https://doi.org/10.55343/CogSust.21280

Road transport safety and children's cognitive attitudes

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Abstract
This paper summarizes evidence on road transport safety with a focus on children's cognitive attitudes and pedestrian behaviour. It integrates findings on attention, visual processing, executive functions, risk perception, knowledge–behaviour transfer, and environmental complexity. Consistent evidence indicates that developmental limitations in attention and processing speed constrain safe crossing decisions in younger children. Knowledge-focused education alone does not reliably improve real-world behaviour, and behavioural training targeting procedural skills yields modest safety improvements. Built environment features – particularly traffic speed and volume, as well as visual clutter – systematically shape both perceived and objective safety outcomes. The paper concludes with implications for training, urban design, and family practices, and outlines directions for future research.

Keywords
road transport safety, child pedestrian behaviour, cognitive development, risk perception, behavioural training

1. Introduction

Road transport injuries remain a leading cause of death and disability among children worldwide. Within this public health challenge, child pedestrians represent a particularly vulnerable group because safe participation in traffic requires integrated cognitive, perceptual, and motor skills that are still developing during early and middle childhood (Vijay et al., 2024; Zeedyk et al., 2001). Globally, road traffic injuries remain the leading cause of death for children and young people aged 5–29 years, with an estimated 1.19 million fatalities annually. More than half of these fatalities occur among vulnerable road users – pedestrians, cyclists, and motorcyclists – especially in low- and middle-income countries (WHO, 2023).

Beyond mortality, the morbidity and disability burden impose substantial socioeconomic costs on families and health systems. The United Nations' Global Plan for the Decade of Action for Road Safety 2021–2030 (WHO, 2021) targets a 50% reduction in road traffic deaths and injuries by 2030. It explicitly frames child safety within Safe System principles: human life is paramount; predictable errors must not be fatal; responsibility is shared across system actors. Children's active travel confers major developmental, health, and environmental benefits but exposes them to complex traffic environments. Systematic evidence indicates that high traffic speeds and volumes consistently reduce both objective and perceived safety for children, whereas sidewalk presence and protected crossings improve safety (Amiour et al., 2022; Cloutier et al., 2021).

Environmental visual clutter – e.g., billboards – adds extraneous cognitive load, increasing missed crossing opportunities and widening gaze dispersion in children compared with adults (Tapiro et al., 2020). Developmental research indicates that inflexion points in pedestrian competence occur: a strategic shift in visual search emerges around ages 7–8, and general competence is typically achieved by about age 10 (Whitebread and Neilson, 2000). Younger children rely on simpler heuristics (e.g., distance gap) and are markedly more likely to make unsafe crossing decisions. Cognitive functioning subsumes chronological age as a predictor of risky route selection (Oxley et al., 2007; Barton et al. 2012; Tabibi and Pfeffer, 2003). Crucially, classroom education successfully increases declarative road-safety knowledge with months-long retention, yet it does not translate into improved real-world crossing behaviour. In contrast, behaviourally oriented training that targets procedural competencies yields small-to-moderate improvements sustained for months (Zeedyk et al., 2001; Schwebel et al., 2014). Protecting children in traffic, therefore, requires

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capability building under realistic cognitive load, complemented by Safe System design that reduces the demands placed on developing cognitive systems. Finally, recent syntheses highlight the underrepresentation of LMICs (low- and middle-income countries) and the need for exposure-adjusted injury data linked to intervention evaluations (Vijay et al., 2024; Wazana et al., 1997). Safeguarding children in road transport is not only a scientific goal and a policy imperative, but also aligns with the SDGs (Sustainable Development Goals) on health, equity, and sustainable cities.

In this paper, it is hypothesised that children's pedestrian safety is primarily limited by developmental constraints in attention, visual search efficiency, and processing speed. A literature review is conducted to test the hypothesis and find effective ways of intervention. The rest of the article is structured as follows: the Methodology section describes how evidence from empirical and review studies was extracted. Results summarise key findings across cognitive domains, behaviours, interventions, and environmental/social moderators with child pedestrians. The Analysis section integrates mechanisms that reconcile apparent contradictions (knowledge–behaviour gap), and the Discussion outlines implications for policy, urban design, education, and family practices. The Conclusion assesses the hypothesis and proposes future research directions.

2. Methodology

A detailed bibliographic search on sciencedirect.com was conducted. Sources included empirical studies, systematic reviews, and meta-analyses on child pedestrian safety, cognitive factors, and built-environment influences. Study characteristics, cognitive constructs (attention, visual processing, executive functions, risk perception), behavioural outcomes (crossing judgments, route selection, dash-out), intervention modalities (education vs. behavioural training), and environmental/social moderators (traffic speed/volume, visual clutter, sidewalks, parenting styles) were extracted.

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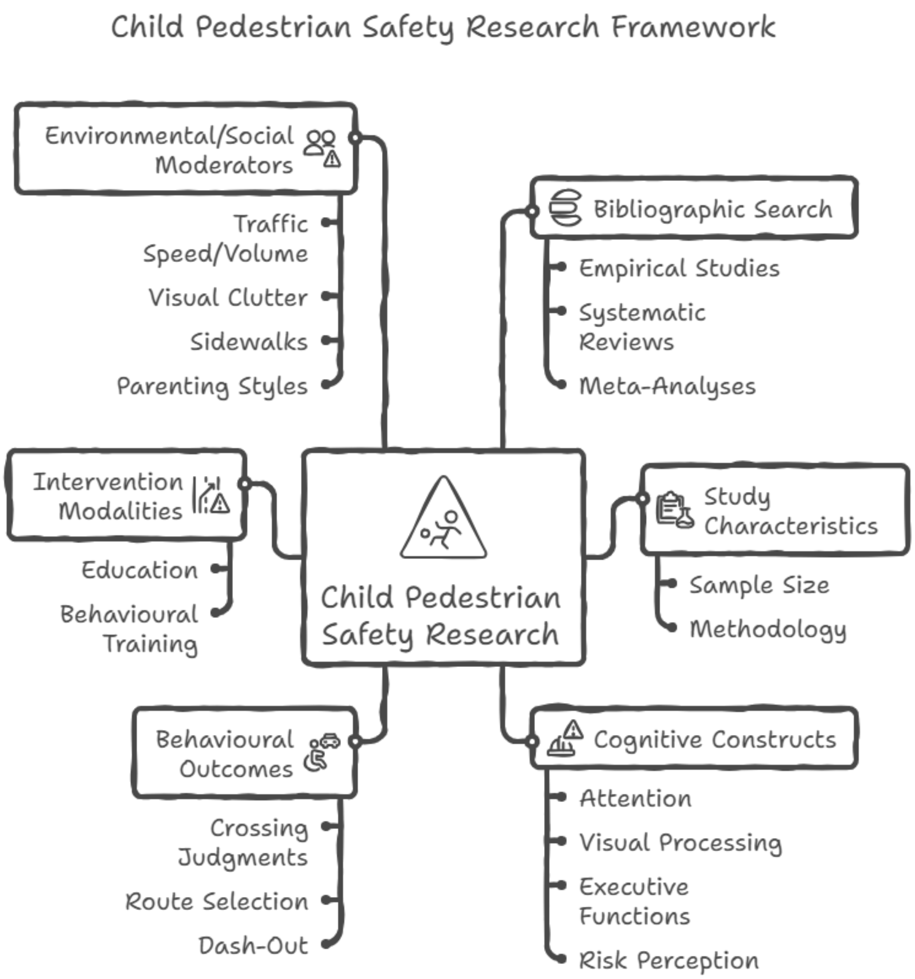

Figure 1. Child Pedestrian Safety Research framework
Source: own compilation with napkin.ai

3. Results

Children's ability to identify safe crossing sites and resist attentional interference improves with age, with a strategic shift around 7–8 years and general competence by ~10 years. Lower perceptual, attentional, and executive performance predicts unsafe crossing decisions; cognitive functioning can subsume age as a predictor of risky route selection (Amiour et al., 2022). Educational interventions reliably increase declarative knowledge about safe/dangerous crossing locations, with retention lasting up to six months; however, they do not improve real-world crossing behaviour compared with controls (Tapiro et al., 2020). Individualised/small-group training targeting dash-out prevention, crossing at parked cars, and safe route selection produces small to moderate safety gains, sustained for 2–8 months (Oxley et al., 2007). High vehicle speed/volume consistently associates with unsafe perceptions and increased injuries, while sidewalk presence improves perceived and objective safety. Visual clutter increases missed crossing opportunities and widens children's gaze dispersion relative to adults. Risk perception relates to age, gender, socioeconomic status, and parenting styles. Negative parenting (e.g., poor monitoring) associates with poorer risk perception

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(Barton et al., 2012).

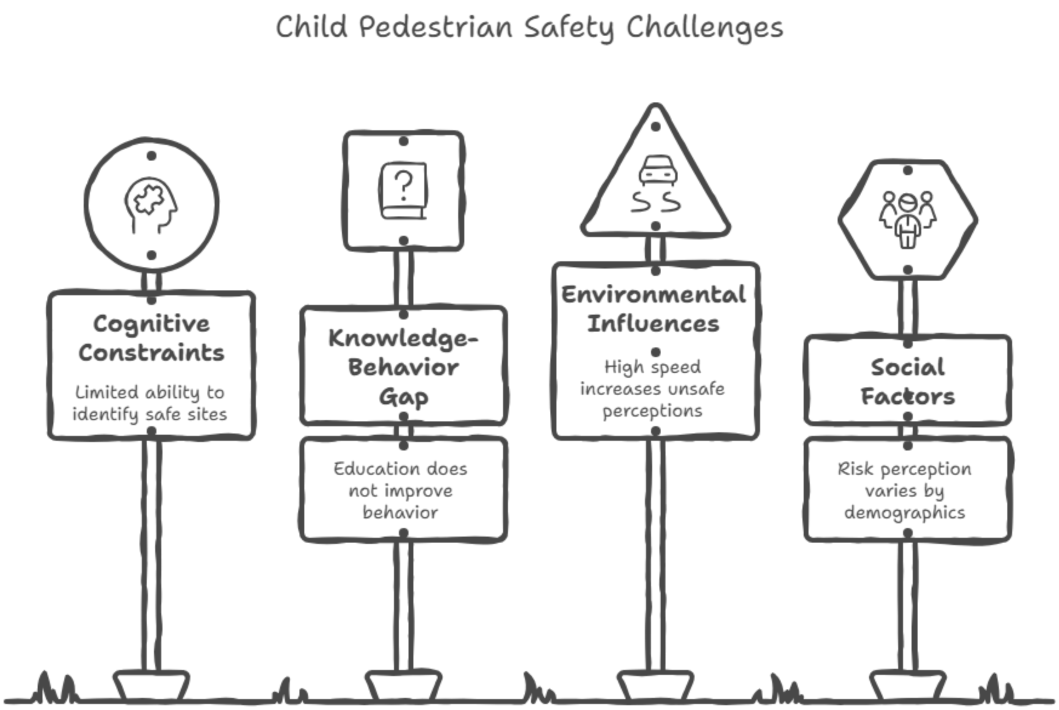

Figure 2. Child Pedestrian Safety challenges
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4. Analysis

Dual-process decision models help explain errors in child road crossing. Under time pressure, younger children rely on fast heuristics rather than effortful integration, which is limited by working memory and slower processing, and is biased towards distance-gap judgments, increasing error susceptibility when traffic streams are complex (Whitebread and Neilson, 2000; Oxley et al., 2007). Cognitive load theory clarifies the knowledge–behaviour gap: declarative schemas gained via classroom learning are not readily applied under high extraneous load (noise, visual clutter, multi-stream traffic), whereas procedural training automates gaze patterns and hazard detection, enabling transfer to real contexts (Zeedyk et al., 2001; Schwebel et al., 2014). VR (virtual reality) laboratory evidence shows that higher visual load reduces crossing opportunities and broadens gaze dispersion among children, consistent with immature inhibitory control (Tapiro et al., 2020). Population-level milestones (strategy shift at 7–8; competence by ~10) coexist with substantial within-age variability in executive functions (attention, inhibition, processing speed). Cognitive functioning can outperform age in predicting risky route selection, supporting screening for cognitive readiness and tailoring instructional intensity (Barton et al., 2012; Tabibi and Pfeffer, 2003).

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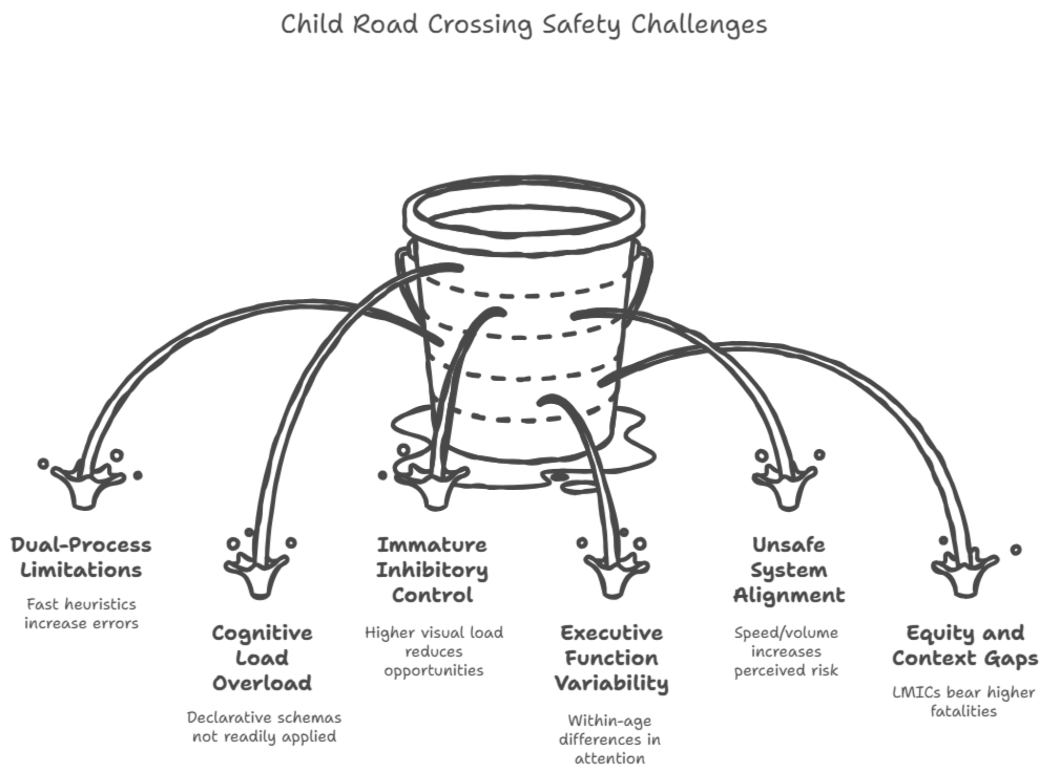

Figure 3. Child Pedestrian Safety challenges
Source: own compilation with napkin.ai

Speed management, protected crossings, and sidewalk continuity reduce cognitive demands and error consequences for child pedestrians. Reviews consistently identify speed/volume as primary determinants of both objective and perceived safety. The WHO's Global Plan centres on systemic responsibility to prevent typical human errors from being fatal (Amiour et al., 2022; Cloutier et al., 2021; WHO, 2021, 2023). LMICs bear a higher share of vulnerable user fatalities, as exposure patterns (longer walking distances), enforcement gaps, and infrastructure deficits elevate risk even for well-trained children. Social determinants – such as parental supervision and socioeconomic status – shape risk perception and behaviour, signalling the need for integrated family/community components (WHO, 2023; Wazana et al., 1997; Amiour et al., 2022). Education is necessary but insufficient without procedural fluency. Although age predicts average gains, executive functions predict individual outcomes, and environmental complexity actively modulates cognitive demand. A combined pathway – procedural training, exposure-aware urban design, and family/school practices – should be evaluated using robust, exposure-adjusted outcomes across diverse geographies (Vijay et al., 2024; Cloutier et al., 2021).

5. Discussion

The above results suggest that in education hands-on practice in realistic scenarios (on-street supervision and VR/AR) are to be prioritized to automate gaze strategies, hazard detection, and speed–distance judgments. Furthermore, curricula must be differentiated by developmental stage. In practice, this means that heuristics should be simplified for younger children and anticipatory strategies may be incorporated in the curriculum for older cohorts.

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As far as urban design and policy are concerned, it is advisable to implement 30–40 km/h limits in school zones and residential streets. Moreover, raised crossings, curb extensions, protected mid-block crossings, and continuous sidewalks might also increase safety levels. The regulation of visual clutter near crossings may reduce extraneous load. Crossing-guard deployments should be aligned with risk-based site selection and monitored for behavioural compensation.

Parental modelling of safe road-crossing behaviour together with consistent adult supervision should be actively promoted as a core component of child pedestrian safety interventions. Socioeconomic barriers to safe transport can be mitigated through structural programmes such as Safe Routes to School and through investment into targeted crossing infrastructure.

Future research should systematically screen for children's cognitive readiness for independent road use, and should report exposure-adjusted outcomes (e.g. injuries per km walked; missed crossing opportunities; safe route selection rates). Embedding randomised or quasi-experimental comparisons of procedural versus knowledge-only curricula into future studies and linking outcomes to police/injury registries would also be promising. Studies in LMICs would also be advisable, as data remain sparse from those regions, while risks are the highest.

Regarding methodologies, eye-tracking studies should be carried out in realistic environments. Methods should be found to quantify the benefits of visual clutter reduction. Scalable digital training tools should be developed, together with an effective testing system for their efficiency. Finally, integrating Safe System analytics (e.g. kinetic energy thresholds, forgiving street design) with developmental metrics would enable the derivation of design standards optimised for child pedestrians.

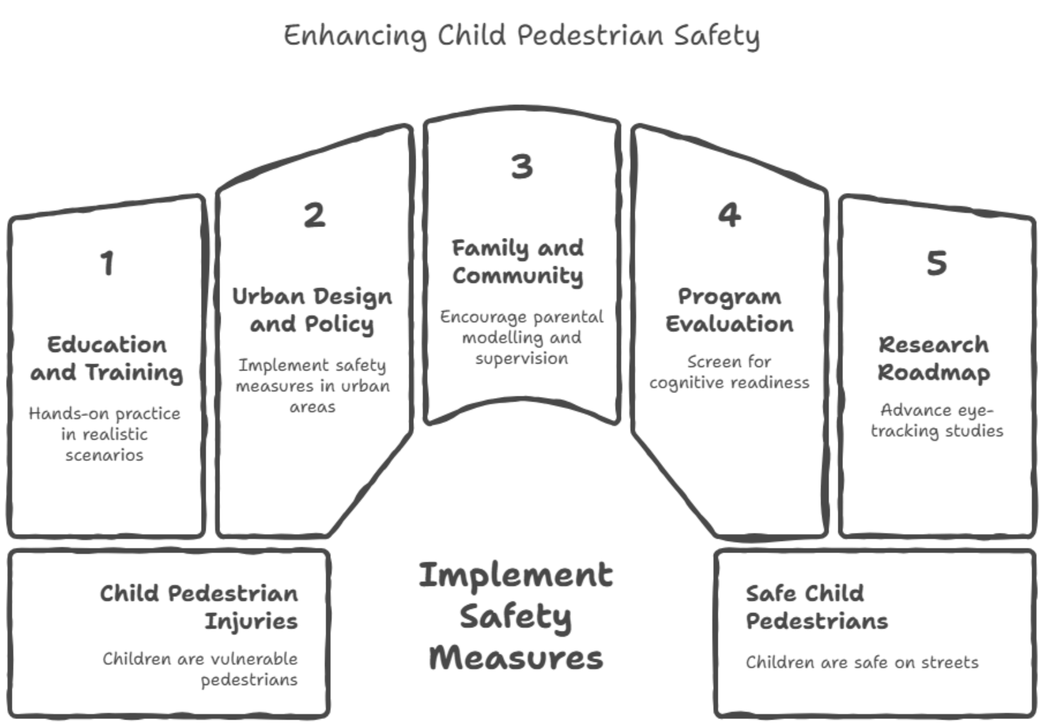

Figure 4. Child Pedestrian Safety challenges
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6. Conclusion

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The evidence supports the hypothesis: developmental constraints in attention, visual search, and processing speed are primary limits on younger children's pedestrian safety. This means, interventions that train procedural skills under realistic cognitive load outperform declarative education in improving behaviour. Future research should design scalable behavioural training calibrated to cognitive readiness, quantify the benefits of speed management and visual clutter reduction near crossings, integrate parent-focused components, and extend evaluations to LMIC contexts to strengthen generalisability.

7. Acknowledgement

Project no. KDP-IKT-2023-900-I1-00000957/0000003 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary, financed under the National Research, Development and Innovation Fund, as part of the KDP-2023 funding scheme.

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