CHILDREN’S UNDERSTANDING OF PUBLIC SAFETY SIGNAGE: A SCOPING REVIEW

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ABSTRACT

Objective: This study aims to provides a scoping review of papers published before 30 July 2023 that explore the level of development of public safety signs design among children. Descriptive analyses were performed on 28 articles.

Method: Because the review question is comprehensive, we found the scoping review to be the most appropriate way to answer this question. In order to ensure clarity and transparency, and to avoid adverse and poor reporting, We conducted our scoping review based on the 2020 PRISMA Checklist.

Result: Since cultural background and signage category can also affect signage comprehension, separate studies are required by country, region, and signage type. The types of signage and countries in the current related research are relatively scattered, and there is no specific classification of public safety signage types. Most of them are safety signs in specific scenarios, such as trains and swimming pools. At the same time, the research areas are mostly concentrated in the UK in Europe, Hong Kong and Indonesia in Asia.

Conclusion: These data could provide stronger evidence to identify and establish pathways to improve children’s understanding of public safety signage.

Keywords: children, public safety signage, understanding level, design features.

Received: 28/08/2023
Accepted: 27/11/2023
DOI: https://doi.org/10.55908/sdgs.v11i12.1867

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ENTENDIMENTO DAS CRIANÇAS SOBRE A SINALIZAÇÃO DE SEGURANÇA PÚBLICA: UMA REVISÃO DO ESCOPO

RESUMO

Objetivo: Este estudo tem como objetivo fornecer uma revisão de escopo de trabalhos publicados antes de 30 de julho de 2023 que exploram o nível de desenvolvimento de design de sinais de segurança pública entre crianças. Foram realizadas análises descritivas em 28 artigos.

Método: Como a questão da revisão é abrangente, descobrimos que a revisão do escopo é a maneira mais apropriada de responder a essa pergunta. A fim de garantir clareza e transparência, e para evitar relatórios adversos e ruins, realizamos nossa revisão de escopo com base na Lista de Verificação PRISMA 2020.

Resultado: como o fundo cultural e a categoria de sinalização também podem afetar a compreensão da sinalização, estudos separados são exigidos por país, região e tipo de sinalização. Os tipos de sinalização e os países na atual pesquisa relacionada são relativamente dispersos, e não há classificação específica de tipos de sinalização de segurança pública. A maioria deles são sinais de segurança em cenários específicos, como trens e piscinas. Ao mesmo tempo, as áreas de pesquisa estão concentradas principalmente no Reino Unido na Europa, Hong Kong e Indonésia na Ásia.

Conclusão: Esses dados podem fornecer evidências mais fortes para identificar e estabelecer caminhos para melhorar a compreensão das crianças sobre a sinalização de segurança pública.

Palavras-chave: crianças, sinalização de segurança pública, nível de compreensão, características de design.

1 INTRODUCTION

The application of public safety signage to children has become the focus of governments and safety organizations in various regions. This is because accidental injury to children is a global public health challenge in the 21st century, about 1 in 5 child deaths is a result of unintentional injury (Dellinger & Gilchrist, 2019). Governments at all levels in various countries and regions have begun to adopt different methods like law, Community policing and public signage to protect the safety and health of children, (Musofiana et al., 2023; Zulkarnain et al., 2023). Unintentional injuries, including road traffic accidents, drowning, falls, burns and poisoning, are the leading cause of death among children and adolescents worldwide. (Unicef, 2022; WHO, 2008). Meanwhile, it also affect the whole society, including medical and social service resources, and may seriously affect family income and quality of life (Laughery & Wogalter, 2006). Attempts to reduce the incidence of accidents involving young children continue to be a severe problem for governments worldwide (Waterson & Monk, 2014). Public safety signage as one of the important intervention measures to prevent and reduce children’s unintentional injuries, how to maximize its effectiveness is a very important issue.
Properly setting up different public safety signs is an indispensable intervention measure in preventing and reducing children’s unintentional injuries. A common way to alert people to dangerous and injury-risk behaviors is to post warning signs. Of course, whether the warning signs are adequate for these purposes depends partly on the audience’s understanding of the expected information (Wogalter et al., 1987). Safety signs can directly or indirectly affect children’s accidental injuries by preventing and reducing unsafe behaviors and conditions. They are essential interventions to prevent accidental injuries to children (Zhang, 2005).

Children are prone to severe injuries when they are unattended or under improper supervision. Therefore, when children are in a public environment, how identifying hazards, preventing accidents, and conveying safety information through images are often significant issues (Chang, 2020). Using warning signs or other forms of visual communication to alert children and carers of the dangers or hazards associated in hazardous surroundings or potentially risky activities is one strategy to reduce the number of casualties (Waterson & Monk, 2014). At the same time, safety signs are the most direct and the only way to convey hazard information (Ibrahim et al., 2021).

The path from sign to behavior involves two general processes: understanding and decision-making (Meis & Kashima, 2017). Therefore, only when signage can be perceived by children and their intentions are successfully understood can signage prevent or reduce the risk of children accidental casualties and vice versa. In order to maximize the role of public safety signage, the first thing to consider is whether children can correctly understand the information conveyed by public safety signage.

The existing literature points out that children cannot accurately understand current safety signage. This is due to the limited perception and cognitive abilities of children, safety signage designed for children should be different from those designed for adults (Kalsher & Wogalther, 2007; Rice & Lueder, 2007). In studies of public safety signs, children and adults need to be studied separately.

Design features can directly affect children’s understanding level of public safety signage. Although many factors affect children’s understanding of signs, including cultural background (Ben & Shinar, 2018; Waterson et al., 2012; Hurlbert & Ling, 2007) school education (Zou & Chen, 2020; Alonso et al., 2018), family education (Dempsey et al., 2022), social intervention (Hall et al., 2017; Thomson, 2006), etc. However, for children, the impact of low understanding caused by certain cognitive development
characteristics cannot be eliminated through intervention. Only signage design features can quickly and directly affect children’s level of comprehension of signage (Yin et al., 2015). Among them, children’s preferred design features had a positive impact on comprehension levels. Compared with the comprehensibility of existing safety signage, the new safety signs are easier to be noticed and understood by children after the design features of safety signs are redesigned according to children’s preferences (Waterson et al., 2012). Therefore, children’s preference for public signage design has become a topic that many researchers are studying. However, to the best of our knowledge, previous publications did not have a literature review, or employed a scoping review approach.

This scoping review elaborates on the current state of knowledge on "child public safety signage design features" and attempts to shed light on future needs in the field. Conducting traditional systematic reviews is less effective due to the diversity and relative paucity of evidence; we therefore undertook a systematic scoping study on this topic to highlight the currently available literature and identify gaps in our knowledge. We hope that our efforts will reveal areas requiring immediate attention and guide future research efforts.

Our focus here is to synthesize research in the literature on the design features of child public safety signage, its impact on levels of comprehension, and design recommendations. We also wish to highlight gaps in our understanding of the child public safety signage design features. In this review, we provide a structured overview of empirical research that focuses on the developmental level of children’s public safety sign design. We limit the review to empirical studies published before 30 of July 2023 in order to lay a contemporary foundation for future research. Our aim in this article is not to conduct a comprehensive systematic review (Andrews, 2005). Instead, we attempted to investigate children’s preferences for different public signage design and the extent to which they influenced understanding level. Unlike systematic reviews, scoping reviews provide a "domain-specific snapshot" (Booth et al., 2012), and does not assess the quality of any research (Arksey & O’Malley, 2005). In contrast, a scoping review usually aims to: examine the nature, breadth, and depth of research on a particular topic or research question; summarize and disseminate findings from the research; and ultimately identify gaps and inadequacies in existing research (Arksey & O’Malley, 2005).
2 METHODOLOGY

Because the review question is comprehensive, we found the scoping review to be the most appropriate way to answer this question. In order to ensure clarity and transparency, and to avoid adverse and poor reporting, we conducted our scoping review based on the 2020 PRISMA Checklist.

2.1 INCLUSION CRITERIA

(1) No language restriction was considered
(2) Published before 30 July 2023
(3) The sample of participants is limited to children under the age of 18
(4) Information related to public safety signs, level of comprehension, design preferences of children
(5) Include all types of reports: original research, reviews and editorials, opinion pieces, guidelines, letters to the editor, and commentaries.

2.2 EXCLUSION CRITERIA

(1) Content that is not relevant to children
(2) Those irrelevant to public safety signs
(3) Preprints
(4) Articles for which the full text is not available.

2.3 SEARCH STRATEGY

We followed a four-step search strategy with no language restrictions. First, a limited preliminary search was performed on August 10, 2023 in multiple databases, including Google Scholar and Scopus, appropriate keywords will be identified and determined. Next, we used a search strategy to search electronic databases on 20 August 2023, including the following sources: Web of Science, Taylor & Francis, Wiley, SpringerLink. Search terms were consistent across all databases when conducting searches, including: public safety signs; children; level of comprehension; design factors. While Endnote will be used for review of results. When duplicate publications were removed, the titles and abstracts of all articles were independently checked and screened by two authors, and irrelevant studies were removed based on the stated inclusion and exclusion criteria. Any disagreements regarding the inclusion
or exclusion of articles were resolved through discussion and eventually reached a consensus. In the third step, the authors checked and searched forward or backward based on the reference lists of the already included papers to identify more relevant studies. In order to maximize the collection of all studies related to the keywords, in the fourth step, we browsed Google Scholar for article citations and current publications. Just like the previous steps, when there are disagreements or discrepancies, the discussion will continue in steps three and four for final approval. Since there are no language restrictions when screening and checking papers, non-English papers were translated by Google and then checked to see if it met the inclusion criteria.

3 RESULTS AND DISCUSSION

The original database search yielded a total of 71 articles, with four duplicates deleted. And five additional publications were removed after assessing the titles and abstracts of the articles for relevance. After that, to further evaluate the applicability of the articles, 62 papers were found and read in full text. Of these, 40 articles were excluded (26 articles were not related to children, 11 articles were not related to public safety signage, and 3 articles did not have full text). 22 articles were left for data synthesis. We next did forward and backward screening of these papers’ references and citations in order to uncover as many relevant studies as possible. We found 6 more publications. So far, a total of 28 papers have been found meeting the inclusion criteria. Figure 1 outlines the review process.

Figure 1. PRISMA flow chart, the process of study selection.

Source: Authors data
3.1 DESCRIPTIVE OVERVIEW

3.1.1 Study countries

For each country studied in each article, geographical region and income level are also included in our analysis.

As shown in Figure 2 and Table 1, among these 28 articles, in terms of country and geographical region, 17 articles (60.7%) originated from 4 countries: 8 articles from China (including mainland China, Hong Kong, and Taiwan), 3 articles from the United Kingdom, and 3 articles from the United States, 3 papers from Canada. In terms of geographical region, 9 articles (32.1%) came from East Asia, 9 articles (32.1%) came from Europe, and 6 articles (21.4%) came from North America. 3 articles are from Southeast Asia and West Asia, and 1 article is from the Pacific region. According to the World Bank’s country classification for fiscal year 2023-2024, we classify these regions into high-income countries, upper-middle-income countries, lower-middle-income countries, and low-income countries (Worldbank, 2023). 18 articles (64.2%) came from high-income countries, 9 articles (32.1%) came from middle-high-income countries, and only 1 article came from low-middle-income countries.

Figure 2. Distribution of included papers based on their study countries.
### Table 1. Distribution of included papers based on their study countries.

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Source: Authors data

### 3.1.2 Date of publication

As of July 31, 2023, the largest number of articles was published in 2015 (n=5), followed by 2017 (n=4) and 2013 (n=3). Since 2004, the number of related journals published has shown a stable state, and only increased between 2017 and 2020, indicating that although interest in research in this field has increased in recent years, it still needs to continue to be explored in depth. The release date distribution chart is shown in Figure 3.

![Figure 3. Number of articles according to dates of publication.](image)
3.1.3 Methodological approaches

Since the research subjects were children, qualitative methods were the most frequently chosen research method by different researchers (n=18), more than three times the number of articles using quantitative research. At the same time, only 2 articles used mixed methods research.

3.1.4 Participants

Sample sizes vary widely across research methods, with samples ranging from roughly 60 to over 500 participants in quantitative studies, mostly 30 to 65 children in qualitative samples, and 90 to over 2,400 in mixed methods studies participants.

In studies of children, the ages of study samples vary. According to Piaget’s classification of children’s development levels, children are in the Preoperational stage between the ages of 2 and 6, the Concrete operational stage between the ages of 7 and 11, and the Formal operational stage between the ages of 12 and 18. Since the age span of the participants selected in the article is large, children of different ages will have different cognitive development levels and understanding styles. Therefore, the age of the participants will be divided according to their cognitive development levels. Among them, the age group with the largest number of studies is on children in the concrete operational stage between 7 and 11 years old, with up to 75% (21) of the participants in the papers including 7 to 11 years old. Five articles used studies conducted with children in the Preoperational stage, mostly 4-6 years old. The researchers in the 6 articles used children in the Formal operational stage aged 12-18 to conduct research, with a wide age range, and the age range of the participants ranged from 5-16 years old and 7-17 years old. The age distribution of the participants is shown in Figure 4.

Figure 4. Distribution of included papers based on participants’ age.

Source: Authors data
3.1.5 Language of the papers

Since this study was conducted without any language restrictions, we also screened the titles and abstracts and text of non-English papers. Finally, we included one non-English paper in the Chinese language (Liumin & Wenwei, 2011) and one in Korean language(Xiong & Hong, 2020).

3.2 DISCUSSION

Our study retrieved 28 papers based on inclusion and exclusion criteria. Here, we will discuss the research focus and depth of research to obtain what is known from literature about children and public safety signage design.

3.2.1 Research focus

Among the 28 existing articles, although the selection and research of public safety signs are different, they all follow the same principle when selecting: public safety signs that are related to children and need to be understood by children.

Daily public signage are the most studied type of signage (Iftadi et al., 2018; Siu et al., 2017; Siu et al., 2015a; Siu et al., 2015b), and it is a very coincidence that the choices of daily public signage in these four articles are the same. They are all selected based on the signs in the ISO standard, consisting of 12 common public safety signs that children use in their daily life, include four mandatory action signs (Use footbridge, Use handrail, Wash your hands, Use this walkway), four prohibition signs (Do not touch, No sitting, No pushing, Not drinking water) and four warning signs (Slippery surface, Toxic materials, Drop/fall, Floor-level obstacle). Another article on public signage from Jordan (Ahmad et al., 2018) has strong cultural characteristics. In the study, not only daily public safety signs were selected, but also mosque signs were included.

At the same time, there are also 5 studies on traffic signage, which from South Korea (Xiong & Hong, 2020), Mainland China (Zhao et al., 2017), Serbia (Trifunović et al., 2017), Sweden (Sandels, 1995) and Italy (Zedda et al., 2013). Although the research focus of these five articles is all on children’s daily traffic signage, due to different traffic laws and traffic conditions in different countries and regions, the traffic signs faced by children will be different. Therefore, the traffic signs mentioned in the article are The selection of traffic signs performed varies.
Another category of public safety signage that has attracted much attention from authors is the signage related to poisoning and pharmaceuticals. This is when children come into contact with poisonous products such as rat poison, pesticides, medicines, etc. released in the wild or products that are prohibited for children to eat. Because children themselves cannot recognize the text or signage pictogram content, poisoning occurs. Studies have been carried out in Portugal (Boto et al., 2015), Finland (Hämeen-Anttila et al., 2004), Canada (Korenevsky et al., 2013; Mok et al., 2015) and the United States (Goldsworthy et al., 2008).

At the same time, the choice of public safety signage is also related to the characteristics of disasters related to the areas where children live. Compared with other signage, Indonesia (Ismail et al., 2019), which is often affected by natural disasters such as earthquakes and tsunamis, chose to conduct in-depth research on disaster escape signs to ensure the personal safety of children. The research includes the identification of signs of different disaster types, the content of escape signs, the color of safety signs corresponding to different meanings and hazard levels, and the identification of the content of temporary emergency signs in earthquakes and tsunamis.

The study of public safety signs also includes public areas where national standards are not promulgated, such as swimming pools. As the number of injuries and deaths among children from drowning or swimming increases year by year, relevant studies have been conducted in Canada (Morrongiello et al., 2016), Netherlands (Boersema & Zwaga, 1989), and America (Loring & Wiklund, 1988). The most studied signs are ‘No diving’ and warning signs related to pool slides (no stopping on the slide, do not holding onto edges, etc.). To see if children can associate the content of the sign with "permanent injury" and "you can break your neck." The subway is also one of the areas where children are prone to safety accidents, such as hand pinched by subway door. An article from Taiwan (Mei-Chun, 2020) conducted a study on the "mind your hands" sign in the subway at different ages according to children’s different cognitive development levels.

Train operators in Great Britain have become aware that there have been a number of accidents involving child safety on board trains in recent years, such as the use of lobby doors, flip-up seats and handrails, which are common devices on trains. Accidental injury due to improper use by children. Therefore, two studies (Waterson & Monk, 2014; Waterson et al., 2013) on train safety signage were conducted in partnership with
Loughborough University and funded under a Rail Safety and Standards Board (RSSB) managed UK Department for Transport research programme. Although their study focused on safety signs, it only focused solely on non-emergency safety signage, which include ‘Do not obstruct this door’, ‘Do not place hands on glass’, ‘No climbing’ and etc.

In addition to studying public safety signage, Lin et al. (2015) and Easterby and Hakiel (1981) chose to test comprehension levels on individual design elements in safety signs, including color (such as orange, red, green and black), shape (such as triangle, diamond and circular), and pictograms (such as palm, cross oblique line). They combined and studied different design elements respectively, and obtained the best design combination by matching the degree of danger, the meaning of the signs, etc.

3.2.2 Research depth

Our study retrieved 28 papers based on inclusion and exclusion criteria and divided them into six different research stages based on the depth of research in each paper: "Evaluate children’s understanding level of existing signage", "Analyze factors that affect children’s understanding level", "Evaluate children’s design preferences", "Analyze the reasons for children’s preferences", "Propose design suggestions or recommendations", "Modify and improve the design outline guidelines"

3.2.2.1 Evaluate children’s understanding level of existing signage

Identifying whether children have low levels of understanding of existing signage is one of the first phase in conducting child-centred signage research and improving design. More than half of 28 overall publications included assessing the level of understanding of existing signage as a first stage of research. Existing signage that emerged from the assessment fell into three main categories, starting with public safety signs that are intended to be used in particular scenarios. Chang (2020) conducted a study on "mind your hand" signage in the subway with children in Taiwan. In the first stage of the study, a questionnaire was used to assess the level of comprehension of five different sign pictograms, resulting in children aged 4-6 years showed the highest level of understanding of pictures with animal pictograms. In a study of safety signs in swimming pools that also tested the comprehension level, Boersema and Zwaga (1989) found that none of the safety signs for swimming pool slides was easy enough for children aged 7-
19 to understand. Loring and Wiklund (1988) and Morrongiello et al. (2016) found through a 5-point likert scale that although children in the "no diving" signage could understand the meaning conveyed by the pictograms in the sign, but most kids don’t automatically associate the broken neck pictogram in the signage with permanent damage. Similarly, in a study of train safety signage among children aged 5 to 10 years, it was found that people of all ages found existing safety signs very difficult to understand (Waterson et al., 2013). Children interpret the signage very differently than adults.

The level of comprehension among children of public safety signs that appear in everyday life has also received attention from many authors. Children aged 7-11 years in elementary school are the focus of most traffic sign studies, and almost all studies show that most existing traffic signs are difficult for children to understand (Xiong & Hong, 2020; Trifunović et al., 2017; Zhao et al., 2017), especially younger children, know little about traffic signs, some children believe that "pedestrian crossing" means only adults can cross the street, and warning signs "school or playground " means "where the child must move quickly across the road to avoid being run over (Sandels, 1995). Likewise, for children in Indonesian, their level of understanding and background knowledge of "Tsunami and Earthquake safety signage" is extremely low, even though these symbols and signage are placed in their environment. Low levels of understanding of existing signs are also seen with public signs in Jordan (Ahmad et al., 2018), way-finding signage in New Zealand (Water et al., 2017), and poisoning warning signs (Boto et al., 2015; Goldsworthy et al., 2008; Hämeen-Anttila et al., 2004). The level of serious confusion among children even exceeds the ANSI limit of 5%, and more than 90% of children cannot correctly understand existing warning signs, which is very worrying.

Lin et al. (2015) and Easterby and Hakiel (1981) tested the understanding level of design elements in signage by combining colors, shapes and pictograms respectively. The results showed that even the best signage comprehension level was not particularly high, with only 20% correct understanding. Some of the poorer signage tested failed to reach the point of correct understanding. Even with relaxed comprehension standards, comprehension rates exceeded 5%. At the same time, children aged 4 to 6 years old can only recognize a limited number of pictograms and are unable to correlate the colours of some warnings with the associated hazard levels.

Evaluating children’s understanding level of existing signage is critical to identifying and clarifying which public safety signage are not suitable for children to
3.2.2.2 Analyse factors that affect children’s understanding level

What factors influence children’s level of understanding is a further step in exploring sign understanding levels. The study found that the main factors affecting children’s understanding of public safety signs are mainly divided into six categories, including age, gender, education level, use environment, signage design and signage category.

In multiple studies on traffic signage, it was found that the understanding level of traffic signage among children aged 4-5 and 7-18 years old is affected by the age and gender of the child (Xiong & Hong, 2020; Zhao et al., 2017; Ahmad et al., 2018; Trifunović et al., 2017). Meanwhile, in Easterby and Hakiel’s (1981) study of safety signage, gender was found to have a significant effect on comprehension levels. However, a study of children aged 7 to 10 found that, unlike signage in other scenarios, children’s understanding of swimming pool safety signage has nothing to do with gender, but only with swimming experience. Therefore, whether gender can affect children’s level of comprehension is also influenced by the type of sign. Studies by Ahmad et al. (2018) and Xiong and Hong (2020) also show that even for children of different ages, the usage environment and education level are one of the factors that affect children’s understanding level.

As mentioned before, the type of sign is also one of the factors that affects the level of children’s understanding. In the study of Trifunović et al. (2017), it was found that compared with other warning and indicative signage, children aged 7-10 had the lowest level of understanding of prohibitory traffic signage, with only 25% of the correct answers. Similarly, descriptive signs and indicative signage are easier to understand than prohibition signs, and are the sign category with the highest level of comprehension (Ahmad et al., 2018; Easterby and Hakiel, 1981).

The most critical influencing factor is the design elements of the safety signage itself. Zhao et al. (2017) studied the comprehension level of traffic signage in China among children aged 7-18, and they found that the comprehension level of red traffic
signs in the study was significantly higher than that of traffic signs of other colours. The design of pictograms also has a significant effect on children’s guessing and comprehension (Mok et al., 2015; Easterby & Hakiel, 1981; Zedda et al., 2013). At the same time, other design elements in signage design, such as size, shape, etc., also affect children’s understanding level (Li, 2012; Easterby & Hakiel, 1981). Whereas, signage design based on children’s preferences had a positive impact on comprehension levels (Waterson et al., 2013; Boersema & Zwaga, 1989). Thus, a key way to improve children’s level of understanding is to understand children’s preferences for signage design.

3.2.2.3 Evaluate children’s design preferences

During our review period, 11 articles assessed children’s preference for signage design at the next stage after evaluating the understanding level. The most studied one is children’s preference for pictograms in signage. Among them, children’s preference for signage design using human figures or human silhouettes is the consensus reached in most studies. Waterson et al. (2013) found in a study of children aged 5-10 years that human figures, especially "safety human figures" with facial expressions, can be relatable to children, especially when facial expressions convey specific emotions associated with good or bad behaviour. The same preference was also found among children aged 4-6 years, with boy or girl figures being more attractive for children, compared to signs with only a palm or crying face and animal (Chang, 2020). In a study targeting children aged 12-18 A study of 20-year-old children also found that most children preferred pictograms that contained humanoid heads and torsos (Goldsworthy et al., 2008). Loring and Wiklund (1988) also reached the same conclusion in the study of swimming pool signs emphasizing dangerous consequences. Children prefer human figures with head dislocation in signage. The second most popular is indicating symbols. For prohibition signs, children aged 4-5 years old most recognized "palm" while children aged 6 years old most recognized "cross" (Lin et al., 2015). For the "no diving" sign, children preferred designs with an exclamation point for emphasis (Loring & Wiklund, 1988).

Of course, not all studies yield patterns in pictogram preferences. Boersema and Zwaga (1989) found that the most effective pictographic representation for swimming pool safety signage for children aged 7-19 appeared to depend on the situation or activity being described, and the optimal pictogram design for describing the content of the
signage did not yield clear conclusion. Similarly, in a study of children aged 12–18 it was found that while some graphic elements in pictograms were preferred over others, no simple trends or patterns were easily observed (Korenevsky et al., 2013).

Colour preference in signage design is a point that is also examined in most articles. However, compared with pictograms, the same or similar research conclusions cannot be drawn due to differences in countries, sign types, genders, and ages. For example, Siu et al. (2017) found in a study of public safety signs for children aged 7-11 that children would apply red, which indicates prohibition and the highest level of danger in ISO, to warning signs. And in Waterson et al. (2013) study, children found that for train safety signage, the blue background was more effective than any other colour because it contrasted with the green tick and red cross, making them appear more prominent. Similarly, in the study of Siu et al. (2015), children's colour preferences have age and gender differences. At the same time, children will prefer different colours and colour combinations according to different types of signage.

Although it is impossible to draw a unified children's preferred signage colour design, most studies have found that children's preferred signage colours and ISO registered signage colours have different results (Iftadi et al., 2018; Siu et al., 2017; Siu et al., 2015; Waterson et al., 2013). This suggests that children are unable to associate different hazard levels with corresponding colours as ISO expected. Therefore, since differences in region, sign type, gender, and age all affect children's preference for sign design, it is necessary to differentiate and classify them during research.

3.2.2.4 Analyse the reasons for children’s preferences

There are only three articles explored and analysed the reasons for children's design preferences. Siu et al. (2017) In a study of children aged 7-11 years, after assessing children's colour preferences through drawings, semi-structured interviews were used to understand the reasons for children's colour preferences and map them to the framework constructed by Osgood et al. (1975). Studies have found that children associate some colours with concepts or objects. For example, according to Osgood’s four types of colour association, children associate blue and green with water and mountains, which is a specific recognition, and yellow with signage, which is concrete association, Surprisingly, children will associate red with "don't" through abstract association.
A study of children aged 12-18 reported a majority preference for the skull pictogram, which is probably the most striking element of all pictograms and the one most widely understood to convey danger (Goldsworthy et al., 2008).

Waterson et al. (2013) found in a study of train safety signage with children aged 5-10 years that children preferred and were better able to understand safety messages in signs that used human pictograms, especially when facial expressions conveyed good or specific emotions associated with bad behaviours. Through classroom discussions, it was found that children understand the meaning of the signage based on the emotions conveyed by the pictograms in the signage.

3.2.2.5 Propose design suggestions or recommendations

After assessing children's preferences, most articles present specific design suggestions or recommendations. In a study of subway safety signs, Chang (2020) found that signage pictograms designed for children should consider “warnings” and “consequences” of non-compliance. Similar design suggestions were also proposed in the study of Siu et al. (2015). At the same time, Siu also mentioned the need to include different human figures, tangible and real objects and consequences, as well as indicators and usage scenarios in signage design. Besides, the design recommendations presented in different types of signage are not exactly the same. In the design suggestions for poison warnings signs, the triangle and the character's mouth need to be present and emphasized. And due to gender differences, colorful signage may be more effective than monotonous signage or signage with fewer colors in specifically targeting girls aged 7-11 years (Siu et al., 2015).

Meanwhile, Watson et al. (2013) proposed an outline guidelines for the design of warning signs for children in a study of train safety signs for children aged 5-10 years, which include four aspect: design prototyping, general format, textual aspect and visual aspects. Every aspect is explained in detail, and it provides a relatively detailed basis for the subsequent research and design of signs for children.

While in the studies of Liumin and Wenwei (2012), Lin et al. (2015) and Zhao et al. (2017), relatively vague design suggestions were put forward, including using figuratively designed pictograms to make the design as simple as possible and easy to understand. and memories, color unity and more. And Loring and Wiklund (1988)
summarize a good warning signage for a swimming pool. There should be signal words, text messages, and concrete pictograms.

The design suggestions or outline guidelines proposed in the literature are very limited. At the same time, because age, cognition, sign type, etc. will affect children's preferences and understanding, classification research needs to be conducted according to the specific conditions of users.

3.2.2.6 Modify and improve the design outline guidelines

Conducting iterative designs and evaluating and improving signage design guidelines and suggestions are important steps to improve children's understanding. Waterson and Monk (2014) completed testing of understanding levels of existing signage, assessed children's design preferences, and assessed the level of understanding of new train safety signage. Following a series of iterative designs, a set of recommendations was developed based on existing experience and research findings aimed at taking a more holistic approach to evaluating and designing signs for children. This includes everything from preparation, setting, participants and methods about how to working with children. Importantly, the article also points out that much of the existing guidance is anecdotal in nature and currently lacks an evidence base from scientific research.

4 CONCLUSION

In this article, we outline the nature, extent and scope of research published in the journal before 31 July 2023, seeking to illuminate what is known about and future needs for children and safety signage design. Overall, the 28 literatures on this topic highlighted the worryingly low level of children's understanding of existing public safety signage. And signage design based on children's preferences has a significant positive impact on children's understanding levels. At the same time, since country, gender, age, sign category, etc. will all have an impact on children's preferences and understanding, when conducting relevant research, it is necessary to conduct separate research according to the characteristics of the target group. Our review shows that, starting in 2004, researchers from many different countries became interested in the topic of children and public safety signs, and that the amount of research on this topic has increased over the past period. However, it is impossible to draw a unified
conclusion in studies with different backgrounds, and these studies are all localized and lack programmaticity. Therefore, a lot of research is still needed to fill the gaps.

We found many discrepancies and flaws in the vast literature on this topic, the most critical being that most papers did not take children's cognitive development levels into account when selecting subjects for study. Although children are defined as anyone under the age of 18, according to Piaget's cognitive development theory, children at different ages are at different stages of cognitive development, and different stages of cognitive development will significantly affect children's mental models, reasoning methods, and understanding styles (McLeod, 2007; Flavell, 1982; Tomasello, 2000). This will lead to differences in the understanding of marks by children of different ages. When conducting research on children, consideration needs to be given to whether the children studied are at the same level of cognitive development.

There are flaws in the research methods in some literature. When conducting research on children of different ages, the same method may not be universal due to differences in cognitive development. At the same time, studies on children's design preferences and design suggestions are all based on children's lack of understanding of existing signs. However, some articles do not evaluate the understanding level of existing signs. Similarly, design suggestions for children's logos require secondary measurement of understanding levels to clarify which children's preferences have a positive impact on understanding levels. Most articles do not perform this step but make design suggestions. As Waterson and Monk (2014) pointed out, many existing studies are anecdotal in nature and lack evidence base and scientific procedures and justification.

Secondly, some factors that would affect the research results were not explored in depth. For example, cultural questions about children's color associations have not yet been resolved (Siu et al., 2017). It's unclear whether studying children in other cultures would yield similar results, and there is no comparisons have been made with children from different cultures.

At the same time, future work should also aim to conduct some form of behavioral testing to demonstrate the likelihood that child-appropriate signs actually affect children's behaviour. Although the findings suggest that children's preferences have a positive impact on comprehension levels, future research should focus on comprehensive measures of children's visual field to gather solid evidence to support the idea of installing standardized public safety signage appropriate to child characteristics in public settings.
Larger samples must be used in testing, and comprehension testing with a new sample of children will improve the general applicability of the findings and create a wider context for signage design recommendations and guidelines.

In summary, the articles included in this scoping review indicate that current research on children public safety signage is in its infancy and has not yet resulted in programmatic or instructive design recommendations or outline guidelines. At the same time, since many factors affect children's understanding level, future research needs to conduct targeted research based on the characteristics of the target group (such as country, gender, age, education level, etc.) to ensure the validity and reliability of the research results.
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