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# Lost in Transmission: Digital Distraction and Pedestrian Safety in Urban Tram Environments – The Case of Gothenburg

Mikael Johansson

*Populus Perspective, Sweden. E-mail: mikael@mitcha.se*

Anna-Lisa Osvalder

*Division Design & Human Factors, Chalmers University of Technology, Sweden. E-mail: anna-lisa.osvalder@chalmers.se*

Pedestrians are a vulnerable group of road users, and safety risks are pronounced in complex urban environments where tram systems coexist with pedestrian traffic. While tram systems improve urban accessibility and sustainability, they also introduce challenges at tramway level crossings and tram stops, where pedestrians must interact closely with rail infrastructure and moving vehicles. Digital distraction, such as mobile phone use and wearing headphones, has been identified as a contributing factor to unsafe pedestrian behaviour, yet its prevalence and effects in tramway level crossing environments remain underexplored.
This study investigates digital distraction among pedestrians at tramway level crossings and examines how distraction and infrastructure design influence behaviour and safety. Structured observations were conducted at eight level crossing areas across six tram stops in Gothenburg, Sweden, representing a range of design characteristics. In total, 1,110 pedestrians were observed over three observation rounds.
The results show that digital distraction was common, with 57 percent of pedestrians exhibiting some form of distraction, most frequently headphone use. Younger pedestrians were more likely to be distracted than older age groups. Approximately one quarter of distracted pedestrians displayed predefined hazardous behaviours, most commonly failing to adequately check their surroundings before crossing. Hazardous behaviours varied between locations, indicating that infrastructure design and traffic complexity influence pedestrian safety. Safety-critical situations were identified in environments with limited visibility or approaching trams from behind, where distraction further exacerbated hazards. The findings indicate that targeted design and information measures may be necessary to mitigate safety risks associated with digital distraction at tramway level crossings.

*Keywords*: Vulnerable road users, Pedestrian safety, Hazardous behaviour, Digital distraction, Mobile phone use, Urban traffic environment, Infrastructure design, Tram systems, Track crossings.

## 1. Background

Globally, more than 300,000 pedestrians are killed annually in traffic accidents, accounting for approximately 22% of all traffic-related fatalities (WHO, 2018). One critical situation is at road crossings; in the United Kingdom, over one quarter of pedestrian accidents occur at or in close proximity to pedestrian crossings (Murphy et al., 2020).

In cities with tram systems, trams not only contribute to improved accessibility, capacity, and sustainability of urban transport, but can also pose challenges in complex urban environments. Because trams often coexist closely with pedestrians and other traffic modes, these groups must regularly cross tracks to reach their destinations. Particularly at tramway level crossings and tram stops, conflicts may occur between trams and vulnerable road users, potentially resulting in significant hazardous interactions or safety risks. To improve safety at crossings, a range of technical and physical measures has often been employed, including barriers, signals, warning lights, and pavement markings (Hirsch et al., 2017). However, a prerequisite for pedestrians to comply with the intended function of these measures is that they are aware of them.

Several road safety studies have shown that distraction is an important contributing factor in pedestrian-involved accidents (Pešić et al., 2016;

Sobhani et al., 2017), and that distracted pedestrians generally exhibit more hazardous behaviours than non-distracted pedestrians. Such behaviours include choosing smaller and less safe gaps between vehicles, complying with traffic signals to a lesser extent, and paying less attention to visual and auditory signals (Thompson et al., 2013; Zhang et al., 2019).

Distraction is commonly defined as a state of inattention in which the pedestrian's focus shifts from the primary task—such as crossing a road—to another activity (Larue et al., 2021). Distraction can be divided into visual, manual, auditory, and cognitive components (Tian et al., 2022). One of the most frequent sources of distraction, and a well-documented contributing factor in pedestrian accidents, is mobile phone use (Hamann et al., 2017; Jiang et al., 2018), which may activate one or several of these components (Arafat et al., 2023).

The prevalence of pedestrian distraction while crossing roads is high. Observational studies indicate that between 15% and 45% of pedestrians are distracted while crossing the road (Aghabayk et al., 2021; Thompson et al., 2013; Wells et al., 2018; Zhang et al., 2019). These studies indicate that wearing headphones is the most common form of distraction, followed by texting and phone calls.

Although research has primarily focused on road crossings, studies also indicate that distraction is a significant factor at track crossings (Larue & Watling, 2022). As mobile phones and headphones have become more prevalent, inattention in rail-adjacent environments has increased (Larue et al., 2018). Accident investigations from, among others, New Zealand show that mobile-related distraction has contributed to incidents at railway crossings, leading to technical countermeasures such as in-ground lighting and auditory warnings (Hirsch et al., 2017). A study on traffic users' perceptions of the tram system in Gothenburg shows that although the majority hold a positive view of the tram system, 64% have experienced a hazardous situation related to infrastructure design and behaviour, such as mobile phone use or listening to music (Johansson & Osvalder, 2025).

However, even though the effects of distraction on pedestrian safety at road crossings are relatively well documented, there is less knowledge regarding how prevalent digital distraction is at tramway level crossings and how infrastructure design and digital distraction influences pedestrians' behaviour at these locations.

Therefore, the aim of this study is to identify hazardous behaviours among pedestrians using digital devices in tramway crossing areas in Gothenburg and to identify how design characteristics influence distracted pedestrian behaviour.

## 2. Method

To identify the prevalence of digital distraction in tramway crossing areas and to examine how it affects pedestrian behaviour, data were collected through observations in the city of Gothenburg.

### *2.1. Participants*

In total, 1,110 pedestrians were included across three types of observations. The observed pedestrians exhibited an even gender distribution, with 54% females and 46% males. While the age distribution differed to a larger extent, with the largest proportion of pedestrians was estimated to belong to the age group under 25 years (42%), followed by the 25–44 (40%) and 45–64 (15%) age groups. The oldest category, 65 years and older, constituted the smallest proportion of pedestrians (3%).

### *2.2. Tram stops*

A selection of different types of tram stops was made to investigate how various design features influence pedestrians' behaviours and interactions. Six tram stops with varying design characteristics were selected, including differences in the presence of physical barriers, signal systems, and the number of tracks. The selected tram stops were Chalmers, Gamlestads torg, Järntorget, Stenpiren, Svingeln, and Vasaplatsen. Järntorget and Stenpiren each included two crossings, resulting in a total of eight observed tramway crossing areas.

### *2.3. Data collection*

Three rounds of unobtrusive observations were carried out to identify pedestrian behaviours and safety-critical events associated with the use of digital devices. Data were collected between May and June 2025, with each tramway crossing area observed for approximately 45 minutes per session and with systematic rotation between tram stops. Observations were conducted at varying times of day to include differences in traffic intensity and situational conditions.

The main observations included 715 pedestrians and consisted of two parts. The first was a flow analysis, in which pedestrian movement paths were mapped to understand how design influences movement patterns at and around tramway crossings. The second part was a behaviour and incident analysis, focusing on the observation of hazardous behaviours and incidents, with the aim of identifying where hazardous situations occur and how these differ between tram stops with different design characteristics.

All observations were conducted by a single observer using a structured observation protocol. Demographic characteristics were estimated visually. The protocol was designed to identify hazardous pedestrian behaviours, defined in this study as observable actions that may increase exposure to traffic hazards or reduce safe interaction with trams or other road users in tramway crossing areas. The upper section of the protocol contained checkboxes related to: (i) the situation, such as the presence of an active light signal; (ii) distractions, including whether the pedestrian was wearing headphones, talking on the phone/hands-free, or looking at their phone; (iii) estimated demographics, including gender and age categories; and (iv) observed hazardous behaviours and incidents, including failing to check the surroundings before crossing, crossing against a red signal, colliding with objects or other road users, stumbling or falling, whether a vehicle had to signal, or whether an incident with a vehicle occurred.

The lower section of the protocol contained a schematic map of each tram stop and its track crossing(s). When a pedestrian moved toward or away from the tram stop area in connection with a track crossing, their movement path was observed and marked as a line on the schematic map. If hazardous behaviours or incidents were observed, these were noted in the checkboxes and marked on the map.

Additional observations were conducted at all tramway crossing areas to assess the prevalence of digital distraction among pedestrians. During these observations, 283 pedestrians were observed, and type of distraction and estimated age category were recorded. The main observations also revealed that it was common for pedestrians to cross the tracks despite active light signals. Therefore, additional observations of 112 pedestrians were conducted with a specific focus on pedestrian behaviour at red signals and how different types of digital distraction influenced behaviour compared to non-distracted pedestrians.

### *2.4. Analysis*

An initial spatial analysis compiled movement paths and event markers for each tram stop to identify the most common pedestrian routes and where hazardous behaviours or incidents tended to occur.

Pedestrian characteristics were analysed using descriptive statistics to provide an overview of the observed sample. Hazardous behaviours and incidents were compared between tramway level crossings to identify potential patterns related to site design. Descriptive statistics were also produced for data related to the prevalence of digital distraction and behaviour at red signals, providing an overview of how common these behaviours were and how they influenced compliance with red signals.

A more detailed spatial analysis was also conducted for each individual tramway crossing by compiling movement paths and event markers to identify how pedestrians move and where hazardous behaviours are most prevalent. Because the number of observations differed between tram stops, all data were normalized by the total number of observations at each crossing prior to comparison.

## 3. Findings

The findings include occurrence of digital distraction, identified hazardous behaviours, Pedestrian flows and spatial analysis, and behaviours at signal-controlled tramway level crossings.

### *3.1. Occurrence of digital distraction*

Various forms of digital distraction among pedestrians in the vicinity of tram stops were common. A majority (57%) of the observed pedestrians exhibited some form of digital distraction, with the use of headphones being by far the most common form. The findings also show a clear age-related difference. Among pedestrians in the oldest age category (65 years and older), only 9% exhibited digital distraction, whereas the corresponding proportion in the youngest age category (under 25 years) was as high as 82% (see Figure 1).

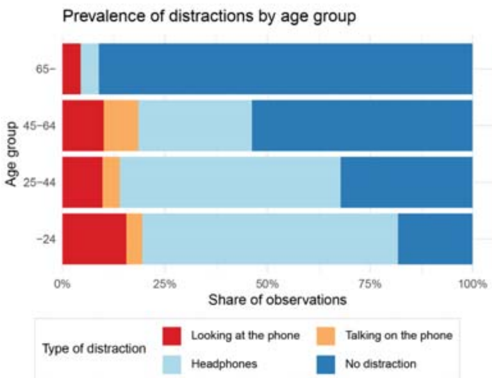


Fig. 1. Distribution of observed types of digital distraction among pedestrians in the vicinity of tram stops during the first additional prevalence observations, presented across four age groups (n=283).

### *3.2. Hazardous behaviours*

Approximately one quarter of all distracted pedestrians exhibited one or more predefined hazardous behaviours or incidents. The most prevalent behaviours were failing to adequately check the surroundings before crossing the tracks and crossing against a red signal, each occurring in 19% of the observations—substantially more frequently than other categories (Figure 2). Situations in which a vehicle was required to signal to pedestrians were observed in approximately 5% of cases, which is notable given that this was classified as one of the most severe predefined hazardous incidents. Collisions with pedestrians or objects, as well as trips or falls, were rare, and no collisions with vehicles were observed.

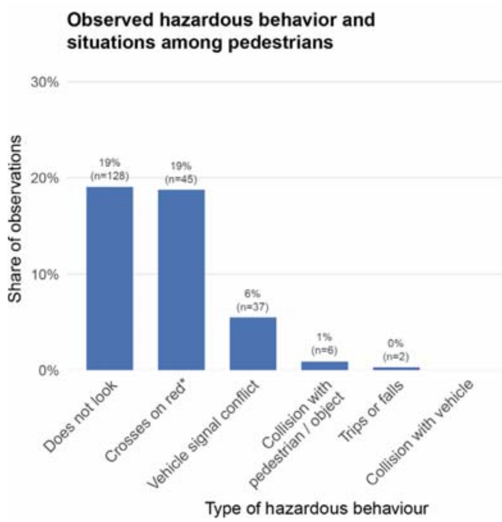


Fig. 2 Proportion of pedestrians exhibiting one or more predefined hazardous behaviours or situations. A single pedestrian may have exhibited multiple behaviours or incidents. *Only the crossings at Chalmers and Järntorget were equipped with traffic signals.

These hazardous behaviours and incidents were not evenly distributed but differed between tram stops (see Table 1).

Vehicle signalling was consistently the least common hazardous incident or behaviour at all tram stops. The proportion was generally low, though with some variation, with Järntorget – West, Järntorget – East, and Vasaplatsen exhibiting higher levels than other locations.

Crossing against a red signal did not vary substantially among the three tram stops equipped with signal-controlled crossings. At Järntorget – West, a slightly lower proportion of pedestrians crossed against the red signal.

Failing to check the surroundings before crossing varied considerably between tram stops. This behaviour was particularly common at Vasaplatsen, Stenpiren, and Gamlestads torg, where a relatively large proportion of pedestrians crossed without clearly checking the traffic environment beforehand. At Stenpiren and Gamlestads torg the environment is more visually clear open spaces and with perpendicular crossings. In contrast, Vasaplatsen features a highly complex traffic environment with tracks from multiple directions as well as car and bus traffic.

Table 1. Observed hazardous behaviours and incidents by track crossing. Rare events ('collision with pedestrian/object', 'trips or falls', and 'collision with vehicle') are excluded due to the low number of observations.

| Location | n | Did not look (%) | Crossed on red* (%) | Vehicle signal (%) |
|---|---|---|---|---|
| Chalmers | 120 | 15.8 | 19.2 | 3.3 |
| Gamlestads torg | 104 | 22.1 | - | 3.8 |
| Svingeln | 104 | 12.5 | - | 6.7 |
| Vasaplatsen | 88 | 29.5 | - | 8.0 |
| Stenpiren - West | 80 | 25.0 | - | 3.8 |
| Järntorget - East | 64 | 10.9 | 20.3 | 7.8 |
| Järntorget - West | 56 | 14.3 | 16.1 | 7.1 |
| Stenpiren - East | 56 | 21.4 | - | 5.4 |

*Only the crossings at Chalmers and Järntorget were equipped with traffic signals, which affected the occurrence of crossings against a red signal.

### *3.3. Pedestrian flows and spatial analysis*

Certain tram stops, such as Chalmers, exhibited more distinct pedestrian flow lines, shown by darker lines in Figure 3 (left), indicating that pedestrians tended to follow similar movement paths. In contrast, at other tramway crossings, such as Järntorget–East, the flow lines were more diffuse, reflecting greater variation in pedestrian movement paths (Figure 3, right).

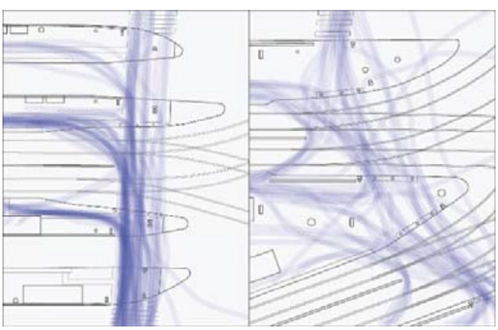

Fig. 3. Pedestrian movement flows at two tram stops. At Chalmers (left), trajectories are more concentrated, while at Järntorget–East (right), trajectories are more varied. Darker lines indicate higher pedestrian density.

The overall movement flows at the tram stops appeared to be primarily affected by pedestrians' destinations (e.g., the opposite platform or a pedestrian crossing) and by physical barriers, such as railings. In some cases, physical barriers contributed to perpendicular and clearly guided crossings at intended locations, such as at Chalmers. In other cases, barriers combined with pedestrians' destinations led pedestrians to walk longer distances along or adjacent to the track area, even in locations where crossing was not intended and where barriers simultaneously restricted movement space, such as at Stenpiren (see Figure 4).

Fig. 4. Flow diagram of Stenpiren - East illustrating observed pedestrian movements in the vicinity of the tramway level crossings.

Two particularly safety-critical types of situations were identified in the observational material. The first occurred in complex track environments with multiple tracks and trams, where trams approached from behind or diagonally behind relative to pedestrians' direction of movement, such as at Vasaplatsen. The flow analysis at Vasaplatsen shows two main movement flows: one parallel to the platforms (horizontal in Figure 5) and one between the platforms (vertical in Figure 5). When pedestrians moved between platforms, crossings typically occurred at marked crossings, particularly at the initiation of the crossing, and relatively few hazardous behaviours were observed. In contrast, pedestrians frequently failed to check their surroundings (indicated by green circles) when moving parallel to the platforms, particularly on the right side of the figure, where many signalling events (indicated by red circles) also occurred, especially in connection with turning vehicles.

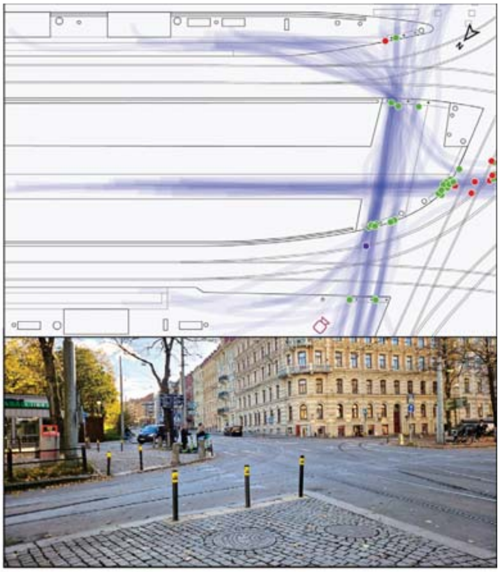

Fig. 5. Safety-critical situations at Vasaplatsen caused by a complex track environment with multiple tracks and trams. The green circle highlights a pedestrian not properly looking before crossing, the red circle indicates a vehicle signalling, and the purple circle marks a pedestrian tripping.

The second situation occurred when visibility of one track was visually obstructed by a tram on an adjacent track, such as at Gamlestads torg. This situation arose when trams departed the platform toward the left in the schematic shown in Figure 6 and stopped to wait for a green signal. The stationary tram obstructed the view of the adjacent track, making it difficult for pedestrians to detect approaching trams. This led to multiple instances where vehicles had to signal (indicated by red circles), often at the central railing, typically from vehicles approaching from the left in Figure 6.

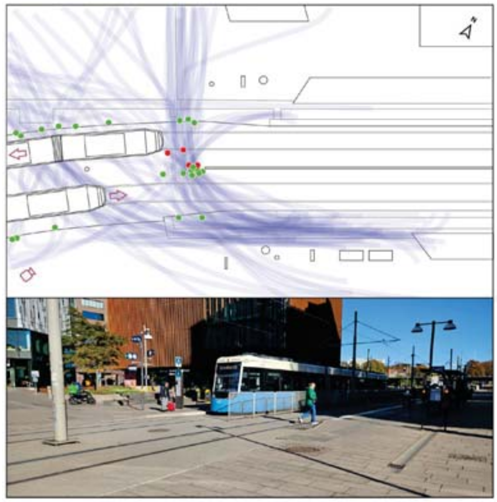

Fig. 6. Safety-critical situation at Gamlestads torg caused by a stationary tram obstructing visibility.

### 3.3. *Behaviour at signal-controlled crossings*

Observations showed that many pedestrians crossed the track despite a red signal, while approximately half stopped (Figure 7). Among those who crossed against the red signal, many nonetheless checked the track direction for approaching vehicles before crossing. Non-distracted pedestrians were the group most likely to avoid crossing against a red signal without checking their surroundings (5%). In contrast, pedestrians looking at their mobile phone screen crossed against a red signal without checking in more than half of the cases (57%).

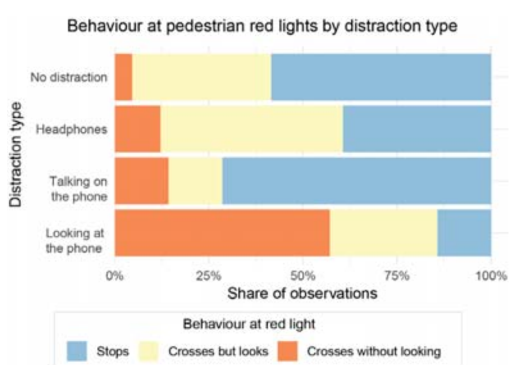


Fig. 7. - Distribution of behaviours at red signals by type of distraction. The proportions of pedestrians who stopped, crossed while checking, and crossed without checking are shown for each distraction category (n = 112). Percentages sum to 100 % within categories.

## 4. Discussion and Conclusion

The aim of this study was to examine the prevalence of digital distraction in tramway crossing areas and to identify how pedestrians using digital devices behave in these environments. The results show that digital distraction at tram stops and tramway level crossings was common, with just over half of the observed pedestrians exhibiting some form of distraction. Headphone use was the most prevalent, and a clear age-related difference emerged, with mobile phone use being substantially more common among younger pedestrians. The prevalence of digital distraction lies at the upper end of the range reported in previous observational studies (Aghabayk et al., 2021; Thompson et al., 2013; Wells et al., 2018; Zhang et al., 2019), likely reflecting the increasing normalization of mobile phone use over time.

Pedestrian movements at the tram stops were primarily governed by destinations and physical barriers, such as railings. While barriers often contributed to clearly guided crossings at intended locations, they sometimes led pedestrians to walk longer distances along or adjacent to track areas, including locations where crossing was not intended. Differences between tramway crossings were also evident in the occurrence of hazardous behaviours. These findings show that tram crossing design influences safety-critical behaviour, although larger observational samples are needed to draw more robust conclusions regarding specific design features. However, two specific situations were identified as particularly hazardous. They occurred when trams approached from behind or diagonally behind pedestrians and at visually obstructed tracks. These findings indicate that complex environments with limited visibility or divided attention are further exacerbated by reduced access to visual or auditory information due to digital distraction.

Mobile phone use, particularly visual engagement with the screen, had a pronounced effect on pedestrian attention. Those focused on their screens displayed the most hazardous behaviour, often crossing on red without properly checking their surroundings. This is consistent with research showing that screen viewing is associated with increased hazard in traffic environments (Jiang et al., 2018; Simmons et al., 2020; Mukherjee & Mitra, 2020). A plausible explanation is that cognitive and visual focus on the phone, often combined with reduced auditory awareness due to headphone use, leads to missed signal information.

The results suggest that changes in traffic environment design may be necessary to counteract safety-critical behaviours associated with digital distraction. Technical and infrastructural measures, such as clearer and more consistent auditory and visual signals, may support safer behaviour. Examples include in-ground lighting or downward-directed lights targeting pedestrians looking at their phones, as well as clearer markings and signage indicating track layout and risk zones. While pavement icons have shown limited long-term effects (Barin et al., 2018; Violano et al., 2015), in-ground lighting has been shown to increase compliance even among distracted pedestrians (Larue et al., 2021; Sobhani et al., 2017). However, the effects of such measures should be further investigated through intervention studies comparing conditions before and after implementation.

Some limitations of the study should be acknowledged. First, all observations were conducted in a single city, which limits the generalizability of the findings. Future studies should therefore include a wider range of geographical locations and larger samples to enable broader generalization and to better isolate the effects of specific design features. Second, demographic characteristics were assessed visually by a single observer, which may have reduced the accuracy of categorization; however, the overall trends are likely to remain robust despite potential classification imprecision. Finally, the need to record multiple behavioural variables simultaneously may have increased the risk of recording errors or omissions. Future research could address this limitation by incorporating video recordings and multiple observers.

To conclude, digital distraction is widespread in tram crossing environments in Gothenburg and is associated with more hazardous pedestrian behaviour, particularly among individuals visually engaged with their mobile phones. These findings highlight the need for targeted design and infrastructural interventions to mitigate safety risks in increasingly distraction-prone urban settings.

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