19% in Canada (Quon et al., 2019), 45% in Iran (Aghabayk et al., 2021), 16% in Greece (Ropaka et al., 2020), 15% in

China (H. Zhang et al., 2019) and 20% in Australia (Horberry et al., 2019). However, such studies are often conducted at school or university locations, which is likely to constrict the range of participants being studied.

Headphones and texting are reported as the most prevalent uses in numerous studies (Aghabayk et al., 2021; Horberry et al., 2019; Ropaka et al., 2020; Vollrath et al., 2019), often at similar levels and substantially larger than other forms of distraction. Vollrath et al. (2019) also found that 3.1% of the observed pedestrians engaged in multiple distracting behaviours concurrently.

Types of intersection can affect distraction prevalence. Pedestrians using unsignalised crossings were found less likely to engage in a distracting task than pedestrians using signalised crossings (Aghabayk et al., 2021), suggesting that pedestrians adapt their behaviours based on the environmental characteristics and/or their risk perceptions. For instance, one study found higher distraction levels at signalised intersections compared with unsignalised intersections (Piazza et al., 2020).

Despite the limitations in the types of locations observed, age has been found to affect mobile device use. Distraction was greater for those aged 15-30 (H. Zhang et al., 2019; Zhou et al., 2019) compared with middle-aged pedestrians and children (Gitelman et al., 2019; Zhou et al., 2019). Gender was also found to affect distraction, females appearing in numerous studies as more prone to distractions at intersections than males (Baswail et al., 2019; Piazza et al., 2020). However, one Chinese study found males more likely to be distracted than males (H. Zhang et al., 2019).

2.4 Study aim

The current literature has shown that pedestrian distraction is prevalent at road intersections, and their adverse effects on behaviour and safety have been documented. Anecdotal evidence suggests that distraction is also an issue at railway crossings, but limited information currently exists in the literature for these intersections. With the rail industry considering implementing new countermeasures (i.e., signage, alerting lights) to mitigate the effects of distraction, it is crucial to understand these issues at level crossings, so safety improvements are as effective as possible. Therefore, this study aims to estimate the prevalence of distraction at level crossings.

2. Method

2.1 Study design

The behaviour of users of pedestrian railway level crossings was video recorded during daytime. The video recordings were used to estimate the prevalence of distraction behaviour that road users engaged in at these intersections and factors that affected these proportions. Based on the review of the literature, the contributing factors considered included the estimated age of the road user classified into four categories (adult, teenager, child, and elderly); gender (male, and female); whether the road user was part of a group (alone, small group/family unit, group of unrelated road users, and large group); and the type of intersection (road intersection, and railway crossing). A signalised road intersection adjacent to one of the level crossings was also observed as a comparison point.

Observations combined with reviews of the videos identified the following types of distraction that the road users engaged in at the observed locations: road users with a mobile device; road users wearing a headset; and road users having a conversation with another road user. Pedestrians with a mobile phone were further divided into the following subcategories: users with the phone in their hands, users having a phone conversation and users looking at the screen of their mobile devices. Based on the literature on the effects of distraction types on behaviour (Section 2.2), distraction was then categorised into low (phone in hand, conversation with another road user), medium (phone conversation, headset), and high (looking at the screen of the phone) distraction levels. The prevalence of the different levels of distraction was statistically modelled using the contributing factors presented above.

The road user distraction behaviour was recorded during the average 8 seconds it took to traverse the crossing or intersection and the average 6 seconds on the path next to the crossing/intersection. It was possible to observe the behaviour of pedestrians only on the side of the camera, which means that for some users, behaviour on the path corresponds to the approach of the intersection, while for others, it represents their behaviour after their traversal. The user behaviour was recorded dynamically, allowing extraction of changes in behaviour as the user navigated and durations of the different types of distraction they engaged in during their navigation.

For road users approaching from the side with the camera, we then investigated how distraction changed between the approach of the crossing and the time they traversed rail tracks. This analysis provides insights into how road users perceive risks at the intersection and whether they adjust their behaviour accordingly.

The video recordings also captured the status of the crossing. This also allowed to estimate the probability for road users (approaching the crossing from the side with the camera) to disregard signal activation and proceed through the crossing while closed. In particular, we investigated whether distraction affected the chance of non-compliance with signal activation for pedestrians who approached the crossing while activated.

2.2 Observed sites

Field-based observations were conducted at five Australian level crossings and a signalised road intersection adjacent to one of the selected railway crossings. The selection of level crossings was informed by the data provided by the Australian Level Crossing Assessment Model (ALCAM) Technical Committee (2016), which provided level crossing protection, road and rail traffic volumes. The selection focussed primarily on crossings with the most pedestrian traffic. The five level crossings were active pedestrian level crossings located next to a train station. They were equipped with steady pedestrian lights (green/red man; Figure 1), barriers and audible warning devices (bells), which were activated before and during the passage of a train through the level crossing. Four crossings were located next to a road, while one was solely designed for pedestrians. Four of the level crossings were in metropolitan areas, three in Brisbane and one in Melbourne. The last crossing was in a regional city one hour drive away from Brisbane (Figure 1).

The road intersection consisted of a signalised road intersection located next to one of the metropolitan railway crossings (Figure 1). It was equipped with steady pedestrian lights and required pedestrian to press a button to request the right of way.

Observations lasted 1 hour 10 minutes on average (SD=24 min; range: 45 min – 2 h 10 min) and occurred during the afternoon peak times of a weekday, except for one level crossing, which was observed around midday. Pedestrian traffic at the selected sites was 110 users per hour (SD=86; range: 31-224) during the times of observation. An average of 9 trains (SD=2.4; range: 5-12) traversed the level crossing per hour at the sites during the observations. The sites were adjacent to major arterial roads, with average road traffic of 885 vehicles per hour (SD=445; range: 437-1,328). Road and rail traffic was mainly composed of commuters.

Figure 1: Locations of the observed sites, and image of one of the observed pedestrian level crossings (black triangle) and of the signalised road intersection (grey triangle)

2.3 Materials

A GoPro Fusion camera was used to record videos with a 360-degree field of view continuously. The GoPro Fusion software was used to export a portion of the video covering the intersection or crossing as well as a section of the path leading to the intersection. Video extracts were then coded and analysed using the Interact software version 8.

An app was developed for the observer to record road vehicles, pedestrians, and rail traffic counts. These counts were used to provide the context of the observed sites (Section 2.2).

This app was developed using AndroidStudio version 3.5 and used on a Samsung Tab S5e tablet.

2.4 Procedure

Two researchers were present for all field observations. The first researcher was responsible for installing the camera at a safe position that allowed optimal visibility on the complete intersection/crossing, as well as a view of the approach of the intersection on the side where the camera was installed. The camera was installed on a tripod unobtrusively, either on the side of the pedestrian path or on fences delineating the path and the rail corridor to ensure pedestrian movement was not affected. This researcher was also responsible for monitoring the continuous operation of the camera. The other researcher was responsible for recording road, pedestrian and rail traffic using the tablet.

Ethical clearance was obtained from the university's Human Research Ethics Committee (Approval number: 1800000987).

2.5 Data analysis

2.5.1 Video coding

A coding scheme for analysing video data was developed through discussions within the research team at the end of data collection and implemented in Interact version 8. This initial coding scheme was informed by the literature review and behaviours that researchers observed in the field while collecting data. It consisted of a crossing/intersection identification number, and the following demographics information: apparent age, gender, being part of a group and type of road user. The information was categorised, as described in Section 2.1. When the coder was unsure of the category to use, it was recorded as 'unsure'. This information was coded once as a static value for each observed user of the intersection or level crossing. Such static information was complemented by dynamic information regarding the pedestrian speed (walking/running), distraction type (phone conversation/headset/phone in hand), pedestrian location (path, intersection/crossing, outside the designated pedestrian corridor) and intersection status (closed/open). For dynamic information, the video coding consisted of identifying when a particular condition started and ended, which allowed the extraction of durations and co-occurrences of events. Videos were coded when pedestrians were moving (i.e. when pedestrians were stopped such as at a red light, that section of the video was not coded).

The scheme was refined during the coding of videos. Unlabelled codes were created so that the video coder could create additional distraction types as necessary while watching videos. The approach resulted in the recording of another distraction type: participant looking down at their mobile device screen. A couple of other distractions were identified by this approach (e.g. eating) but were not further investigated due to their low occurrences. Observed road users were found to engage in running or walking outside the designated area only on few occurrences, and these codes were not investigated further during data analysis.

2.5.2 Measures

All distraction types that an observed pedestrian engaged in during their navigation of the path and intersection/crossing was extracted as a binary value. This information was used to identify all distraction levels (low/medium/high, as described in Section 2.1) that a pedestrian engaged in. The prevalence of the different distraction levels was computed by calculating the proportion of observed pedestrians engaged in each distraction level, using their highest distraction level recorded. For the subset of distracted pedestrians, we also extracted the prevalence of co-occurrences of two different types of distractions.

The duration of their engagement in the different distraction levels was also extracted, as well as their navigation duration. When distracted, these measures were combined into proportions of time they engaged in the different levels of distraction by calculating the ratio between the duration of a distraction level and the navigation duration.

Then, the distraction level was extracted before and while crossing for pedestrians who approached the crossing/intersection from the side where the camera was installed. The distraction levels were combined for this measure, resulting in two categories: none/low distraction and medium/high distraction.

Finally, we extracted a non-compliance measure with the activated signal. A pedestrian was deemed non-compliant with the signal when they approached the activated intersection/crossing (from the camera's side) and were observed to traverse when the signal was activated (i.e. during the closure of the intersection/crossing).

2.5.3 Statistical analyses

The first analysis consisted of modelling the prevalence of different distraction levels as logistic regressions using Generalised Linear Models (GLMs). The effects of the following independent variables were considered on the proportions of a distraction level: demographics (age group, gender), being part of a group, type of intersection (road intersection/rail crossing), as well as first-order interactions between these factors.

As multinomial logistic regressions could not be obtained directly using available statistical software, it was obtained through the following combination of binomial regressions on the predictors $Pred_i$:

$$\begin{cases} \eta_{distracted} = \beta_{distracted_0} + \sum_i \beta_{distracted_i} . Pred_i \\ \eta_{high} = \beta_{high_0} + \sum_i \beta_{high_i} . Pred_i \\ \eta_{medium} = \beta_{medium_0} + \sum_i \beta_{medium_i} . Pred_i \end{cases} \qquad \text{Eq. 1}$$

Where β_i are the fitted parameters of the regression, and resulting in the following probabilities for each distraction level:

$$\begin{cases} p_{no\ distraction} = 1 - e^{\eta_{distracted}} / (1 + e^{\eta_{distracted}}) \\ p_{low} = 1 - p_{no\ distraction} - p_{medium} - p_{high} \\ p_{medium} = \left(1 - p_{no\ distraction} - p_{high}\right) . e^{\eta_{medium}} / (1 + e^{\eta_{medium}}) \\ p_{high} = (1 - p_{no\ distraction}) . e^{\eta_{high}} / (1 + e^{\eta_{high}}) \end{cases} \qquad \text{Eq. 2}$$

Next, the analysis focussed on modelling the effects of the same independent variables on the chance for a pedestrian to change their behaviour while traversing compared to while approaching the crossing/intersection, to assess whether pedestrians adapt their behaviour when entering the intersection. Behaviour change was also modelled with logistic regressions. Two regressions were used: one for modelling the change in behaviour for pedestrians who approached while not distracted or distracted at the low level, and another one for pedestrians approaching at the medium or high distraction levels.

Non-compliance with the activated signal was also modelled with a binomial regression. An additional regressor was used in that statistical model: the effect of being distracted (at any level).

The percentage of time engaged in each distraction level was investigated as a linear regression using the same predictors.

Statistical models were run using R (ver. 4.0.3). The level of significance chosen for the study was set at $\alpha=0.05$. The statistical model with the lowest Bayesian information criterion (BIC) was selected to avoid over-fitting the data.

3. Results

3.1 Demographics

A total of 585 road users were recorded traversing the road and rail intersections selected in this study. The average number of road users per location was 98 (SD=60, range: 36-182), resulting in a total of 453 users of the level crossings, and 132 users of the road intersection adjacent to one of the level crossings.

Road users were approximately evenly split between genders (male: 54.5%, more details in Table 1). Most users were adults and teenagers, in the same proportions and accounting for 93.2% of the sample. The remainders were children (4.0%) and elderly (2.8%). While adults and teenagers were evenly split, the proportion of teenagers at the road intersection was substantially higher (85.7%), the intersection being used by students from a nearby high school. Most users navigated the intersection alone (42.6%), or as family units (27.8%). Large groups were also observed (18.0%), as well as groups of unrelated users (10.9%). The large majority of road users were unassisted (91.9%), the rest of the sample being assisted (e.g. by another user, pram) or using powered or unpowered vehicles.

Table 1: Demographics of the road users of the road intersection and railway crossings

Demographic variable and Frequency/Proportion† (%)			
	Railway level crossings (N=453)	Signalised road intersection (N=132)	Total (N=585)
Gender			
Male	222 (52.2)	78 (62.4)	300 (54.5)
Female	203 (47.8)	47 (37.6)	250 (45.5)
Unsure	28	6	34
Age			
Adult	252 (55.9)	16 (12.7)	268 (46.4)
Teenager	162 (35.9)	108 (85.7)	270 (46.8)
Child	21 (4.7)	2 (1.6)	23 (4.0)
Elderly	16 (3.5)	0 (0.0)	16 (2.8)
Unsure	2	6	8
Group			
Alone	210 (46.6)	36 (28.6)	246 (42.6)
Small group/Family unit	123 (27.3)	38 (30.2)	161 (27.9)
Large group	54 (12.0)	50 (39.7)	104 (18.0)
Group of un-associated people	62 (13.7)	1 (0.8)	63 (10.9)
Unsure	4	7	11
Road user type			
Unassisted	409 (90.7)	121 (96.0)	530 (91.9)
Assisted	12 (2.7)	1 (0.8)	13 (2.3)
Unpowered (bike/skateboard)	22 (4.9)	4 (3.2)	26 (4.5)

Powered (vehicle)	6 (1.3)	0 (0.0)	6 (1.0)
Unsure	4	6	10
†Road users for which it was not possible to determine the applicable category are reported as 'Unsure' and are not included in the proportion calculations			

3.2 Distraction

3.2.1 Prevalence of distraction levels

Out of the 585 users of the road and rail intersection, 245 (41.9%) were distracted. Specifically, 18 (3.1%) were highly distracted, looking at their phone during their close approach of the crossing or while crossing; 102 (17.4%) were distracted at a medium level, as they were either engaged in a phone conversation or wearing a headset. The remaining 153 (26.2%) road users were distracted at a low level, either holding a mobile phone or discussing with another road user as they approached and traversed the intersection. The proportions of each distraction level are presented by age and gender in Figure 2.

Statistical analyses with Generalised Linear Models revealed that age influenced the likelihood of being distracted. The proportion of adults found to be distracted was 44.7%. That proportion was 42.2% for teenagers, and this difference was statistically significant (z=-2.62, p=0.009). A quarter (25.6%) of children and elderly road users were found to be distracted, which was also significantly lower (z=-3.29, p=0.001). No differences were found for the type of intersection (road or rail), gender, or groups.

For distracted road users, we then investigated the probability to be distracted at the high distraction level. Statistical analyses did not identify any effects of gender, age, group or type of level crossing. It results in 3.1% of the observed pedestrians watching the screen of their phone at some point during their navigation, independently of the analysis factors.

For the remaining distracted road users, we then investigated the effects of the independent variables on the chance to be distracted at the medium level. Statistical analyses revealed a statistically significant difference between male and female road users (z=3.72, p<0.001). The proportion of male road users distracted at the medium level was 26.8%, while that proportion was 15.8% for females (proportions considering all levels). Consequently, female road users were more likely to be distracted at the lowest level (42.3%) compared to males (19.2%).

Overall, the probability for a road user to be not distracted ($p_{no\ distraction}$), distracted at the low (p_{low}), medium (p_{medium}) or high (p_{high}) levels can be expressed by Eq. 2 using the following regressions:

$$\begin{cases} \eta_{distracted} = -1.61 + 1.47.Adult + 1.32.Teenager \\ \eta_{high} = -2.56 \\ \eta_{medium} = -0.78 + 1.05.Male \end{cases}$$

And the factors are further detailed in Table 2.

Table 2: Effects of the statistically significant factors on the likelihood of distraction.

	B	SE B	95% Confidence interval for B		z	p
Distracted						
Intercept	-1.61	0.49	-2.61	-0.84	-3.29	0.001
Adult	1.47	0.51	0.66	2.51	2.90	0.004

Teenager	1.32	0.51	0.51	2.35	2.62	0.009
Distracted at the high level						
Intercept	-2.56	0.25	-3.06	-2.12	-10.15	<.001
Distracted at the medium level						
Intercept	-0.78	0.21	-1.18	-0.39	-3.75	<.001
Male	1.05	0.28	0.51	1.60	3.72	<.001

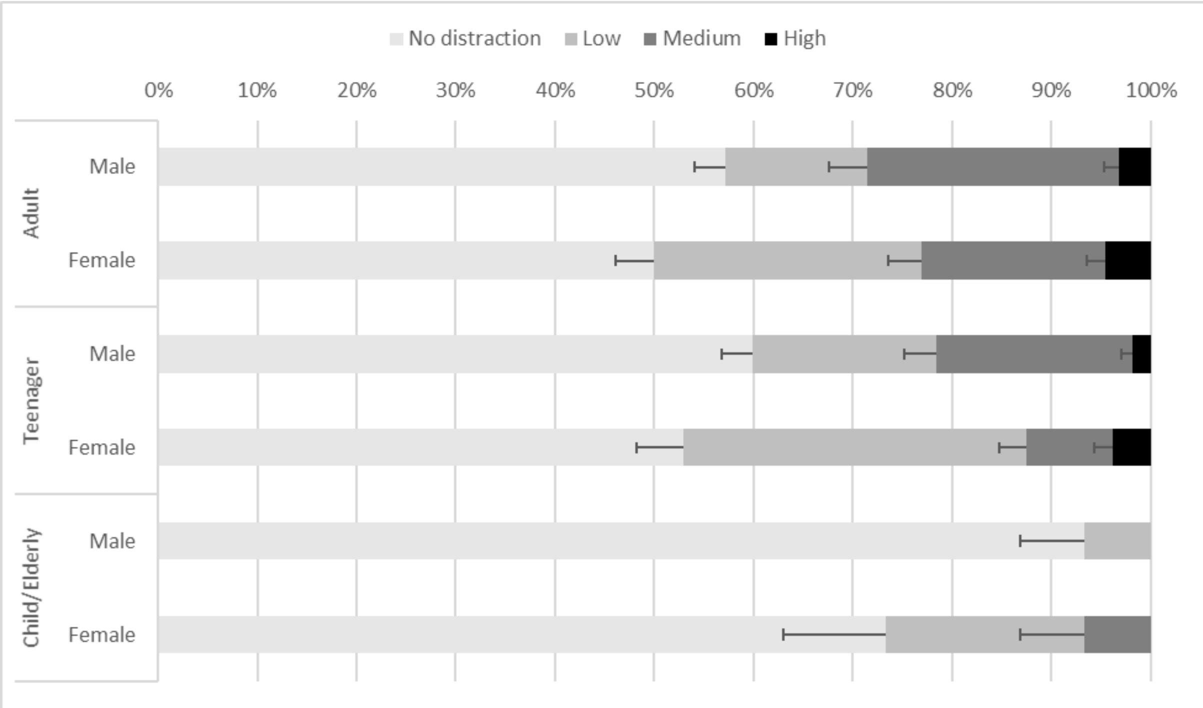

Figure 2: Observed proportions of the different distraction levels by age and gender (with the standard error of the mean).

3.2.2 Multiple distractions

Some pedestrians engaged in multiple distraction types as they navigated the selected intersections/crossings. Specifically, users holding a mobile device in their hands often engaged later in other distraction types: 5% (N=5 out of 126) were found to engage in a phone conversation, and 13% (N=18 out of 139) were found to later look at their phone. Road users involved in a phone conversation also interacted with their mobile device: 8% (N=2 out of 25) looked at their phone. A third (35%, N=28 out of 79) of road users wearing a headset were also holding their mobile device in their hands, one of them looking at their phone at a later stage. One of the pedestrians looking at their phone was also discussing with another pedestrian.

3.3 Approach – Crossing transition

Out of the 585 road users recorded, 411 navigated in the direction that allowed to investigate whether road users changed behaviour when traversing the intersection. Out of the 80 pedestrians approaching the intersection while distracted at a medium or high level, 43 (54%) changed their behaviour, being not distracted or distracted at the low level when traversing the crossing. On the other hand, 51 (15%) of the 331 road users approaching the intersection while not distracted or distracted at the low level were then distracted at a higher level (medium or high) when traversing the intersection. Figure 3 presents road users changes in behaviour by age and road intersection.

Statistical analyses revealed that age and the intersection type affected the likelihood for a pedestrian distracted at the medium or high level while approaching the crossing to reduce their distraction level when traversing. Road users were more likely to change their behaviour at the road intersection (95%) compared to railway crossings (47%; z=3.73, p<0.001). Teenagers (55%) were less likely to change their behaviour compared to other age groups (70%; z=-3.24, p<0.001).

Statistical analyses did not identify any factors affecting the chance of engaging in a higher level of distraction for road users who approached while not distracted or distracted at the lowest level; 16% of these pedestrians were observed to be engaged in the higher distraction levels when traversing the intersection.

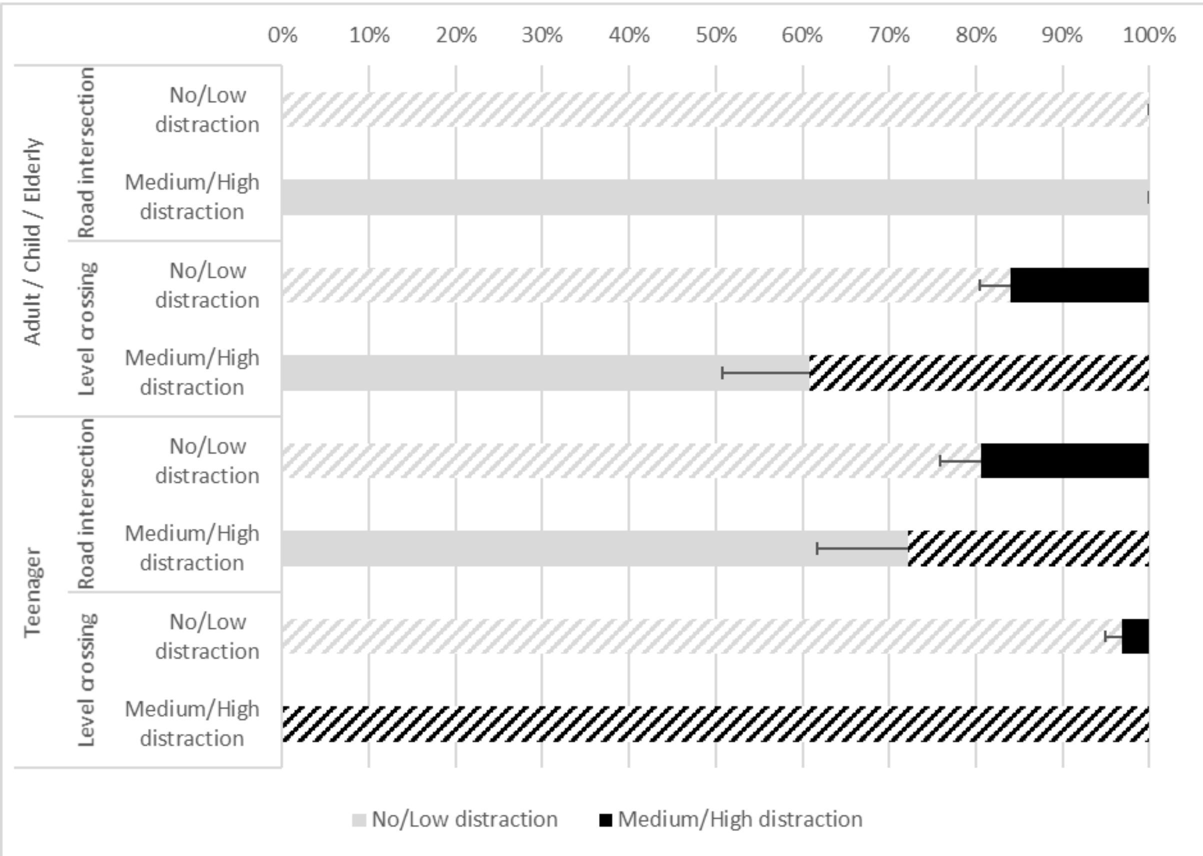

Figure 3: Observed changes in distraction levels between the approach the traversing of the intersection by age and intersection type (with the standard error of the mean; hashed colours represent no change of distraction level).

3.4 Proportion of time distracted

When road users were distracted at the low level, their engagement in the distraction was constant, being on average 98% of the time they approached and traversed the intersection (Figure 4). Similar results were found for the medium level of distraction, the percentage of time being 97% and not statistically different from the low level. On the other hand, the high level of distraction was intermittent, resulting in such distraction to account for 58% of the time road users navigated the intersection. Statistical analyses revealed that this percentage was statistically significantly different from the other two levels, and that this percentage also depended on the type of intersection. The percentage of time distracted at the high level was 40% at road intersections, corresponding to a 57% reduction compared to the two other distraction levels (t=-4.34, p<0.001). At railway crossings, the percentage of time highly distracted was 67%, corresponding to a 30% reduction (t=-7.76, p<0.001).

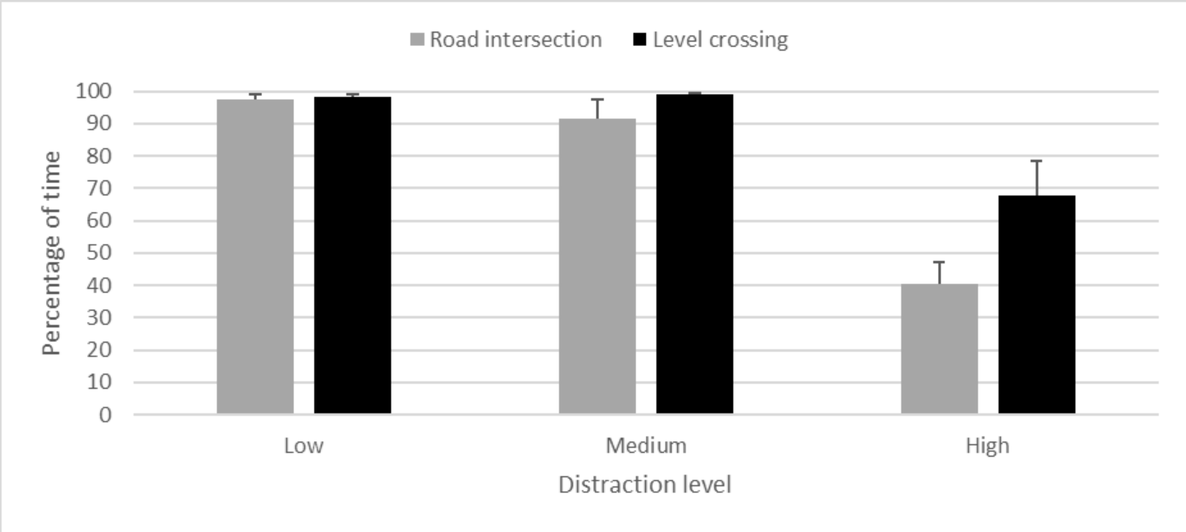

Figure 4: Percentage of time road users were distracted by distraction level and intersection type (with the standard error of the mean).

3.5 Effects of distraction on signal non-compliance

A total of 203 road users approached the road intersection or railway crossing while the lights were activated. Out of these, 137 (67%) were distracted; and 31 (15%) did not comply with the activated signal and traversed the intersection while closed to pedestrians. The 31 non-complying pedestrians were divided into 17 (55%) who were distracted and 14 (45%) who did not engage in any distraction.

Statistical analyses revealed that the chance to traverse the intersection/crossing when signals were activated was higher when pedestrians were not distracted (21%) than when pedestrians were distracted (12%; z=2.80, p=0.005). Teenagers were also more likely to disregard activated signals (29%) compared to other age groups (2%; z=4.33, p<0.001).

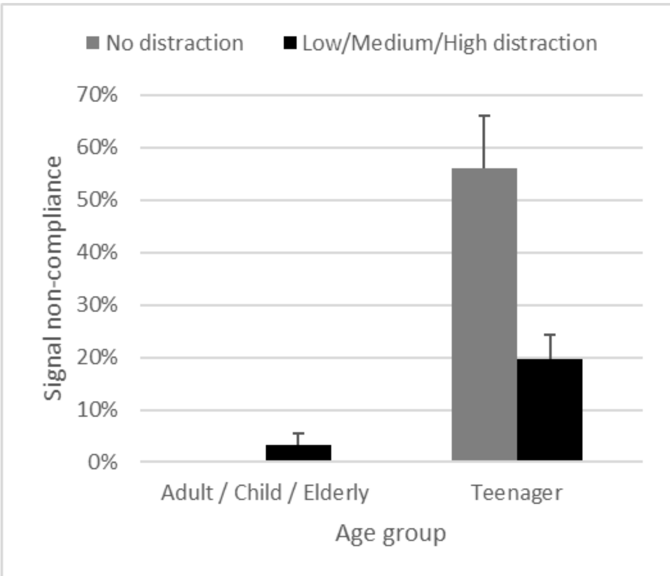

Figure 5: Non-compliance with the activated signal by age group and distraction (with the standard error of the mean).

4. Discussion

Observations of pedestrian behaviour at railway level crossings and a road intersection showed that road users engage in various distraction types. Similar to other research (Mwakalonge, Siuhi, & White, 2015), most types related to mobile devices. The widespread use of smartphones in everyday activities has resulted in concerns around pedestrians' safety at intersections when distracted (Le et al., 2019). This study is the first to estimate the prevalence of distraction at railway level crossings. It is also the first to consider how pedestrians modify their behaviour dynamically when negotiating intersections.

4.1 Prevalence

Distraction, in its various levels was found to be widespread at the observed sites. Prevalence aligned with the observations conducted at road intersections in the literature, as well as observations conducted at the road intersection adjacent to one of the level crossings in this study. The prevalence found in this study was toward the higher range reported in other studies. It is likely due to the use of a systematic and comprehensive classification of distraction, including smallest to highest distraction levels. Nevertheless, our findings suggest that distraction at railway crossings is as much an issue as at road intersections, despite the higher risk inherent to these intersections.

Age group was identified as the main factor affecting distraction prevalence. Similar to previous research, teenagers were an age group highly likely to be distracted (Gitelman et al., 2019; H. Zhang et al., 2019; Zhou et al., 2019). This study suggests that distraction is an issue as relevant to adults as for teenagers, similar to some extent to previous research which has found distraction to be an issue for pedestrians under 30 (H. Zhang et al., 2019). Indeed, distraction prevalence was slightly higher for adults than for teenagers. Such finding may be related to the choice of a location that is not directly adjacent to a school or university, leading to a more diverse sample. Such findings may be explained by the increased reliance on mobile devices to conduct everyday activities, resulting in more age groups using mobile devices on a regular basis. Distraction was less of a concern with children, who are often accompanied by a parent and may not have access to or even require a mobile device for their day-to-day activities.

When considering the level of distraction, this study found that the most distracting uses of mobile devices, which require looking at the screen, were much less frequent. Such observations are also apparent in the existing literature; however, our prevalence (3%) appears to be around a half to a third of that of other research at road intersections (6-10%: Aghabayk et al., 2021; Horberry et al., 2019; Ropaka et al., 2020; Vollrath et al., 2019). It suggests distraction associated with a screen may be less prevalent at railway crossings, but further research would need to confirm this, given that our analysis did not find differences between the behaviour at the observed level crossing and the selected road intersection. In any case, such prevalence is still concerning as pedestrians who look down at their mobile devices may not monitor the environment in which they navigate (Lin & Huang, 2017), and are more likely to engage in unsafe behaviours while crossing, such as crossing when signals are activated (Lin & Huang, 2017; Pešić et al., 2016). Further, given the significant traffic going through such intersections and the repetition of traversals or intersections by pedestrians, during a journey or day after day, the exposure to such risk could result in higher risks than suggested by the observed proportions.

Gender differences were also found with the prevalence of distractions at the low and medium levels. Males were more likely to engage in the distractions categorised as medium, i.e. having a phone conversation while walking or wearing a headset, compared to females. Females were more likely to be involved in the lower distraction levels, i.e. having a conversation with another road user or holding a phone. This suggests that while gender did not affect the likelihood of being distracted, males were more likely to engage in tasks that could impair their performance on the primary task (walking) more so than females. Such a finding has not been reported in previous studies, which have tended to show that females were more likely to be involved in distractions (Baswail et al., 2019; Piazza et al., 2020). However, the lack of comprehensive approach in the literature may have hidden a differential use of the technology by both genders, which result in very different uses when the level of distraction is considered. This could explain why males are over-represented in fatal pedestrian collisions at intersections (Chong, Chiang, Allen, Fleegler, & Lee, 2018). This raises questions on whether such prevalence difference is due to way mobile devices are used or due to different perception of risk with both genders.

4.2 Dynamic process

Current distracted walking observations report the prevalence of distraction types as a binary measure, failing to consider distraction as a dynamic process that evolves with time. Such a limitation is apparent in the review by Mwakalonge et al. (2015). The observations conducted in this study were coded considering the evolution of distraction as pedestrians progressed through intersections. Such an approach showed that distraction was not necessarily constant or unique. Indeed, while pedestrians engaging in the low or medium distraction levels tended to perform that additional tasks throughout their approach and traversal of the intersection, this was not the case for the high distraction level. When engaged in high distractions, pedestrians were found to engage in that behaviour intermittently, and as a result, spent around half of their time looking at their phone.

Further, while some pedestrians behaved the same while approaching and traversing the intersection, some pedestrians changed their behaviour. Some reduced their level of distraction between the approach and traversal, suggesting that they could recognise that they approached an area of higher risk and adjusted their behaviour accordingly. The regulating of behaviour with a phone while walking has been noted previously (Banducci et al., 2016). On the other hand, some participants engaged in high distractions once traversing, suggesting that their perception of risk reduced once the decision to enter the crossing was taken, for instance by walking slowly while traversing (Thompson, Rivara, Ayyagari, & Ebel, 2013) or impairment of gait mechanics (e.g., smaller step length) (Parr, Hass, & Tillman, 2014).

This study also highlighted that pedestrians might engage in multiple distractions simultaneously or in close succession, which was already identified by Vollrath et al. (2019). There may be complex interactions between types of distractions, raising questions on their effects on walking safety. In particular, this study suggests that pedestrians holding a phone, while currently distracted at a low level, are likely to use their device later down the track. Therefore, holding a phone can be seen as a precursor or opportunity for higher levels of distraction.

4.3 Distraction, risk perception and non-compliance

Half of the pedestrians who approached intersections while distracted at the higher levels were not distracted at such levels once traversing. This suggests that some pedestrians perceive the risk associated with sharing their path with road vehicles or trains, and manage the risk accordingly, by changing their behaviour when they are at the decision point. This aligns with previous research, which has already identified that pedestrians tend to walk at a slower pace when distracted (Ropaka et al., 2020; Zhou et al., 2019) or attempt to complete texting prior to crossing a road (Banducci et al., 2016) as a risk mitigation strategy. This is also supported by our finding that pedestrians engaged for lower proportions of time in the highest level of distraction compared to lower types of distraction. Despite such risk management by pedestrians and prevalence of highly distractive tasks appearing low, the high exposure due to the number of pedestrians and repetition of traversal of intersection, combined with the possible severe consequences of a collision suggest that risk remain high, as supported by investigations of pedestrian collision and their link with distraction (Le et al., 2019). Another explanation may be that distraction led to poor scanning of their environment and spatial awareness, as observed in previous studies (Feld & Plummer, 2019; Lin & Huang, 2017).

Further, less distractive tasks were found to be prevalent at an order of magnitude higher than highly distractive task, which suggests that while pedestrians may be less likely to lose awareness of their environment with such distractions, exposure might be high enough to raise concerns on their overall risk to safety.

Such mitigations strategies were a lot less common in the observed teenagers. This age group was much less likely to adapt their behaviour as they entered the crossing. Previous research has found similar results with young adults, who prioritise texting tasks over situational awareness (Feld & Plummer, 2019). Such observation is particularly concerning given that such age group was also found to be more likely to disregard the activation of signals, and enter the intersection/crossing while it was activated. This suggests that younger pedestrians could be at higher risk, combining low adherence to road rules, high prevalence of distraction and limited strategies to manage their risk. This could partly explain why younger pedestrians are involved in a greater proportion of fatal crashes linked to the use of a mobile device (Mwakalonge et al., 2015).

This study also suggests that non-compliance with signals may largely be intentional, pedestrians being more likely not to comply when they are not distracted, and as such more aware of their environment. This aligns with numerous previous research, which failed to link distraction to non-compliance (Baswail et al., 2019; Horberry et al., 2019; H. Zhang et al., 2019). However, some distracted pedestrians did not comply with activated signals, which suggests that distraction can lead to unsafe decisions, or lack or decisions that result in unsafe behaviours.

4.4 Implications

Innovative solutions consisting of visual warning lights installed in the ground or audio messages are currently investigated and trialled in some locations around the world at both road and rail intersections (Hirsch et al., 2017; Potts, 2016; Sulleyman, 2017; Timson, 2016). They aim to attract pedestrians' attention who are visually or auditorily distracted through additional warnings more adapted to road users who may not direct their attention toward traditional signage. Research suggests that such interventions effectively attract pedestrians' attention distracted by mobile devices, both in laboratory conditions (Larue, Watling, Black, Wood, & Khakzar, 2020) and in the field (Larue et al., 2021). Further, when accepted by road users, they also lead to safer behaviours when crossing (Larue & Watling, 2021). However, limited information currently exists on the benefits and viability of such approaches. Through its estimates of the prevalence of distraction, this study provides new information that can inform the viability of these approaches. Indeed, knowing distraction types and prevalence are necessary to model collision risks for distracted pedestrians (risk being a combination of the likelihood of an incident and the consequence of that incident) and eventually assess the cost-benefit ratios of such countermeasures.

4.5 Strengths, limitations, and future research directions

The observations conducted in this study provided new insights into pedestrian distraction at rail and signalised intersections. The observations provided estimates of the prevalence of different distraction types at both road and rail intersections, which are currently missing in the literature. Such measures are necessary for estimating the risk of pedestrian distraction, and for estimating the viability of potential countermeasures. However, there are limitations that need to be acknowledged when interpreting the findings.

First, observations were conducted at a limited number of locations for a short period of time. The crossings and road intersection were all selected based on pedestrian traffic and adjacent to railway stations. The time and location of observations resulted in the sample of pedestrians being largely composed of commuters. The proportion of teenagers at the road intersection was also higher than at the other sites, mainly due to the presence of a high school nearby. While the number of pedestrians were observed was sufficient to analyse data with regressions, the prevalence found may not generalise to other types of locations or other times. It is also not possible to ensure that these values are representative of the average behaviour at the selected site. Longer data collections would be necessary, and future studies should aim to quantify distraction prevalence over longer periods. However, such research would require more automated approaches to be able to scale up.

Active pedestrian railway crossings and signalised road intersections are areas of safety concerns for vulnerable road users such as pedestrians, as pedestrians have to share their path with heavy traffic of road and rail vehicles at such locations. Railway crossings are of particular concern given the size and weight of trains, as well as their lack of opportunity to change direction and limited capability in slowing down. As such this study compared behaviour at level crossings to a signalised road intersection to investigate whether pedestrian behaviour was different at intersections with different risk levels. This study provides some valuable insights on this difference, but observations were limited to one road intersection. The findings from this study align with the literature for the road intersection, giving some confidence in how the findings could generalise. However, additional studies on various types of road intersections, particularly away from railway stations, would be valuable to further investigate how pedestrians adapt their behaviour to intersections of different risk.

The study design being based on video coding of field observations, a limited number of factors contributing to distraction could be investigated. The approach nevertheless identified key demographic factors affecting the prevalence of distraction. This information can be useful for designing interventions and ensuring the appropriate groups are targeted for reducing risky behaviours.

The field observations allowed to identify the dynamic nature of distraction. However, the video coding allowed only to follow a pedestrian for about 15 seconds of their navigation. The observed section was selected as the literature suggests that it is the riskiest for pedestrians, but further studies following more completely pedestrian's navigation would be necessary to understand in depth how pedestrian behaviour dynamically evolves and how it affects the safety of their navigation.

5. Conclusion

This study video recorded the behaviour of pedestrians at an active railway crossing and its adjacent signalised road intersection. Pedestrians' engagement in distractive tasks were coded and classified into low, medim and high distraction levels. This research found that distraction is highly prevalent at railway crossings, similar to what has been already observed at road intersections. While the most distractive tasks are less common, low to medium distraction also affect pedestrian attention to the environment and can contribute to non-compliances and collisions. This research therefore supports the development of new signage and interventions for distracted pedestrians at road and rail intersections. This study also contributed to the literature by looking dynamically at distraction from the approach to completion of the road or rail traversal.

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