

Review

Enhancing Pedestrian Safety through Infrastructure, Behavioral, and Technological Interventions: A Structured Review of Urban Transportation Safety Measures

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Received: 9 March 2026; **Revised:** 14 May 2026; **Accepted:** 29 May 2026; **Published:** 5 June 2026

Abstract: Pedestrian safety remains a major transportation concern as urbanization, motorized traffic growth, and increasing roadway complexity continue to increase pedestrian crashes and injury risks. This study presents a structured review of pedestrian safety interventions by synthesizing findings from 44 studies related to infrastructure-based treatments, behavioral factors, technological applications, and demographic influences. The review focuses on Pedestrian Countdown Timers (PCTs), Pedestrian Crossing Signals (PCS), pavement markings, traffic signs, traffic calming measures, distracted pedestrian and driver behavior, and age-related safety differences. A conceptual framework was developed to organize the reviewed literature around three interacting dimensions: infrastructure-based interventions, behavioral factors, and traffic environment conditions. The findings indicate that traffic calming and speed management measures provide the most consistent safety benefits by reducing vehicle speeds, improving driver yielding behavior, and lowering crash severity. PCTs generally improve pedestrian decision-making and reduce uncertainty at crossings, while PCS show mixed effects because their effectiveness depends on signal timing, pedestrian compliance, driver response, traffic volume, and intersection complexity. Pavement markings and traffic signs improve visibility and guidance, but their performance varies by roadway type, lighting condition, maintenance quality, and traffic environment. Behavioral factors, particularly mobile phone distraction and driver inattention, remain critical challenges that can reduce the effectiveness of infrastructure-based treatments. The review concludes that pedestrian safety is best addressed through integrated, context-specific strategies that combine engineering measures, behavioral interventions, technological applications, and planning approaches. These findings provide practical guidance for transportation planners, policymakers, and safety professionals seeking to reduce pedestrian injuries and fatalities in urban environments.

Keywords: Pedestrian Safety; Pedestrian Countdown Timers; Pedestrian Crossing Signals; Pavement Markings; Traffic Calming; Driver Behavior; Distracted Pedestrians

1. Introduction

Rapid urbanization has increased pressure on transportation systems and has made pedestrian safety a major concern in urban areas. Approximately 68% of the world's population is expected to live in cities by 2050 [1]. This

growth is associated with increased motorized travel, traffic congestion, pollution, and greater exposure of pedestrians to crash risk [2]. Therefore, transportation systems must support sustainable mobility while also improving pedestrian safety. Pedestrians are among the most vulnerable road users because they are not protected by the physical barriers available to vehicle occupants. Global traffic fatality data show that pedestrians account for about 23% of all road deaths, which reflects their high risk of injury and death in roadway environments [3]. In the United States, pedestrian fatalities increased from 5,925 in 2015 to 8,008 in 2022, showing the urgent need for effective and targeted safety interventions.

Pedestrian safety is influenced by several factors, including roadway design, traffic conditions, driver behavior, pedestrian behavior, and perceived safety. Previous research has shown that perceived safety affects travel choices and can discourage walking and bicycling when road users view the transportation environment as unsafe. Weather, infrastructure quality, traffic congestion, and roadway conditions also influence pedestrian comfort, risk perception, and mobility decisions [4]. Therefore, pedestrian safety should be examined not only through crash outcomes. It should also be understood through the interaction between infrastructure, human behavior, and the traffic environment.

A wide range of interventions has been used to improve pedestrian safety, but their effectiveness varies across locations and traffic conditions. Pedestrian Countdown Timers (PCTs) and Pedestrian Crossing Signals (PCS) have received considerable attention because they can influence crossing decisions, pedestrian compliance, and vehicle-pedestrian conflicts [5,6]. Some studies have reported that these signal-based interventions improve pedestrian safety and reduce pedestrian-vehicle crashes, while others have found limited benefits or potential adverse effects under certain conditions [7,8]. Physical infrastructure improvements, including traffic calming measures, pedestrian-priority signs, enhanced pavement markings, improved crossing visibility, raised crosswalks, curb extensions, and pedestrian refuge islands, have also been used to reduce vehicle speeds, improve driver yielding, and increase pedestrian visibility [9,10]. These findings suggest that pedestrian safety interventions can be effective, but their performance depends strongly on local roadway and traffic conditions.

Infrastructure and signal-based treatments alone may not fully address pedestrian safety challenges. Human behavior remains a critical factor, particularly when pedestrians or drivers are distracted. Mobile phone use can reduce pedestrian attention to traffic conditions and signal indications, increasing the likelihood of unsafe crossing decisions. Driver inattention can also reduce yielding behavior and increase conflict risk. These behavioral factors may weaken the effectiveness of otherwise well-designed infrastructure. Age, risk perception, compliance, and decision-making ability further influence how pedestrians and drivers respond to safety treatments. For this reason, pedestrian safety requires an integrated understanding of engineering measures, behavioral factors, and traffic environment conditions.

Although many studies have examined individual pedestrian safety treatments, the evidence remains fragmented across intervention types, roadway contexts, and user groups. Signal-based treatments, pavement markings, traffic signs, traffic calming measures, and behavioral interventions are often evaluated separately, even though their effectiveness depends on how they interact with one another. For example, a crossing treatment may improve pedestrian visibility, but its safety benefit may be limited if vehicle speeds remain high or if drivers fail to yield. Similarly, signal-based interventions may support safer crossing decisions, but their effectiveness can vary based on signal timing, driver response, pedestrian compliance, traffic volume, and intersection complexity. This fragmented evidence makes it difficult for transportation planners and safety professionals to determine which interventions provide consistent benefits and which require context-specific application.

To address this gap, this study provides a structured review of pedestrian safety interventions by synthesizing evidence from 44 studies. The review focuses on Pedestrian Countdown Timers (PCTs), Pedestrian Crossing Signals (PCS), pavement markings, traffic signs, traffic calming measures, distracted pedestrian and driver behavior, technological applications, and age-related safety differences. The main objectives of this study are to:

1. Synthesize existing evidence on major pedestrian safety interventions used in urban transportation environments.
2. Evaluate the safety effects of signal-based interventions, including PCTs and PCS, on pedestrian crossing behavior, compliance, and crash risk.
3. Assess the role of pavement markings, traffic signs, and traffic calming measures in improving pedestrian visibility, driver yielding behavior, and speed management.

4. Examine how behavioral and demographic factors, including pedestrian distraction, driver inattention, age, risk perception, and decision-making, influence pedestrian safety outcomes.
5. Develop an integrated framework and practical guidance to support context-specific, evidence-based pedestrian safety planning.

To support these objectives, this study develops a conceptual framework that organizes the reviewed literature into three interacting dimensions: infrastructure-based interventions, behavioral factors, and traffic environment conditions. As shown in **Figure 1**, infrastructure-based interventions include signal systems, pavement markings, traffic signs, traffic calming measures, and roadway design modifications. Behavioral factors include pedestrian decision-making, distraction, risk perception, compliance, driver yielding behavior, and driver distraction. Traffic environment conditions include traffic volume, vehicle speed, intersection geometry, roadway characteristics, and urban context.

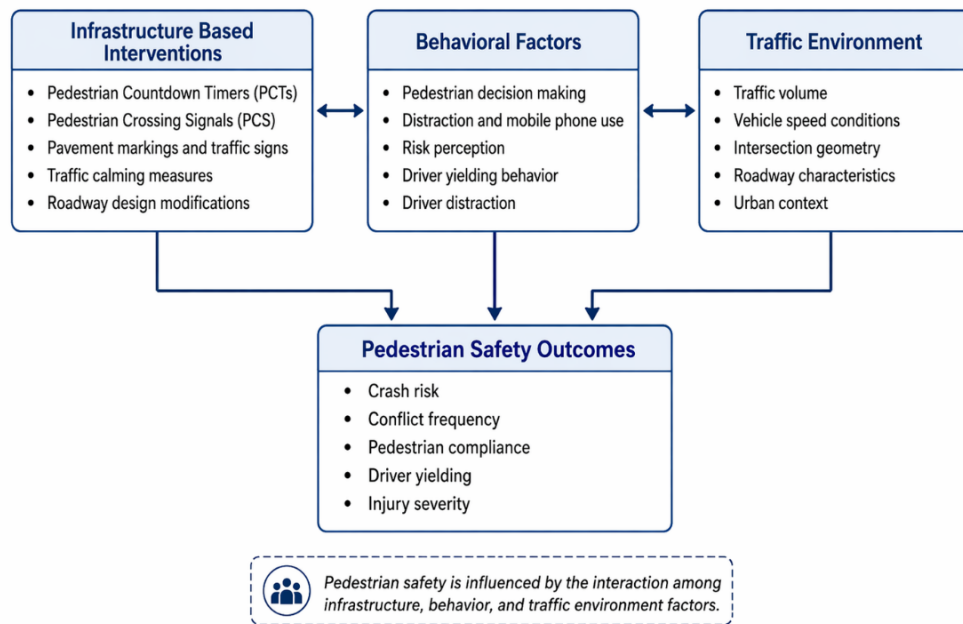


Figure 1. Conceptual framework of factors influencing pedestrian safety outcomes.

Pedestrian safety outcomes are shaped by the interaction among these dimensions rather than by a single intervention. For example, signal-based treatments may improve crossing decisions, but their effectiveness depends on pedestrian compliance, driver response, signal timing, and intersection complexity. Similarly, traffic calming measures can reduce vehicle speeds and improve driver yielding, but their safety benefits may vary depending on roadway design and traffic volume. Distracted pedestrian behavior and driver inattention can also reduce the effectiveness of otherwise well-designed infrastructure.

This framework provides the basis for interpreting why similar interventions may produce different outcomes across different urban settings. By organizing the analysis around infrastructure, behavior, and traffic environment conditions, the study provides a more integrated understanding of pedestrian safety and supports the development of context-specific safety strategies.

2. Methodology

This study used a structured literature review approach to examine pedestrian safety interventions in urban transportation environments. The review focused on Pedestrian Countdown Timers (PCTs), Pedestrian Crossing Signals (PCS), pavement markings, traffic signs, traffic calming measures, pedestrian and driver distraction, and age-related safety factors. Relevant studies were identified through Google Scholar, ScienceDirect, Transportation Research International Documentation (TRID), and other academic databases using keywords such as pedestrian

safety, pedestrian countdown timers, pedestrian crossing signals, traffic calming, speed management, pavement markings, traffic signs, distracted pedestrians, driver behavior, pedestrian injury severity, pedestrian crash risk, and urban pedestrian safety.

The literature identification and screening process was guided by PRISMA principles to improve transparency. As shown in **Figure 2**, 142 records were identified through database searching and 18 additional records were identified through manual reference screening, resulting in 160 records. After removing 24 duplicates, 136 records were screened by title and abstract. Seventy records were excluded because they were outside the scope of the review or did not address pedestrian safety interventions and outcomes. The full texts of 66 studies were assessed for eligibility, and 22 were excluded because they did not focus on pedestrian crossing safety, lacked intervention-specific findings, had insufficient methodological detail, or did not report relevant safety outcomes. A final set of 44 studies was included in the qualitative synthesis.

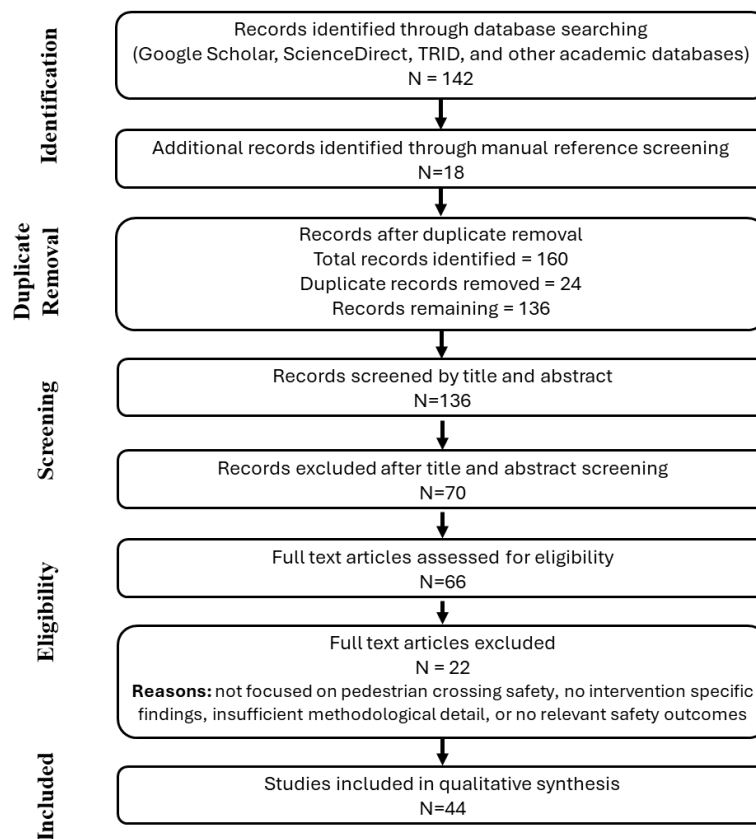


Figure 2. PRISMA-guided literature identification and selection process.

Studies were included if they evaluated pedestrian safety outcomes using empirical, observational, experimental, simulation-based, or modeling approaches. Relevant outcomes included crash reduction, conflict reduction, pedestrian compliance, driver yielding behavior, vehicle speed reduction, crossing behavior, and injury severity. Studies were excluded if they did not directly examine pedestrian safety, lacked relevant outcome measures, or focused only on general transportation behavior.

Key information was extracted from each study, including study design, intervention type, method, study context, safety outcomes, and major findings. The studies were grouped into major categories, including signal-based interventions, pavement markings and traffic signs, traffic calming and speed management measures, behavioral factors, technological interventions, and demographic factors. Because the reviewed studies differed in design, context, and outcome measures, a formal meta-analysis was not conducted. Instead, the findings were synthesized qualitatively and interpreted using the conceptual framework developed in this study.

3. Results and Discussions

3.1. Impact of PCTS and PCS

This section summarizes key studies evaluating the impact of Pedestrian Countdown Timers (PCTs) and Pedestrian Crossing Signals (PCS) on pedestrian safety. The studies presented in **Table 1** examine how these signal-based interventions influence pedestrian behavior, compliance, and crash outcomes under different traffic and environmental conditions. The findings highlight both the safety benefits and the context-dependent limitations of these devices, reflecting variations in user behavior, signal design, and roadway characteristics.

Table 1. Impact of PCT and PCS on Pedestrian Safety.

Study	Intervention	Method	Key Findings	Effect Type
Huitema et al., 2014 [6]	PCT	Time-series intervention analysis	70% decrease in pedestrian accidents at treatment sites with PCTs; minimal change at control sites.	Positive
Schmitz, 2011 [11]	PCT	Before-and-after case study	PCTs increased pedestrian walking speeds and decreased the probability of pedestrian violations at certain intersections.	Positive
Brisbane et al. [12]	PCT	Observational video surveys	PCTs increased the proportion of pedestrians starting during the Flashing Don't Walk phase, reducing overall compliance but perceived safer by pedestrians.	Mixed
Huang and Zegeer, 2000 [7]	PCS	Treatment-control study design	PCS prevented running during flashing "Don't Walk" but decreased adherence to the "Walk" signal. Positive and negative impacts on pedestrian behavior.	Mixed
Pulugurtha et al., 2010 [8]	PCS	Before-and-after methodology	Statistically negligible drop in vehicle-pedestrian crashes but significant decrease in total crashes after PCS installation.	Mixed
Camden et al., 2012 [9]	PCS	Quasi-experimental study design	No significant reduction in pedestrian-motor vehicle collisions after PCS installation in Toronto.	Negative
Eccles et al., 2004 [5]	PCS	Before-and-after observational design	No significant negative effects on pedestrian behavior or vehicle approach speeds; a significant decrease in conflicts at some intersections after PCS installation.	Positive
Nambisan and Karkee, 2010 [10]	PCS	Before-and-after study design	No significant impact on vehicle speeds during the pedestrian clearance interval after PCS installation.	Negative
Do et al., 2023 [13]	PCS	Video-based vehicle trajectory data analysis	PCS visibility led to higher vehicle speeds and more severe vehicle conflicts at intersections.	Negative
Kim et al., 2002 [14]	PCS	Before-and-after study design	Increase in late crossings and pedestrians caught during "Don't Walk"; no significant impact on safety was observed with PCS.	Negative
Schattler et al., 2007 [15]	PCS	Evaluation of pedestrian compliance	PCS significantly improved pedestrian compliance at signalized intersections, but did not affect red or yellow light running.	Mixed
Supernak et al., 2013 [16]	PCS	Detailed crossing behavior analysis	PCS is effective in reducing "exit violations" at busy intersections; less effective for "entry violations" at quieter intersections.	Mixed
Richmond et al., 2014 [17]	PCS	Re-analysis of quasi-experimental data	PCS is associated with a 7.5% increase in pedestrian-motor vehicle collisions, suggesting unintended negative effects on driver behavior.	Negative

Installing PCTs has been shown to improve pedestrian safety and reduce pedestrian crashes by up to 70%, while also increasing the walking speeds of pedestrians [6]. Studies show that these devices inform pedestrians of the remaining time available to cross, allowing them to make more informed decisions and complete crossings more efficiently. PCTs provide real time information on remaining crossing time, which helps pedestrians make safer and more timely crossing decisions. These devices also enhance pedestrian decision-making and reduce uncertainty at intersections by providing clear temporal information [6,11].

However, some studies found that pedestrians begin crossing during the flashing "Don't Walk" phase, which may increase the chances of conflicts and reduce pedestrian safety. This behavior can be explained by the sense of urgency created by countdown displays, which may encourage risk taking decisions under time pressure. Even with this limitation, the overall findings suggest that PCTs generally provide safety benefits in many urban settings [12].

The findings on the impact of Pedestrian Crossing Signals (PCS) are more complex and context dependent. Studies found that pedestrians may start running during the flashing "Don't Walk" signal, increasing the likelihood of unsafe crossings [7,15]. Other studies concluded that PCS do not significantly reduce pedestrian crashes due to reduced adherence to signal indications [9,14,18]. Another study found that installing PCS increased pedestrian motor vehicle collisions by 7.5%, further highlighting the variability in outcomes [17].

These mixed results can be explained by the interaction between pedestrian behavior, driver response, and traffic flow conditions. For example, countdown signals may influence pedestrian expectations regarding available crossing time, while drivers may respond by accelerating to clear the intersection before the signal changes, increasing conflict severity. In high traffic volume or complex intersections, these interactions become more pronounced,

reducing the effectiveness of PCS. This indicates that the safety performance of PCS cannot be evaluated independently of the surrounding roadway and traffic environment.

The results of these studies indicate that installing PCTs generally enhances pedestrian safety by reducing pedestrian vehicle crashes and improving compliance. However, the success of PCS depends on its implementation and integration within specific urban contexts. Factors such as signal timing design, pedestrian clearance intervals, traffic volume, intersection geometry, and local behavioral patterns play a critical role in determining their effectiveness. Therefore, PCS installation must be carefully planned and designed to maximize pedestrian safety, ensuring that local traffic patterns and pedestrian behavior are adequately considered. Key design considerations include optimizing pedestrian clearance intervals based on crossing distance and walking speed, ensuring high signal visibility under different lighting conditions, and coordinating signal timing with traffic flow to minimize conflicts. In addition, high risk locations such as multi lane or high speed intersections may require complementary measures such as advance stop lines, improved lighting, and traffic calming strategies.

Figure 3 provides a visual summary of these pathways by showing how PCTs and PCS influence pedestrian safety through pedestrian decision making, driver response, and intersection conditions. In cases where only negligible reductions in pedestrian crashes were observed, the limited effectiveness can be attributed to factors such as reduced pedestrian compliance, inadequate signal timing, and varying traffic conditions, which influence how both pedestrians and drivers respond to the intervention.

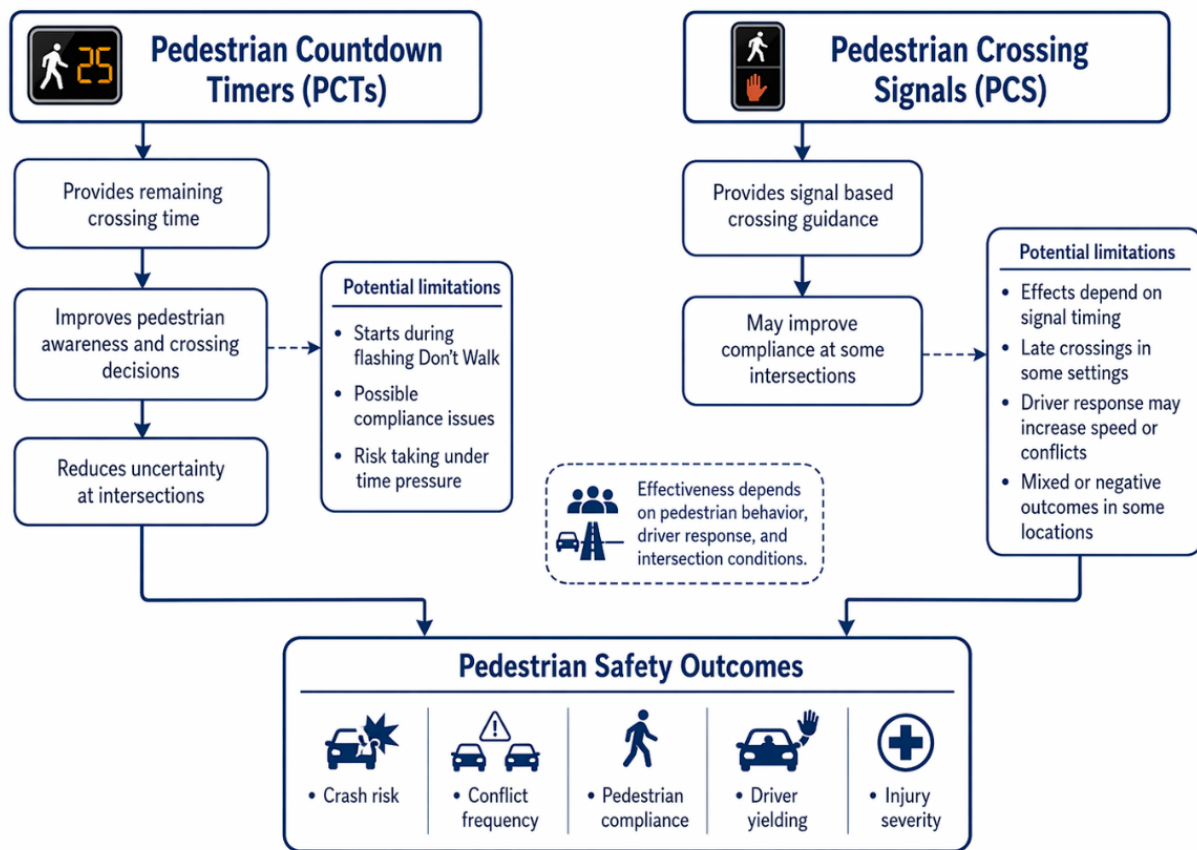


Figure 3. Pathways through which PCTs and PCS influence pedestrian safety.

3.2. Impact of Pavement Markings and Traffic Signs

This section summarizes key studies evaluating the impact of pavement markings and traffic signs on pedestrian safety. These interventions primarily aim to improve visibility, guide driver and pedestrian behavior, and reduce vehicle speeds under different roadway conditions. The studies included in **Table 2** examine various mark-

ing designs, signage strategies, and roadway modifications, highlighting both their effectiveness and limitations across different traffic environments.

Table 2. Impact of pavement markings and traffic signs.

Study	Intervention/Method	Key Findings
Smadi et al., 2010 [19]	Logistic regression analysis	Significant effect of decreased pavement marking retro-reflectivity on increasing crash probability, especially on interstate highways and certain line types.
Park et al., 2019 [20]	Empirical Bayes and Full Bayes before-after analysis	Positive safety effects of wet-weather pavement markings, significant reductions in wet-night crashes, and fatal injury crashes.
Zegeer et al., 2001 [21]	Analysis of pedestrian crash data	Higher pedestrian crash rates at marked crosswalks on multi-lane roads with high traffic compared to unmarked; marked crosswalks may give false security.
Huybers et al., 2004 [18]	Experimental design with sign prompts and markings	Sign prompts significantly reduced vehicle-pedestrian conflicts; a combination of pavement markings and signs is most effective.
Guo et al., 2016 [4]	Study on parallelogram-shaped pavement markings	Markings significantly reduced vehicle speeds and crashes at pedestrian crosswalks, though further study is recommended.
Agent, 1980 [22]	Application of transverse pavement markings	Effective reduction in accidents and vehicle speeds at a high-accident curve, very favorable benefit-cost ratio.
Pulugurtha et al., 2010 [23]	Evaluation of traffic signs	Significant improvements in driver-yielding behavior and pedestrian safety due to various signage interventions at intersections and midblock locations.
Hussain et al., 2023 [24]	Driving simulator study on multiple treatments	Physical road narrowing is most effective in improving driver-yielding rates and reducing vehicle-pedestrian conflicts. Other ITS and marking treatments also improved the yield rates.
Vignali et al., 2020 [25]	A before-and-after study on crosswalk visibility	Repositioned zebra crosswalk markings, installation of median refuge islands, and addition of "Yield Here to Pedestrians" signs improved crosswalk visibility, increased driver visual attention distance, and reduced vehicle speeds, enhancing pedestrian safety at roundabouts.
Kang, 2019 [26]	Analysis of street design components	Pedestrian refuge islands and plazas linked with significant decreases in pedestrian collisions; mixed results with other street design changes.
Strong and Ye, 2010 [27]	Observational study on yield-to-pedestrian devices	Positive spillover effects on pedestrian safety at junctions, negative effects at mid-block locations; overall positive impact on behavior.
Chen et al., 2013 [28]	Quasi-experimental design on safety countermeasures	Signal-related countermeasures such as split-phase timing, pedestrian signal installation, all-pedestrian phases, and extended crossing times significantly reduced crashes. Traffic calming measures, including road diets, also showed strong safety benefits, while attention-based measures such as high-visibility crosswalks and speed limit signs showed comparatively lower effectiveness.

Pavement markings and traffic signs play a vital role in enhancing pedestrian safety, and extensive research has been conducted to evaluate their effectiveness under different traffic conditions. Studies found that retro reflectivity has an inverse relationship with crash risk. As the retro reflectivity of pavement markings decreases, driver visibility is reduced, particularly during night time or low light conditions, which increases the likelihood of crashes. This effect is more pronounced on high speed and high volume roads such as interstate highways [19]. Another study found that wet night crashes and fatal injury crashes can be significantly reduced by wet weather pavement markings, which are specifically designed to improve visibility under severe weather conditions [20].

Innovative designs like transverse pavement markings and parallelogram shaped markings can reduce vehicle speed and thus reduce the risk and severity of a crash, especially near pedestrian crosswalks or curves with elevated crash risk [4,22]. Similarly, narrowing the road near pedestrian crossings can significantly improve driver yielding behavior, thereby reducing the risk of pedestrian vehicle crashes. This improvement can be explained by changes in driver perception, as narrower lanes create a visual constraint that encourages drivers to slow down and exercise greater caution.

These findings indicate that proper design of signage and roadway geometry can enhance pedestrian safety while also contributing to traffic calming. The effectiveness of these measures is largely driven by their ability to improve visibility, influence driver behavior, and reduce vehicle speeds simultaneously [10,23,24]. Integrating safety features into urban design also enhances pedestrian safety and reduces crash risk. These include pedestrian refuge islands, plazas, and traffic-calming measures such as road diets, which have been shown to reduce conflicts and improve safety, while other design changes may produce mixed results depending on the context [26,28].

Traffic calming and speed management further strengthen the effectiveness of pavement markings and signage by directly controlling vehicle speeds. Measures such as speed humps, raised crosswalks, curb extensions, and reduced speed zones are widely recognized as effective and low-cost strategies. Lower vehicle speeds reduce stopping distance and improve driver reaction time, thereby decreasing both crash risk and injury severity. These measures are particularly effective in areas with high pedestrian activity, such as residential zones, school areas, and urban centers, where they complement visibility-based interventions and enhance overall safety outcomes. **Figure 4** summarizes the main pathways through which pavement markings, traffic signs, and related design measures influence pedestrian safety outcomes.

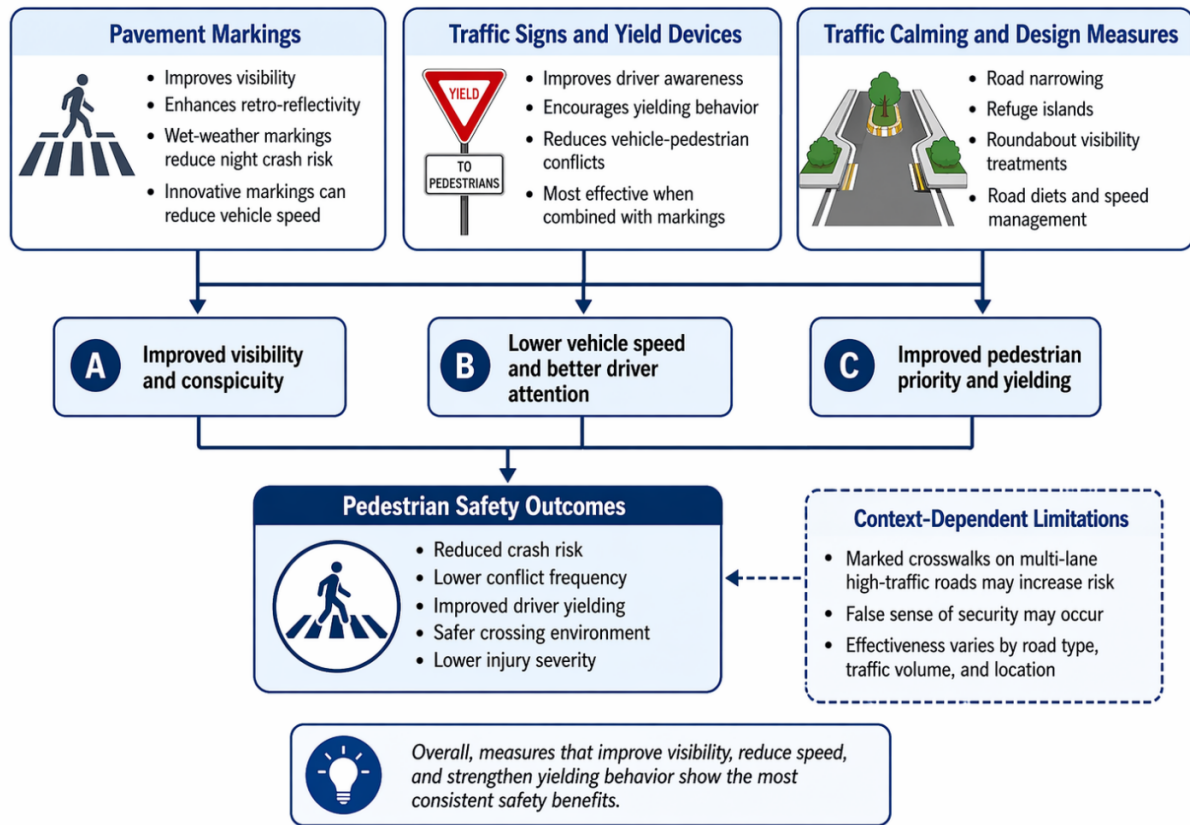


Figure 4. Conceptual pathways linking pavement markings, traffic signs, and traffic calming measures to pedestrian safety outcomes.

However, certain studies showed adverse effects of marked crosswalks. Providing marked crosswalks on multi-lane roads with high traffic density can increase crash risk and adversely affect pedestrian safety because pedestrians may develop a false sense of security and assume that drivers will always yield [21]. In such situations, limited driver visibility and higher vehicle speeds increase the likelihood of conflicts, especially when multiple lanes are involved. In contrast, providing crosswalks with enhanced visibility near roundabouts can significantly reduce crashes and improve pedestrian safety [25]. This is mainly due to lower vehicle speeds, simplified traffic flow, and improved driver awareness in roundabout environments. At roundabouts, vehicles are required to decelerate while entering and circulating, which reduces approach speeds and provides drivers with more time to detect pedestrians. In addition, the geometric design of roundabouts reduces conflict points and often separates pedestrian crossings from the main circulating flow, allowing drivers to focus on fewer simultaneous tasks. Enhanced visibility treatments further improve early detection of pedestrians, increasing yielding behavior and reducing the likelihood of severe conflicts.

From the above discussion, it is clear that traffic signs, pavement markings, and other safety measures can significantly enhance pedestrian safety. Their effectiveness depends on design, implementation, and traffic conditions. Measures that improve visibility, reduce vehicle speed, and strengthen driver yielding behavior appear to provide the most consistent safety benefits. Evaluation and adaptation of these measures should be done continuously to respond to changes in the urban traffic environment and to enhance the safety of pedestrians and other road users.

3.3. Impact of Distraction and Behavioral Factors on Pedestrian Safety

This section summarizes key studies examining the impact of distraction and behavioral factors on pedestrian safety. The studies presented in **Table 3** focus on both pedestrian and driver behavior, including mobile phone use, psychological factors, and situational influences that affect crossing decisions and crash risk. These findings high-

light how human behavior interacts with traffic conditions and infrastructure, influencing overall safety outcomes.

Table 3. Impact of Distraction and Behavioral Factors on Pedestrian Safety.

Study	Intervention/Method	Key Findings
Hossain et al., 2024 [29]	Association rule mining of crash data	Identified complex relationships in distracted pedestrian crashes, highlighting higher severity for certain demographics and conditions, and specific distraction-related tasks linked to different crash settings.
Krishna et al., 2024 [30]	Field experiment with eye-tracking at an intersection	Mobile phone usage increased risk of unsafe pedestrian-vehicle interactions by eight times. Pedestrian speed and visual behavior also significantly influenced safety.
Wang et al., 2024 [31]	Video analysis and statistical models	Mobile phone usage significantly affected pedestrian crossing speed and safety, with screen-based activities being particularly detrimental. Age, companion presence, and traffic environment also influenced behavior.
Yadav et al., 2023 [32]	Survey on pedestrian beliefs and psychological factors	Mobile phone addiction and boredom proneness were significantly associated with pedestrians' beliefs about mobile phone distraction, suggesting targeted interventions could reduce distracted walking.
Sheykhfard et al., 2023 [33]	Real-world driving data analysis	Talking with passengers significantly impaired driver yielding behavior near pedestrian crossings, suggesting the need for targeted interventions like awareness campaigns and infrastructure improvements.
Arafat et al., 2023 [34]	Comparison of in-ground lights and a mobile app	In-ground flashing lights significantly outperformed a mobile app in reducing pedestrian distraction and improving safety, providing evidence-based guidance for urban planning and pedestrian safety enhancements.
Khan and Habib, 2022 [35]	Latent segmentation-based ordered logit model	Built environment and distracted driving types significantly influenced pedestrian injury severity, providing insights for developing targeted safety interventions and policy measures.
O'Dell et al., 2022 [36]	Application of the Theory of Planned Behaviour	Perceived behavioral control was a significant predictor of distracted pedestrians' intentions to cross roads, with marked crossings influencing these feelings. Interventions should focus on enhancing control perceptions at crossings.
Zhu et al., 2022 [37]	Development of motion planning models for automated cars	New AV models tested for preventing crashes with distracted pedestrians showed a hybrid model combining rule-based and learning-based approaches was most effective in ensuring safety and efficiency at crosswalks.
Schwebel et al., 2022 [38]	Observational study on distracted pedestrian behavior	Distraction varied significantly by urban setting, with the highest incidence near college campuses. Findings suggest interventions should be context-specific to effectively reduce pedestrian distraction.
Ralph and Girardeau, 2020 [39]	Survey of transportation practitioners	Concern about distracted walking varied based on personal and professional backgrounds, influencing support for different types of policy solutions. While practitioners concerned about distraction tended to favor educational campaigns, the study emphasizes that safety efforts should instead prioritize major risk factors and more effective systemic interventions such as speed reduction.
Cox et al., 2023 [40]	Nationwide survey of U.S. drivers	High prevalence of distracted driving, particularly among specific demographics. Findings highlight the need for targeted interventions to reduce risky behaviors associated with modern technology use while driving.

Distracted pedestrian behavior has been identified as a significant contributor to pedestrian crashes, particularly due to the increasing use of mobile phones in urban environments. Studies show that pedestrians who are distracted by mobile phones tend to have slower crossing speeds and reduced situational awareness, which significantly increases the likelihood of unsafe interactions with vehicles. For example, mobile phone usage has been found to increase the risk of pedestrian-vehicle conflicts by up to eight times compared to non-distracted pedestrians [30,31].

The underlying mechanism behind this increased risk is reduced visual scanning and delayed decision-making, which limits the pedestrian's ability to accurately judge traffic gaps and respond to approaching vehicles. In addition, pedestrians who are addicted to mobile phones or prone to boredom are more likely to engage in distracted behavior, further increasing crash risk [32]. These behavioral tendencies highlight the role of psychological factors in influencing pedestrian safety. They also show that distraction related risk is shaped not only by momentary inattention, but also by broader behavioral and psychological characteristics.

The level of distraction also varies across different urban environments. Studies indicate that distraction rates are highest near college campuses and high-activity urban areas, where mobile phone usage is more prevalent [38]. This suggests that the effectiveness of safety interventions is highly context-dependent and should be tailored to specific environments and user groups.

In addition to pedestrian behavior, driver behavior plays an equally critical role in pedestrian safety. Drivers who are distracted, such as those engaged in conversations with passengers or using mobile devices, are less likely to yield at pedestrian crossings and more likely to be involved in conflicts [33]. This interaction between distracted pedestrians and distracted drivers significantly increases crash risk, as both parties may fail to respond appropriately in critical situations. **Figure 5** summarizes the pathways through which distraction and behavioral factors influence pedestrian safety, as well as the intervention strategies that may reduce risk.

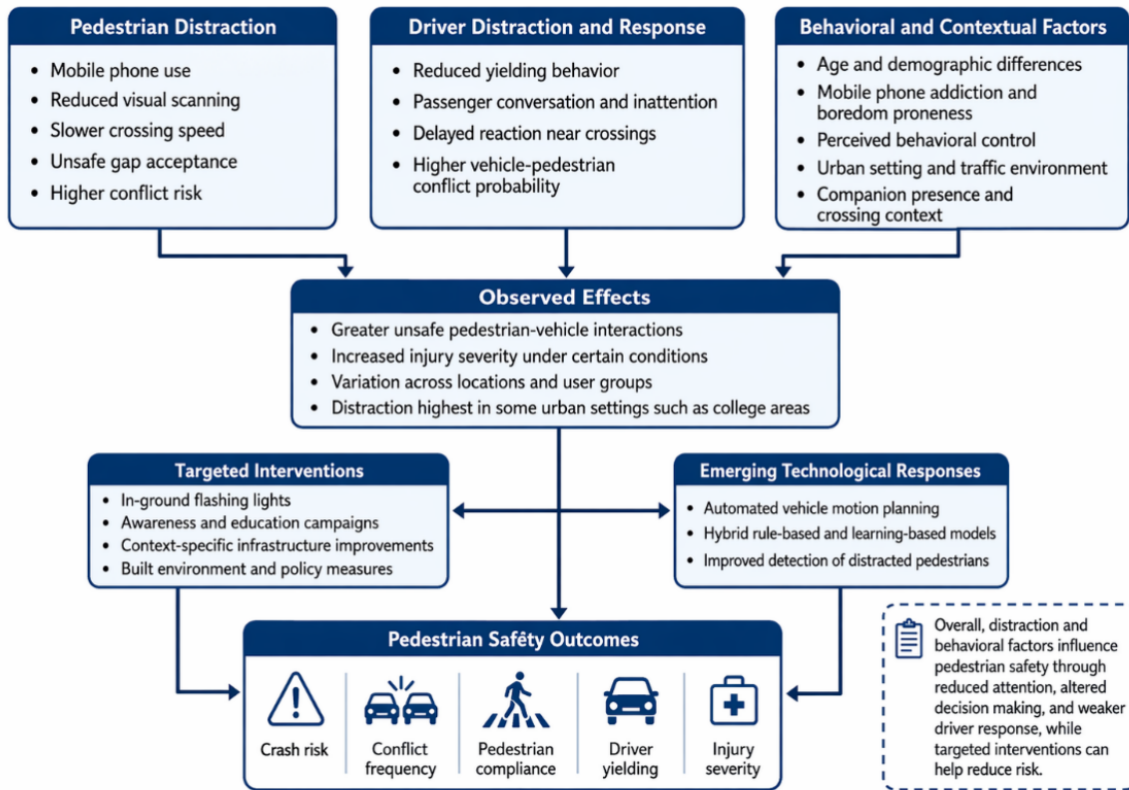


Figure 5. Pathways through which distraction and behavioral factors influence pedestrian safety outcomes.

To address these issues, comprehensive strategies are required. Behavioral interventions such as awareness campaigns and targeted education can help reduce distraction, but they are most effective when combined with infrastructure-based solutions. For example, in-ground flashing lights have been shown to effectively capture pedestrian attention and reduce distraction-related risks at crossings [34]. Similarly, improvements in the built environment and roadway design can guide safer behavior and compensate for human limitations.

Technological approaches also offer promising solutions. Advanced systems, including automated vehicle technologies that integrate rule-based and learning-based models, can detect and respond to distracted pedestrians, thereby reducing crash risk and improving safety outcomes [37]. These findings suggest that technology can serve as an important complementary tool, particularly in environments where distraction related risks are high.

The findings highlight that distracted behavior is a critical factor affecting pedestrian safety. However, its impact is not isolated and is strongly influenced by the interaction between pedestrian behavior, driver response, and traffic conditions. Therefore, improving pedestrian safety requires integrated, context-specific strategies that combine behavioral interventions, infrastructure design, and technological solutions to effectively reduce crash risk across different urban environments. This evidence suggests that distraction related safety problems are best addressed through coordinated approaches that target both human behavior and the surrounding traffic environment.

3.4. Impact of Age on Pedestrian and Driver Behavior and Safety

This section summarizes key studies examining the influence of age and psychological factors on pedestrian and driver behavior. The studies presented in **Table 4** analyze how different age groups vary in terms of risk perception, decision-making ability, and response to traffic conditions. These differences play a significant role in pedestrian safety and highlight the need for age-specific interventions and planning strategies.

Pedestrians of different age groups exhibit distinct behaviors while crossing the road. Wang et al. [41], using a virtual reality environment, found that children aged 10–13 years can navigate simple traffic conditions effectively,

but struggle in more complex situations, making them more prone to unsafe crossings and potential crashes. This suggests that children may act quickly but lack the ability to accurately interpret complex traffic environments. As traffic conditions become more demanding, their limited hazard assessment ability may increase exposure to unsafe crossing situations.

Table 4. Impact of age on pedestrian and driver behavior and safety.

Study	Intervention/Method	Key Findings
Wang et al., 2022 [41]	Virtual reality environment to study pedestrian behavior	Children (10–13 years) showed the shortest start delays in easy traffic conditions, but all age groups had more dangerous crossings in challenging conditions. High sensation-seeking individuals had riskier crossings but missed fewer opportunities.
Åbele et al., 2018 [42]	Driving simulator for different pedestrian scenarios	Young male drivers (18–24 years) were less likely to slow down and drive faster near child pedestrians than adults, despite similar initial fixation times, potentially increasing accident risks.
Arnett et al., 1997 [43]	Survey on high school students driving behaviors	The majority reported engaging in reckless driving, influenced by sensation seeking, aggressiveness, mood, and social context. Findings emphasize the role of state and trait factors in adolescent driving behaviors.
Biassoni et al., 2018 [44]	Eye-tracking technology in traffic scenarios	Adults displayed a more dynamic visual exploration strategy than children (5–6 years), who focused on fewer areas, potentially missing hazards. This suggests a need for training to enhance children's hazard perception.
Greene et al., 2000 [45]	Study on adolescent and college students' risk behaviors	High levels of egocentrism combined with sensation-seeking were strongly linked to risky behaviors such as drug use and risky driving. This underscores the importance of addressing developmental and personality factors in interventions.
Herrero-Fernández et al., 2016 [46]	Study on risk perception and pedestrian behavior	Risky pedestrian behaviors among young adults correlated with higher impulsiveness and lower conscientiousness. Risk perception, as measured by physiological arousal, also predicted risky behaviors.
Arnett, 1991 [47]	Study on young adults' reckless behaviors	High rates of recklessness were observed in driving and sexual behaviors among college-educated young adults (23–27 years). Sensation-seeking and risk perceptions influenced such behaviors. Married individuals reported less risky behavior.

Similarly, Åbele et al. [42] found through a driving simulator study that young male drivers aged 18–24 years are less likely to drive cautiously around child pedestrians compared to adults, increasing the risk of child-related crashes. High school students are influenced by aggressive emotions, sensation-seeking behavior, peer influence, and mood while driving, which leads to reckless driving and increases the likelihood of pedestrian crashes. Arnett et al. [43] highlighted that young drivers are more likely to take risks due to emotional and social influences. These findings indicate that both age and social behavioral influences contribute to unsafe interactions between drivers and pedestrians.

Biassoni et al. [44], using eye-tracking technology, found that adults exhibit more dynamic visual scanning behavior while crossing roads, whereas children tend to focus on limited areas, increasing their exposure to potential hazards. This indicates that children require targeted training to improve hazard perception and decision-making skills. The findings also suggest that differences in visual attention may partly explain why children are more vulnerable in complex traffic environments.

Herrero-Fernández et al. [46] reported that adolescents and young adults exhibit higher levels of risk-taking behavior, including unsafe driving practices and substance use, which can negatively affect pedestrian safety. These behavioral tendencies significantly increase the risk of pedestrian-related crashes and highlight the importance of addressing psychological and developmental factors. **Figure 6** summarizes the pathways through which age related and psychological factors influence pedestrian safety outcomes.

From the above discussion, it is clear that age groups play a vital role in pedestrian safety. Transportation planning should incorporate age-specific considerations by designing infrastructure and interventions that account for differences in perception, behavior, and decision-making across user groups. Before implementing PCTs, PCS, road markings, traffic signs, and other safety measures, transportation planners should consider both age-related characteristics and behavioral factors such as distraction, and support these interventions with education, community engagement, and appropriate policy measures. Such an integrated approach can enhance the safety of both pedestrians and drivers.

These differences in behavior can be explained by variations in cognitive development, risk perception, and decision-making ability across age groups. Younger pedestrians and drivers are more likely to engage in risk-taking behavior, while children may lack the ability to accurately assess traffic conditions and respond appropriately to complex traffic environments. The evidence suggests that pedestrian safety interventions are likely to be more effective when they are tailored to the behavioral and perceptual characteristics of specific age groups.

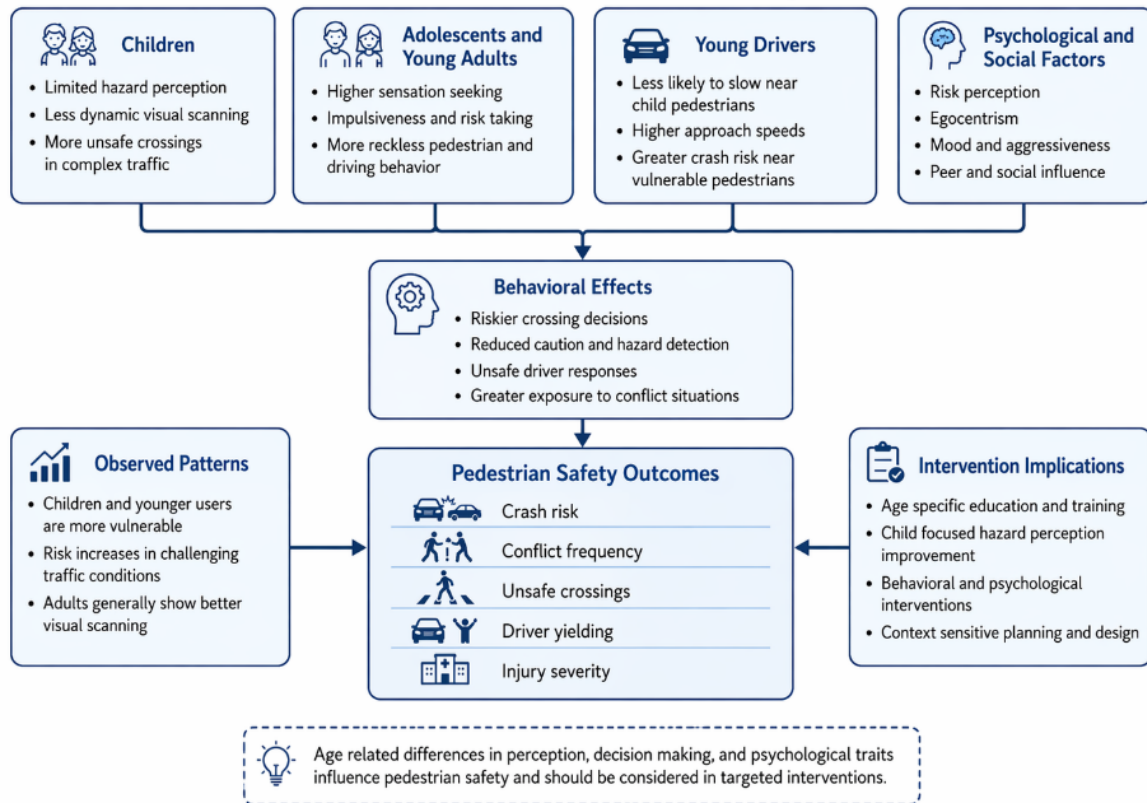


Figure 6. Pathways through which age related and psychological factors influence pedestrian safety outcomes.

4. Synthesis of Findings across Studies

To improve the interpretation of results across different studies, the findings were further synthesized using a combination of categorical and qualitative approaches. For signal-based interventions (**Table 1**), the reported outcomes were grouped into three categories: positive, mixed, and negative effects on pedestrian safety. Positive effects include reductions in crashes, conflicts, or improvements in pedestrian compliance and driver yielding behavior. Mixed effects refer to studies reporting both beneficial and adverse outcomes depending on context or location, while negative effects indicate no improvement or potential increase in risk.

This qualitative categorization allows for a more structured comparison of intervention effectiveness across different studies. However, due to variations in study design, data sources, evaluation methods, and outcome measures, a direct quantitative comparison or statistical synthesis was not feasible. The reviewed studies differ significantly in terms of geographic context, traffic conditions, and methodological approaches, which limits the ability to establish a unified quantitative standard.

Despite these limitations, the synthesis highlights consistent patterns. Traffic calming and speed management measures show relatively strong and consistent positive effects, while signal-based interventions such as PCTs and PCS demonstrate context-dependent outcomes. Behavioral factors, including pedestrian and driver distraction, also play a significant role in influencing safety outcomes. Findings from pavement markings, signage, and age-related studies were synthesized qualitatively, reflecting variations in effectiveness based on design, user behavior, and environmental conditions. **Figure 7** presents an integrated synthesis of these findings by grouping the major intervention categories according to their relative effectiveness, associated benefits, and key influencing factors. These findings provide a more consolidated understanding of the effectiveness of different interventions.

To provide a consolidated overview of the reviewed studies, **Table 5** summarizes the effectiveness, benefits, and limitations of major pedestrian safety interventions across infrastructure, behavioral, and technological dimensions.

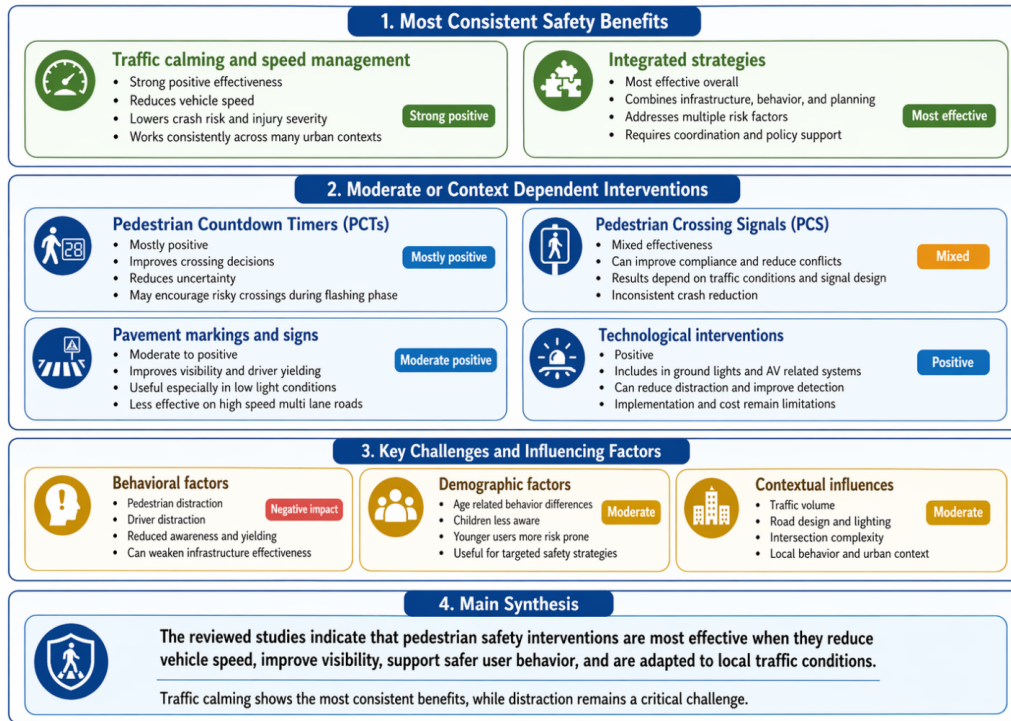


Figure 7. Integrated synthesis of pedestrian safety interventions, relative effectiveness, and key influencing factors across reviewed studies.

Table 5. Summary of Pedestrian Safety Interventions and Key Findings.

Category	Intervention Type	Overall Effectiveness	Key Benefits	Key Limitations	Influencing Factors
Signal-Based Interventions	Pedestrian Countdown Timers (PCTs)	Mostly Positive	Reduces crashes, improves crossing decisions, increases walking speed	May encourage risky crossings during flashing phase	Pedestrian behavior, signal timing, intersection complexity
Signal-Based Interventions	Pedestrian Crossing Signals (PCS)	Mixed	Improves compliance in some cases, reduces conflicts at busy intersections	Can increase risky crossings, inconsistent crash reduction	Traffic volume, driver response, signal design
Pavement Markings & Signs	Standard and Enhanced Markings	Moderate to Positive	Improves visibility, reduces crashes especially in low-light conditions	Limited effectiveness on high-speed multi-lane roads	Road type, lighting, maintenance quality
Pavement Markings & Signs	Traffic Signs and Yield Devices	Positive	Improves driver yielding behavior and reduces conflicts	Effectiveness varies by location (intersection vs midblock)	Driver awareness, placement, traffic conditions
Traffic Calming Measures	Speed humps, curb extensions, road diets	Strong Positive	Reduces speed, lowers crash severity, improves pedestrian safety consistently	May affect traffic flow if not properly designed	Road design, traffic density, urban context
Behavioral Factors	Pedestrian distraction (mobile use)	Negative Impact	Highlights need for targeted interventions	Increased crash risk, reduced awareness	Age, environment, psychological traits
Behavioral Factors	Driver distraction	Negative Impact	Identifies need for enforcement and awareness	Reduced yielding, increased conflict probability	Traffic conditions, driver workload
Technological Interventions	In-ground lights, AV systems	Positive	Reduces distraction, improves detection of pedestrians	Limited implementation and cost concerns	Technology adoption, infrastructure readiness
Demographic Factors	Age-related behavior differences	Mixed	Helps design targeted safety strategies	Younger users more risk-prone, children less aware	Cognitive ability, risk perception, experience
Integrated Strategies	Combined infrastructure + behavior	Most Effective	Addresses multiple risk factors simultaneously	Requires coordination and planning	Local context, policy support, urban design

The summary presented in **Figure 7** and **Table 5** highlights that traffic calming and speed management measures provide the most consistent safety benefits across different contexts. In contrast, signal based interventions

such as PCTs and PCS show variable effectiveness depending on user behavior and traffic conditions. Behavioral factors, particularly distraction, remain a critical challenge that can reduce the effectiveness of infrastructure based measures.

5. Implications of the Study

The findings of this review have practical implications for transportation planners, roadway engineers, policy-makers, and traffic safety professionals. The results show that pedestrian safety should not be addressed through isolated countermeasures. Effective safety planning requires an integrated approach that combines infrastructure design, speed management, traffic operations, and behavioral considerations. Traffic calming and speed management measures should be treated as foundational strategies, especially in school zones, residential areas, transit corridors, urban centers, and high-risk intersections. These measures directly reduce vehicle speeds, improve driver reaction time, increase yielding behavior, and lower crash severity.

The findings also indicate that signal-based treatments, pavement markings, and traffic signs should be implemented based on site-specific conditions. PCTs and PCS can improve pedestrian awareness and crossing decisions, but their effectiveness depends on signal timing, pedestrian clearance intervals, traffic volume, intersection geometry, pedestrian compliance, and driver response. Similarly, markings and signs can improve visibility and guidance, but they may provide limited benefits on high-speed or multi-lane roads unless supported by refuge islands, improved lighting, advance stop lines, raised crossings, or other speed reduction measures.

This review also highlights the need to incorporate human behavior into pedestrian safety programs. Pedestrian distraction, driver inattention, age-related differences, risk perception, and decision-making ability can reduce the effectiveness of well-designed infrastructure. Therefore, education, enforcement, awareness campaigns, and emerging technologies should complement engineering treatments. Transportation agencies should also monitor implemented countermeasures over time to evaluate their effects on crashes, conflicts, unsafe crossings, vehicle speeds, and driver yielding. This evidence-based and context-specific approach can help improve pedestrian safety, guide investment decisions, and support safer urban mobility.

6. Conclusions

This review shows that pedestrian safety interventions vary in effectiveness depending on infrastructure design, user behavior, traffic conditions, and roadway context. Traffic calming and speed management measures provided the most consistent safety benefits across the reviewed studies. These measures directly reduce vehicle speeds, improve driver reaction time, support yielding behavior, and lower the risk and severity of pedestrian crashes.

Signal-based interventions showed more mixed results. Pedestrian Countdown Timers (PCTs) generally improved pedestrian awareness, reduced uncertainty, and supported safer crossing decisions. However, Pedestrian Crossing Signals (PCS) produced context-dependent outcomes. Their effectiveness was influenced by signal timing, pedestrian compliance, driver response, traffic volume, and intersection complexity. These findings suggest that signal-based treatments should not be implemented as isolated measures. They should be supported by appropriate clearance intervals, high visibility, traffic calming, and location-specific design.

Pavement markings and traffic signs also contributed to pedestrian safety by improving visibility, guiding road users, and encouraging driver yielding. However, their effectiveness was not uniform across all roadway types. Marked crosswalks and signs may provide limited benefits on high-speed or multi-lane roads unless they are combined with complementary measures such as refuge islands, improved lighting, advance stop lines, raised crossings, or speed reduction treatments.

Behavioral factors remain a major challenge for pedestrian safety. Pedestrian distraction, driver inattention, age-related differences, risk perception, and decision-making ability can reduce the effectiveness of otherwise well-designed infrastructure. Therefore, pedestrian safety should be addressed through integrated strategies that combine engineering treatments, behavioral interventions, enforcement, education, and emerging technologies.

Based on the reviewed evidence, traffic calming and speed management should be prioritized in areas with high pedestrian activity, including school zones, residential areas, urban centers, and complex intersections. Signal-based interventions, pavement markings, and traffic signs should be implemented based on site-specific conditions

rather than applied uniformly. Transportation agencies should also conduct continuous monitoring after implementation to evaluate whether the selected treatments are improving safety outcomes.

This review highlights the need for context-specific pedestrian safety planning. Effective pedestrian safety strategies should connect infrastructure design, traffic operations, and human behavior. Such an integrated approach can help transportation planners, policymakers, and safety professionals reduce pedestrian crash risk, improve crossing safety, and support safer urban mobility.

Author Contributions

Conceptualization, K.A.N., A.K., W.A.K., and J.A.C.; methodology, K.A.N., A.K., W.A.K., and J.A.C.; project administration, K.A.N., A.K., W.A.K., and J.A.C.; formal analysis, K.A.N., A.K., W.A.K., and J.A.C.; supervision, J.A.C.; visualization, K.A.N., A.K., W.A.K., and J.A.C.; writing—original draft, K.A.N., A.K., and W.A.K.; writing—review and editing, K.A.N., A.K., W.A.K., and J.A.C. All authors reviewed the results and approved the final version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable. This study is a literature review and did not involve human participants, animal subjects, clinical records, or personally identifiable data.

Informed Consent Statement

Not applicable.

Data Availability Statement

This study is based on a structured review of previously published literature. No new primary data were collected or generated. The data and materials used in this study are available from the published articles cited in the manuscript.

Acknowledgments

The authors acknowledge the University of Louisiana at Lafayette for providing academic and research support.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

AI Use Statement

During the preparation of this manuscript, the authors used ChatGPT only for minor grammar correction, language polishing, and image generation support. ChatGPT was not used for data analysis, interpretation, literature synthesis, or generation of scientific content. All outputs were carefully reviewed and approved by the authors. The authors take full responsibility for the integrity and accuracy of the manuscript.

References

1. Economist Intelligence Unit. *Safe Cities Index 2019: Urban Security and Resilience in an Interconnected World*; Economist Intelligence Unit: London, UK, 2019.
2. Majumdar, B.B.; Mitra, S. Identification of factors influencing bicycling in small sized cities: A case study of Kharagpur, India. *Case Stud. Transp. Policy* **2015**, *3*, 331–346.
3. World Health Organization. *Global Status Report on Road Safety 2018*; World Health Organization: Geneva, Switzerland, 2019.

4. Guo, Y.; Liu, P.; Liang, Q.; et al. Effects of parallelogram-shaped pavement markings on vehicle speed and safety of pedestrian crosswalks on urban roads in China. *Accid. Anal. Prev.* **2016**, *95*, 438–447.
5. Eccles, K.A.; Tao, R.; Mangum, B.C. Evaluation of pedestrian countdown signals in Montgomery County, Maryland. *Transp. Res. Rec.* **2004**, *1878*, 36–41.
6. Huitema, B.E.; Van Houten, R.; Manal, H. Time-series intervention analysis of pedestrian countdown timer effects. *Accid. Anal. Prev.* **2014**, *72*, 23–31.
7. Huang, H.; Zegeer, C. *The Effects of Pedestrian Countdown Signals in Lake Buena Vista*; Florida Department of Transportation: Tallahassee, FL, USA, 2000.
8. Pulugurtha, S.S.; Desai, A.; Pulugurtha, N.M. Are pedestrian countdown signals effective in reducing crashes? *Traffic Inj. Prev.* **2010**, *11*, 632–641.
9. Camden, A.; Buliung, R.; Rothman, L.; et al. The impact of pedestrian countdown signals on pedestrian-motor vehicle collisions: A quasi-experimental study. *Inj. Prev.* **2012**, *18*, 210–215.
10. Nambisan, S.S.; Karkee, G.J. Do pedestrian countdown signals influence vehicle speeds? *Transp. Res. Rec.* **2010**, *2149*, 70–76.
11. Schmitz, J.N. The Effects of Pedestrian Countdown Timers on Safety and Efficiency of Operations at Signalized Intersections. Master's Thesis, University of Nebraska, Lincoln, NE, USA, 2011.
12. Brisbane, G.; Levasseur, M.; McTiernan, D. An Evaluation of Pedestrian Countdown Timers in the Sydney CBD. In Proceedings of the Australasian Road Safety Research, Policing and Education Conference 2011, Perth, Australia, 6–9 November 2011.
13. Do, W.; Saunier, N.; Miranda-Moreno, L. An empirical analysis of the effect of pedestrian signal countdown timer on driver behavior at signalized intersections. *Accid. Anal. Prev.* **2023**, *180*, 106906.
14. Kim, K.W.; Kim, Y.; Seo, H.Y. An evaluation of pedestrian countdown signals. *KSCE J. Civ. Eng.* **2002**, *6*, 533–537.
15. Schattler, K.L.; Wakim, J.G.; Datta, T.K.; et al. Evaluation of pedestrian and driver behaviors at countdown pedestrian signals in Peoria, Illinois. *Transp. Res. Rec.* **2007**, *2002*, 98–106.
16. Supernak, J.; Verma, V.; Supernak, I. Pedestrian countdown signals: what impact on safe crossing? *Open J. Civ. Eng.* **2013**, *3*, 39–45.
17. Richmond, S.A.; Willan, A.R.; Rothman, L.; et al. The impact of pedestrian countdown signals on pedestrian-motor vehicle collisions: A reanalysis of data from a quasi-experimental study. *Inj. Prev.* **2014**, *20*, 155–158.
18. Huybers, S.; Van Houten, R.; Malenfant, J.L. Reducing conflicts between motor vehicles and pedestrians: The separate and combined effects of pavement markings and a sign prompt. *J. Appl. Behav. Anal.* **2004**, *37*, 445–456.
19. Smadi, O.; Hawkins, N.; Nlenanya, I.; et al. *Pavement Markings and Safety*; Iowa State University: Ames, IA, USA, 2010.
20. Park, E.S.; Carlson, P.J.; Pike, A. Safety effects of wet-weather pavement markings. *Accid. Anal. Prev.* **2019**, *133*, 105271.
21. Zegeer, C.V.; Stewart, J.R.; Huang, H.; et al. *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Analysis of Pedestrian Crashes in 30 Cities*; Transportation Research Board: Washington, DC, USA, 2001.
22. Agent, K.R. *Transverse Pavement Markings for Speed Control and Accident Reduction*; Kentucky Department of Transportation: Frankfort, KY, USA, 1980.
23. Pulugurtha, S.S.; Nambisan, S.S.; Dangeti, M.R.; et al. *Evaluation of Effectiveness of Traffic Signs to Enhance Pedestrian Safety*; Transportation Research Board: Washington, DC, USA, 2010.
24. Hussain, Q.; Alhajyaseen, W.K.; Kharbeche, M.; et al. Safer pedestrian crossing facilities on low-speed roads: Comparison of innovative treatments. *Accid. Anal. Prev.* **2023**, *180*, 106908.
25. Vignali, V.; Pazzini, M.; Ghasemi, N.; et al. The safety and conspicuity of pedestrian crossing at roundabouts: The effect of median refuge island and zebra markings. *Transp. Res. Part F Traffic Psychol. Behav.* **2020**, *68*, 94–104.
26. Kang, B. Identifying street design elements associated with vehicle-to-pedestrian collision reduction at intersections in New York City. *Accid. Anal. Prev.* **2019**, *122*, 308–317.
27. Strong, C.; Ye, Z. Spillover effects of yield-to-pedestrian channelizing devices. *Saf. Sci.* **2010**, *48*, 342–347.
28. Chen, L.; Chen, C.; Ewing, R.; et al. Safety countermeasures and crash reduction in New York City—Experience and lessons learned. *Accid. Anal. Prev.* **2013**, *50*, 312–322.
29. Hossain, M.M.; Zhou, H.; Sun, X.; et al. Crashes involving distracted pedestrians: Identifying risk factors and their relationships to pedestrian severity levels and distraction modes. *Accid. Anal. Prev.* **2024**, *194*, 107359.
30. Krishna, K.V.; Kapruwan, R.; Choudhary, P. Understanding distracted pedestrians' risky behaviour: The role

- of walking and visual characteristics through a field study. *Transp. Res. Part F Traffic Psychol. Behav.* **2024**, *101*, 111–129.
31. Wang, C.; Hou, M.; Easa, S.M.; et al. Safety analysis of pedestrians distracted by mobile phones at street crossings: Field study in Nanjing. *Accid. Anal. Prev.* **2024**, *200*, 107563.
32. Yadav, A.K.; Pawar, N.M.; Velaga, N.R. Do mobile phone addiction, boredom proneness, and self-reported mindfulness predict pedestrian beliefs on distracted walking? *IATSS Res.* **2023**, *47*, 372–381.
33. Sheykhfard, A.; Haghighi, F.; Das, S. How does talking with passengers threatens pedestrian life? An analysis of drivers' performance based on real-world driving data. *Transp. Res. Part F Traffic Psychol. Behav.* **2023**, *95*, 464–479.
34. Arafat, M.E.; Larue, G.S.; Demmel, S.; et al. Evaluating interventions for phone distracted pedestrians in a virtual reality environment. *Transp. Res. Part F Traffic Psychol. Behav.* **2023**, *98*, 354–367.
35. Khan, N.A.; Habib, M.A. Exploring the impacts of built environment on pedestrian injury severity involving distracted driving. *J. Saf. Res.* **2022**, *80*, 97–108.
36. O'Dell, A.L.; Filtiness, A.J.; Morris, A.P. Predicting the intention of distracted pedestrians at road crossings. *Accid. Anal. Prev.* **2022**, *173*, 106707.
37. Zhu, H.; Han, T.; Alhajyaseen, W.K.; et al. Can automated driving prevent crashes with distracted Pedestrians? An exploration of motion planning at unsignalized Mid-block crosswalks. *Accid. Anal. Prev.* **2022**, *173*, 106711.
38. Schwebel, D.C.; Canter, M.F.; Hasan, R.; et al. Distracted pedestrian behavior: An observational study of risk by situational environments. *Traffic Inj. Prev.* **2022**, *23*, 346–351.
39. Ralph, K.; Girardeau, I. Distracted by “distracted pedestrians”? *Transp. Res. Interdiscip. Perspect.* **2020**, *5*, 100118.
40. Cox, A.E.; Cicchino, J.B.; Reagan, I.J.; et al. Prevalence of distracted driving by driver characteristics in the United States. *J. Saf. Res.* **2023**, *86*, 346–356.
41. Wang, H.; Wang, A.; Su, F.; et al. The effect of age and sensation seeking on pedestrian crossing safety in a virtual reality street. *Transp. Res. Part F Traffic Psychol. Behav.* **2022**, *88*, 99–110.
42. Abele, L.; Hausteine, S.; Møller, M. Young drivers' perception of adult and child pedestrians in potential street-crossing situations. *Accid. Anal. Prev.* **2018**, *118*, 263–268.
43. Arnett, J.J.; Offer, D.; Fine, M.A. Reckless driving in adolescence: 'State' and 'trait' factors. *Accid. Anal. Prev.* **1997**, *29*, 57–63.
44. Biassoni, F.; Bina, M.; Confalonieri, F.; et al. Visual exploration of pedestrian crossings by adults and children: Comparison of strategies. *Transp. Res. Part F Traffic Psychol. Behav.* **2018**, *56*, 227–235.
45. Greene, K.; Krcmar, M.; Walters, L.H.; et al. Targeting adolescent risk-taking behaviors: the contributions of egocentrism and sensation-seeking. *J. Adolesc.* **2000**, *23*, 439–461.
46. Herrero-Fernández, D.; Macía-Guerrero, P.; Silvano-Chaparro, L.; et al. Risky behavior in young adult pedestrians: Personality determinants, correlates with risk perception, and gender differences. *Transp. Res. Part F Traffic Psychol. Behav.* **2016**, *36*, 14–24.
47. Arnett, J. Still crazy after all these years: Reckless behavior among young adults aged 23–27. *Pers. Individ. Dif.* **1991**, *12*, 1305–1313.



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