Child Pedestrian Safety Education

Applying Learning and Developmental Theories to Develop Safe Street-Crossing Behaviors

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16. Abstract

Motor vehicle crashes are the leading cause of death among young children, and 20% of these fatalities among ages 5-9 represent child pedestrians. Recent discussions in the literature on child pedestrian education have argued the effectiveness of education approaches versus engineering approaches for increasing child pedestrian safety. One of the main arguments against education is that children rarely show increases in safe street-crossing behavior after education interventions. A majority of child pedestrian education in the United States utilizes videos and classroom instruction to teach young children. Often, these programs find an increase in children's knowledge of pedestrian safety but do not show similar gains in increasing children's safety behaviors. One possible explanation for this consistent finding is that psychological theories of learning and more updated child development theories are not often used when developing programs. Interventions based on relevant learning theories and child development might be more effective in increasing safe pedestrian behaviors in young children. This report scientifically reviews the literature on child pedestrian education and discusses possible child pedestrian safety programs that could be more effective in keeping child pedestrians safe.

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EXECUTIVE SUMMARY

Motor vehicle crashes are the leading cause of death among young children. Twenty percent of fatal crashes involving children between the ages of 5 and 9 involve pedestrian-related fatalities (NHTSA, 2008). The rise of childhood obesity coupled with the growing number of advocacy groups for increased walking and bicycling could result in an increase in child pedestrian fatalities if children are not properly educated to safely negotiate traffic. There is general agreement among traffic safety professionals that children under the age of 10 should not cross traffic alone; however, research has shown that parents believe children as young as 7.6 years are old enough to cross a street (MacGregor, Smiley, & Dunk, 1999). More than likely, children will find themselves crossing a street without an adult at least once before they turn 10 years old. Unfortunately, more than half of young children observed crossing streets engage in unsafe street-crossing behavior (MacGregor, Smiley, & Dunk, 1999; Rivara, Booth, Bergman, Rogers, & Weiss, 1991; Thomson & Whelan, 2000). Therefore, it is important that children are properly trained in safe pedestrian skills. The objective of this paper is to review the research on child pedestrian safety education and evaluate the strategies based on theories of learning and child development.

In the United States, pedestrian safety education is often taught in elementary schools. It is based on some early work conducted through the National Highway Traffic Safety Administration (NHTSA) which tested the effectiveness of a film showing *Willy Whistle* safely crossing the street (Blomberg, Preusser, Hale, & Leaf, 1983). The film instructed children to stop at a curb, look left-right-left before crossing the street, and to continue searching while crossing the street. The program was considered a success because it was associated with a 20% decrease in child pedestrian crashes; however, there were very few observed increases in children's safe street-crossing behaviors. The conclusion that the program was effective may have been premature because extraneous factors cannot be ruled out. More importantly, if children's street-crossing behaviors were as unsafe at the end of the program as they were at the beginning of the program, then it is unlikely that the film, which was aimed at modifying behavior, resulted in the decrease in crashes.

In addition to decision making skills, the ability to engage in safe street-crossing behaviors relies on the fact that these behaviors are a motor skill. The habit of stopping at a street before crossing, searching for traffic, and searching for traffic while crossing needs to be built into a person's repertoire of street-crossing behaviors through practice. A successful pedestrian safety education program that produces behavioral change in children should incorporate motor skill acquisition. Children should continue to receive instruction about safely crossing the street, but the instruction should be coupled with enough practice that the motor actions become automatic. Once motor skills are automatic, there is increased mental capacity for problem-solving and decision-making.

A successful pedestrian education program must also incorporate important learning principles. For instance, a program should consider the principle of

encoding specificity. Learning that takes place in a specific context does not always transfer to a different situation. If children learn about safe street-crossing behavior in a classroom, the likelihood of it transferring to an actual traffic situation is low even if they are allowed to practice in miniature towns. In addition, people are more likely to remember what they learned if the context is similar to when it was encoded. Therefore, a program must incorporate some supervised and structured experience in real traffic situations. Lastly, while the best learning is that which is intrinsically guided, engaging in safe street-crossing behaviors is probably not intrinsically rewarding to children. In order for children to engage in safe street-crossing behaviors, a program should include positive reinforcement for correct behaviors to ensure that the habit is developed.

A successful pedestrian education program should also incorporate Vigotsky's zone of proximal development when the program involves children. The basic premise of the zone of proximal development is that learning occurs in the context of social interactions. Both peers and adults help children grasp concepts that cannot be achieved alone or through a lecture-type format. Many studies in the United Kingdom on child pedestrian education have utilized this approach and have found that young children show significant increases in safe street-crossing behaviors (Thomson & Whelan, 2000; Thomson et al., 2005; Tolmie, Thomson, Foot, McLaren, & Whelan, 1999).

The research program in the United Kingdom breaks down the street-crossing task into specific cognitive skills. Crossing the street involves cognitive skills that utilize problem-solving skills to identify a safe place to cross, visual search skills, estimating speed and distance, and predicting how long it will take a car to cross one's intended path to determine the safe time to cross. The research conducted in the United Kingdom for the Department for Transport has effectively trained children using a combination of real-traffic training, peer and adult interactions using computer simulations, and reinforcement.

While it behooves the United States to develop a similar model, the large U.S. population makes a program like this difficult to implement in every school. However, it is important to develop a program that is easy to implement that utilizes parental involvement and does not take time away from normal classroom instruction. With the alarming growth of childhood obesity, advocates are urging children to spend more time outdoors. In addition, the National Safe Routes to School Program may result in an increase in the number of children crossing traffic. It is important that we develop some innovative strategies in pedestrian education to ensure the safety of our children.

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INTRODUCTION

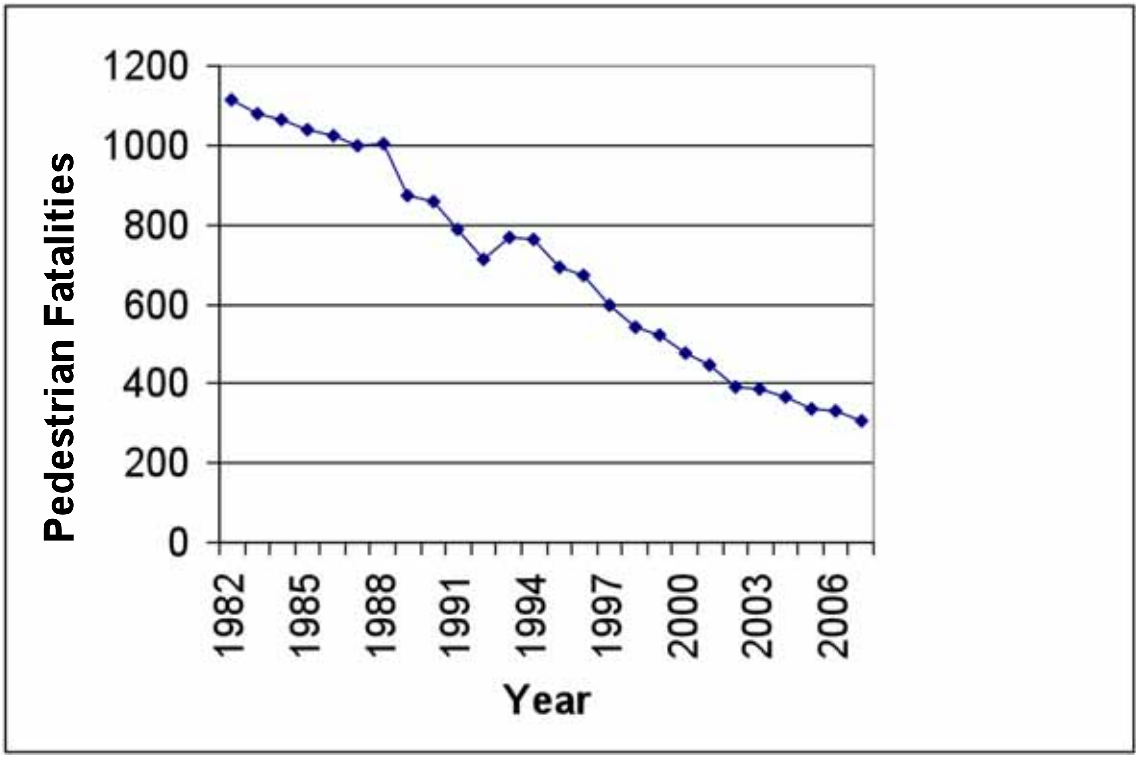
Child pedestrian safety should be an important parental concern once children develop more mobility and independence. Parents often turn to popular magazines to get the latest information on parenting concerns and strategies. *Parenting* magazine reaches nearly 11 million readers (parenting.com, 2004); yet, very few articles are published about child pedestrian safety (Finello, 2005; Hochbaum, 2000; Koontz, 2001). The most recent and brief article was published for Halloween activities and reminded parents to increase conspicuity, walk with their children on sidewalks, cross at intersections, and to make sure costumes are not too long and that shoes fit well (Finello, 2005). Koontz (2001) advised parents on safety issues for several different age groups. The only mention of crossing a street in the entire article was for children ages 7 to 8 and advised parents to create a zone in the neighborhood from which children should not stray since they are often out on their own in the neighborhood for the first time. In 2000, Hochbaum did give more specific safety strategies to parents about teaching their children, ages 8 to 9, to cross at a green light; to look left, right, left before crossing; not to cross between parked cars; and avoid streets with heavy traffic or difficult intersections.

With the little attention focused on child pedestrian safety in a widely read parent magazine, it is not surprising if few parents realize that motor vehicle crashes are the leading cause of death in children ages 4 to 15 (NHTSA, 2008) and that 20% of all children ages 5-9 who were in fatal traffic crashes were pedestrians (NHTSA, 2008). Children in this age group are more likely to be involved in pedestrian crashes mid-block in residential areas near the home. Boys are more likely than girls to be involved in pedestrian crashes; urban areas pose a greater risk to children than rural areas; and socioeconomic status (SES) and its correlates increase children's risks for pedestrian injury (Agran, Winn & Anderson, 1994; Applied Management Science, 1985; Jonah & Engel, 1983; Kraus et al., 1996; Lightstone, Dhillon, Peek-Asa, & Kraus, 2001; Nance, Hawkins, Branas, Vivarelli-O'Neill, & Winston, 2004; Snyder & Knoblauch, 1971; Stevenson, Lo, Laitin, & Jamrozik, 1992).

Risk Factors

Pedestrian fatalities for children age 14 and younger have declined since the 1980s (See Figure 1); however, this may be a reflection of decreased pedestrian exposure. Over time, the increased use of auto transportation resulted in a decreased need for walking as a means of transportation. Exposure has been measured several different ways with the number of roads crossed used most frequently (Howarth, Routledge, & Repetto-Wright, 1974; Jonah & Engel, 1983; Keall, 1995; Macpherson, Roberts, & Pless, 1998; Posner et al., 2002; Rao, Hawkins, & Guyer, 1997; Roberts, Keall, & Frith, 1994; Roberts, Norton, & Taua, 1996; Routledge, Repetto-Wright, & Howarth, 1974). Exposure has also been measured in terms of time spent in and near streets (Bly, Jones, & Christie, 2005; Jonah & Engel, 1983; Keall, 1995; Posner et al., 2002), mode choice (Bly et al., 1994; Rau et al., 1997; Roberts & Norton, 1994), distance traveled (Jonah & Engel, 1983), and by the number of pedestrians crossing predetermined roads (Cameron, 1982; Knoblauch, Tobey, & Shunaman, 1984).

Figure 1. Pedestrian Fatalities for Age 14 and Younger From 1982 to 2007



Source: NCSA

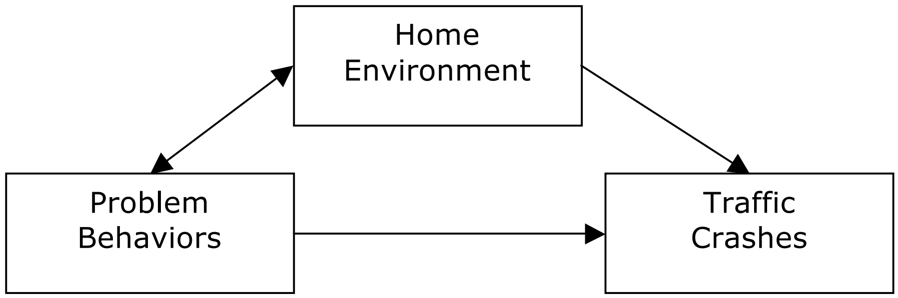
As noted, boys are more likely than girls to be involved in pedestrian crashes. Although exposure is one possible explanation for the sex difference, research has not been able to document this. A majority of studies have found that boys and girls do not differ in exposure (Bly et al., 2005; Howarth, Routledge, & Repetto-Wright, 1974; Knoblauch et al., 1984; Macpherson, Roberts & Pless, 1998; Roberts, Norton, & Taua, 1996; Routledge, Repetto-Wright, Howarth, 1974). Several other studies have found that girls have greater exposure than boys (Roberts, Keall, Frith, 1994; Bly et al., 2005). Often, gender differences in exposure depend on how exposure is measured.

Exposure has been shown to be a factor in differences across SES in pedestrian crashes where children from low SES backgrounds are at a greater risk for pedestrian injury than children of high SES backgrounds. Researchers have found that low SES is associated with particular environments that increase the likelihood of pedestrian injury. Roberts and Norton (1994) found that twice as many children in the lowest SES category walked home from school compared to children in the highest SES category. These differences in pedestrian exposure are likely a reflection of economic constraints where the majority of children whose families did not have cars were significantly more likely to walk to school than those whose families did have cars (Roberts & Norton, 1994; Roberts et al., 1996; Johnson, Geyer, Rai, & Ragland, 2004; Stevenson, Jamrozik, & Burton, 1996). In addition, children from low-SES families tend to live in crowded urban areas where exposure to heavy traffic flow is high (Bagley, 1992; Braddock et al., 1991; Christoffel et al., 1996; Joly, Foggin, & Pless, 1991; Lascala, Gruenewald, & Johnson, 2004; Rivara & Barber, 1985; Stevenson et al., 1996; West et al., 1999). Other factors associated with low SES that increase children's risk of pedestrian injury include living in single-parent households (Durkin et al., 1994; Rivara & Barber, 1985; Roberts, 1994; Braddock et al., 1991; Bagley, 1992), having a young mother (Roberts, 1994), having parents with low education (Durkin et al., 1994; Rivara & Barber, 1985), and living in areas with a high youth population, high unemployment, and few high-income households (Lascala, Gruenewald, & Johnson, 2004). The difficulty in analyzing precise causal factors is that all of these factors are interrelated.

Some studies have found that behavioral problems or personality factors are associated with an increase in a child's risk for pedestrian injury (Stevenson, Jamrozik, & Burton, 1996; West et al., 1999; Hoffrage, Weber, Hertwig, & Chase, 2003). West et al. (1999) recruited children who were admitted to emergency departments to participate in their study. Fifteen percent of the children in their sample had at least one pedestrian or cycling injury while the remaining children had no traffic-related injuries. West and colleagues assessed children's problem behavior with a Self-Report Delinquency Survey and gave parents and teachers the Rutter Scale which measured impulsiveness, hyperactivity, anxiety, and problem behavior. Parents and teachers rated each behavior on the scale in terms of frequency or degree of severity. They found that after controlling for age, sex, parents' occupations, time spent in traffic, parents' age, and housing type, children who had high self-report social delinquency scores were three times more likely to be involved in a pedestrian or bicycle crash than those with low scores. They also found that compared to girls, boys were less socially responsible, showed greater problem behavior and greater risky road user behavior which might explain the sex differences in pedestrian injury.

West et al.'s study suggests that a possible intervention would target children with particular behavior problems. Unfortunately, there are a number of important issues to consider before reaching this conclusion. Most importantly, the study found a relationship between certain problem behaviors and traffic-related crashes. This does not necessarily mean that the problem behaviors resulted in the traffic crashes. Children with problem behaviors may come from disadvantaged families and environments that are not conducive to dealing with problem behavior. These families may also lack the resources for proper supervision of their children resulting in a high number of traffic crashes. In this case, there is not a direct link from problem behavior to traffic crashes but the home environment has a more direct effect on traffic crashes (see Figure 1). To better identify causal pathways, a research study should incorporate a case-control match for the children recruited from the emergency departments.

Figure 2. Home Environment as a Mediating Factor Between Problem Behaviors and Traffic Crashes



In a more controlled laboratory study, children who were classified as risk-takers made riskier street-crossing decisions than children classified as risk-avoiders. Hoffrage et al. (2003) assessed risk through a game which involved obtaining a number of valued items. In a gambling game, children were presented with 10 closed boxes of which 9 contained a sticker and 1 contained a "'devil' in it" (p. 251). Children could open as many boxes they wanted and take the sticker inside but if they opened the box with the devil they would lose all of their stickers and the game would be over. The optimal strategy is opening 5 boxes because it results in the highest expected outcome. Therefore, opening more than 5 boxes resulted in a classification of risk-taker. Children who opened more than 5 boxes were presumably doing so because they wanted to obtain as many stickers as possible regardless of the risk. Children were categorized as risk-takers or risk-avoiders based on their performance in the gambling game.

Children's risk in traffic was also assessed in the study. The researchers took the children to the curb of a one-way street that had no stop signs or traffic signals. Children watched the traffic and stepped onto a mat to indicate when they would cross the street during a gap[1] in traffic. The mat activated a video camera on the other side of the street to measure the time it took the car to cross the intended path. To define gap sizes, Hoffrage et al. defined medium-size gaps as ranging from 7 seconds to 12 seconds between cars because it was at these two endpoints that risk-takers and risk-avoiders made 50% go-decisions and 50% stay-decisions, so uncertainty of a safe crossing was high. Gaps less than 7 seconds were considered short and potentially unsafe and gaps over 12 seconds were considered long and safe. They found that during short gaps and medium gaps, risk-takers were significantly more likely to make go-decisions than risk-avoiders. More specifically, risk-takers made 12.5% go-decisions compared to risk-avoiders who made 2.8% go-decisions during short gaps and 58.4% go-decisions compared to risk-avoiders who made 40.3% go-decisions during medium gaps. Hoffrage et al. computed a hypothetical crash rate for the two groups and found that risk-takers had a crash rate of 14.4% and risk-avoiders had a crash rate of 3.6%.

[1] A gap is the interval between passing cars.

There were sex differences in children's decisions to cross the street; however, these differences were small in comparison to the observed differences between risk-takers and risk-avoiders. During gaps that were 7 seconds or less, boys made 9% go-decisions compared to girls who made 7% go-decisions. Boys had a higher hypothetical crash rate than girls, with boys having a rate of 3.3% and girls with a rate of 2.0%. While this study reveals why some children may be more prone than others to make risky street-crossing decisions, it is still unclear why more boys are involved in pedestrian crashes than girls especially when there were an equal number of boys and girls in the risk-taker group.

Hoffrage et al.'s (2003) study suggests that children who are risk-takers may have a greater risk of pedestrian crashes; however, the results must be interpreted with caution. The assessment of risk-taking was based on a game where risk involved obtaining a number of valued items. Children who were classified as risk-takers opened more than five boxes in the gambling game presumably because they wanted to obtain as many stickers as possible regardless of the risk. In this case, risk was associated with a gain. However, when risk is taken on a street-crossing task, there is no tangible gain (i.e., immediate reward). In addition, while the measurement used for gap-crossing in the study has proven to be useful and safe (Demetre et al., 1992; Lee et al., 1984; Young & Lee, 1987), children know that there are no risks associated with making a risky decision and may make riskier decisions in this paradigm than they would if they actually had to cross a street. Lastly, even though there appears to be a relationship between risk-taking and safe street-crossing, this relationship may be mediated by children's poorly developed impulse control.

Several parent-related factors have been shown to increase children's risk for pedestrian injury. For instance, children whose parents provided low levels of supervision are at an increased risk of pedestrian crashes (Christie, 1995; West et al., 1999). From neighborhood observations, Thackray and Dueker (1983) found that 80% of the time, children played in or near the street without adult supervision. Children were 2.5 times more likely to dart out into the street without looking for traffic when supervision was absent than when supervision was present.

Parents often overestimate children's knowledge and abilities of safe street-crossings. They perceive their children as knowing more than they really do. Dunne, Asher, and Rivara (1992) examined parental expectations of their children's knowledge and road safety behavior. Parents overestimated their children's knowledge and road safety behavior, especially for 5- and 6-year-old children. Parents expected their young children to be as proficient in knowledge and behavior as 9- to 10-year-old children. This might explain the lack of supervision among young children who should be supervised. MacGregor, Smiley, and Dunk (1999) found that parents thought children as young as 8 years old can safely cross roads alone and thought children as young as 7.6 years old could safely cross a road with no stop sign or signal with same-age friends. In addition, they found that parents think their children engage in safety behaviors more often than they really do and report teaching their children safe pedestrian behavior. The most common behaviors parents reported teaching were look both ways (100%), meaning of walk/don't walk symbols (80%), stop before crossing (70%), meaning of traffic light colors (70%), and meaning of flashing symbols (63%).

Children in Traffic

Researchers who have observed children's behavior when crossing the street have shown that children engage in very few safe street-crossing behaviors. Zeedyk, Wallace, and Spry (2002) created a treasure hunt game which involved several different types of street crossings. The roads were closed to traffic while 5- to 6-year-old children engaged in the game; however, the children did not know that traffic was closed off. Traffic was allowed between games and a police officer drove a car through the street during the game which gave the appearance of normal traffic occurring in the road. Zeedyk et al. found that only 11% of the children looked any direction before reaching the curb; 41% of the children stopped at the curb; only 7% looked any direction while stopped at the curb; 15% looked any direction while crossing the road; and 74% of the children ran or skipped while crossing the road. When a car was approaching, 60% of the children looked at the moving car and 15% waited for the car to move away before crossing.

Although the low percentage of children engaging in safe crossing behaviors is alarming, adult presence may have confounded the results. Children engaged in the game by themselves; however, there were a large number of adults available to ensure the children's safety. Children may have assumed that these adults were looking out for them and their behaviors may not have been as natural as if they were observed out in the real world as the authors had hoped. In fact, other researchers who have observed children in their daily routines have found higher percentages of safe street-crossing behavior than Zeedyk et al. but the low levels of engagement are still of concern. For instance, MacGregor, Smiley, and Dunk (1999) found that children ages 5-12 stopped at the curb 43% of the time, looked any direction before crossing 43% of the time, and looked while crossing 49% of the time. Rivara, Booth, Bergman, Rogers, and Weiss (1991) observed 33% of children stopped at the curb before crossing the street and 25% looked for cars before stepping into the street. Finally, Thomson and Whelan (2000) reported that half of their 6-year-old participants stopped at the curb; and though the children made head movements 80% of the time, they seemed to be going through the motions as opposed to conducting a visual search.

Parents are role models to their children. Unfortunately, Quraishi et al.'s (2005) observations of children and parents crossing the street suggest that parents do not always model the correct behavior for children. They found that when parents crossed mid-block with their children, 68% of the parents stopped at the curb and 59% scanned for traffic before crossing the street. While these percentages are higher than what is typically observed among children crossing streets without adults, parents may be sending the message to their children that stopping at the curb and scanning for traffic are not 100% necessary when crossing the street. Some street situations allow for flexibility in utilizing safe street-crossing behaviors. For instance, an adult may scan the street prior to arrival at the curb. If it is safe to cross, there is no need to stop at the curb and search for traffic. Children, however, may not grasp that different situations allow for an alteration in street-crossing behavior and mistakenly learn that it is not necessary to stop at the curb all of the time. Low levels of engagement were also seen at intersections with a traffic light or stop sign where parents were observed stopping at the curb 81% of the time but only scanned for traffic 55% of the time. In these situations, parents' assumptions of right-of-way may have contributed to the low levels of traffic scanning. Similar to behaviors at mid-block crossings, children may not know these subtleties and may assume that scanning is not important.

Safety education can be one of the best ways to arm children against traffic hazards. Safety tips often given to children for crossing the street involve very easy-to-understand directions. Safe Kids Worldwide (2006) advises children to "look both ways for danger before and while crossing the street" and to "walk, do not run, into the street." The United Kingdom's Green Cross Code (2006) and Victoria's guidelines (2002) for safely crossing the street both involve finding a safe place to cross, stopping at the curb, looking and listening for traffic before and during crossing, and walking instead of running. While all of these directions are simple enough for children to understand, and they convey the basic yet important steps necessary to cross the road, the individual tasks involved in crossing the street are complicated skills. While these skills can be learned, they are not skills that emerge naturally in young children.

In order to cross the street safely, young children must engage in a number of cognitive skills (Thomson et al., 1996). First, children must know and identify a safe place to cross. These sites may include intersections, places with unobstructed views, and places with crosswalks. It also involves recognizing that crossing between parked cars, near a curve in the road, or below the crest of a hill is dangerous because a driver cannot see a pedestrian with enough time to avoid a collision. After stopping at a curb, children must pay attention to traffic. This involves knowing what to search for, maintaining attention on traffic, and not getting distracted by irrelevant cues (a kite coming into view, a dog walking along the sidewalk, etc.). After identifying and attending to traffic the child pedestrian has to coordinate visual and auditory information to estimate the speed of vehicles and the timing of their arrival. Children then have to predict which gap will be the safest to cross and to act quickly. Thus, for the young child, he or she must be able to engage in a number of cognitive processes all at once in situations where these decisions must be made quickly.

Engineering and Education Countermeasures

The injury research community has repeatedly debated the value of child pedestrian safety education versus the implementation of engineering countermeasures (Schieber & Vegega, 2002). The proponents of engineering countermeasures argue that any gains achieved through pedestrian training are too modest to make a difference in child pedestrian injuries and fatalities. While training can increase children's safe street-crossing behaviors, there is no guarantee that training alone will keep all trained children safe in traffic. Proponents of engineering countermeasures argue that the best solution might be to develop environmental changes that would keep children out of streets and may be more effective than education. However, solely limiting countermeasures to engineering design deprives children of learning basic traffic interaction skills that they need when riding a bike or driving a car when they become teenagers.

Others argue that child pedestrian-skills training has resulted in significant increases in children's safe street-crossing behavior when compared with traditional classroom educational formats. Proponents of this view argue that children cannot be isolated from traffic and that children eventually have to learn the rules of the road to ride a bike or, later, drive a car. If pedestrian education is entirely left to parents, parents may be ill-equipped to provide children with the proper education they need, especially when parents tend to overestimate their children's abilities (Dunne et al., 1992). If children receive no education, they may learn by trial and error, which is a very dangerous way to learn how to negotiate traffic.

While the ideal solution is a combination of engineering and education countermeasures, this paper will focus on child pedestrian safety education. A consistent and important criticism of traditional child pedestrian education is that education increases knowledge but has little if no effect on behavior. This dissociation can be explained through learning theories and theories of child development. Education programs based on learning theory and child development will result in more effective programs that will help children safely negotiate traffic.

PEDESTRIAN SAFETY INTERVENTIONS

Safety Education in the United States

Child pedestrian safety in the United States mainly utilizes audio, video, and workbook instruction for children in the 2- to 12-year-old age group (NHTSA, 2006). Much of the current child pedestrian safety education stems from NHTSA's early work on the interventions using videos with *Willy Whistle* (Blomberg, Preusser, Hale & Leaf, 1983; Cleven & Blomberg, 1994).

Blomberg et al. (1983) based their program on the finding that children are often involved in dart-out and mid-block pedestrian crashes (Snyder & Knoblauch, 1971). Dart-out crashes are instances where the pedestrian is struck while crossing the street and where there was insufficient time for the driver and pedestrian to see each other before the crash. The driver usually describes the pedestrian as suddenly appearing in the street. Often these crashes occur midblock where there is no intersection or crosswalk.

Blomberg et al. created short films with *Willy Whistle* to teach young children the importance of stopping at the curb mid-block and looking left-right-left for traffic. Children in kindergarten through grade 4 in Los Angeles, Columbus, and Milwaukee saw the footage in their classrooms and all children had the opportunity of seeing *Willy Whistle* on TV during public service announcements. Blomberg et al. found an increase in knowledge among school-age children after the intervention.

While the analysis showed a statistically significant behavior change, the overall penetration was fairly low. In Los Angeles, 5% of the children observed before the intervention completed a correct left-right-left search which increased to 12% after the intervention. In Columbus, 5% of the children observed before the intervention completed a correct left-right-left search which increased to 7% after the intervention. In Milwaukee, 12% of the children made a full stop before the intervention, and 17% of the children made a full stop after the intervention. Before the intervention, 3% of the observed children in Milwaukee conducted a correct left-right-left search and 9% of the observed children conducted a correct search after the intervention.

Changes in making a full stop at the curb were counterintuitive in Los Angeles and Columbus. In Los Angeles, 20% of the children observed before the intervention made a full stop at the curb or at the edge of a parked car, while 17% of the children observed made a full stop after the intervention. In Columbus, 15% of the children made a full stop before the intervention, and this decreased to 12% after the intervention. However, despite the low percentages of correct stopping and searching, dart-out crashes involving pedestrians age 14 and younger declined by an average of 20%.

The puzzling aspect of these findings is that although children showed very little behavioral change as a result of the interventions, there was still a marked decrease in child pedestrian dart-out crashes. Upon closer inspection of the crash distribution by age, there was no reduction among children ages 1-2, an approximately 35% reduction among children ages 3-4, an approximately 31% reduction among children ages 5-6, and an approximately 5% reduction among children ages 7-13. Based on the design of the study, it would be expected that the greatest reductions in crashes would have been seen in children ages 5 through 10 because they saw the *Willy Whistle* videos at school and at home, while the children age 4 and younger could only see the videos at home. However, the greatest decreases occurred in 3- to 4-year-old children followed by the 5- to 6-year-olds. While it is possible that these results reveal that the intervention works best for children ages 3-6 (Blomberg et al., 1983), it is also possible that the reductions among this age group may have been due to increased parental supervision. When parents of young children saw the public service announcements, they may have realized or been reminded of the dangers of crossing the road and either increased supervision or limited their young children's outside play.

Cleven and Blomberg (1994) used a similar strategy in developing pedestrian safety training for elementary school bus riders. Video instruction, which included *Willy Whistle* video footage for kindergarten through grade 3 and a video targeting grades 4 through 6, was shown to children in classrooms. Children also participated in a 40-minute school bus practice session. The study was not designed to look at changes in crash patterns, but did replicate the results from Blomberg et al. (1983). Children showed increases in safety knowledge after the intervention compared to pre-test data but showed very little behavioral change after the intervention. Children from the treatment condition and the comparison condition were observed and scored for 14 behaviors while they waited for and boarded the bus for school.

Cleven and Blomberg found that 5 of the 14 observed behaviors showed statistically significant changes after the intervention. However, most of these changes were not in the expected direction. For instance, there was an increase in the percentage of children waiting five or more feet away from the curb for the bus. However, the proportion of children who waited at least five feet from the curb increased from pre-test to post-test in *both* the treatment and comparison group. Therefore, it is unlikely that this increase was due to the intervention. There was a significant change from pre- to post-test of children using the handrail while boarding. However, this change was a decrease from pre-test to post-test in the proportion of children using the handrail, which is opposite of what the intervention was trying to achieve. There was also a significant increase in the proportion of children in the treatment condition walking three to four feet from the side of the bus from pre- to post-test. However, the recommended distance from the training was six feet from the side of the bus.

Some of the changes observed were in the expected direction and thus attributable to the intervention. For instance there was in increase in the number of children waiting for the door to open before moving to the bus and waiting for the driver's signal to cross the street when the children were waiting across the street for the bus. While these increases in behavior may be attributed to the intervention, it is unlikely that children developed all of the necessary pedestrian behaviors to keep them safe in traffic.

Other researchers have found that increasing safe pedestrian knowledge may not lead to changes in safe pedestrian behavior. For instance, Zeedyk, Wallace, Carcary, Jones, and Larter (2001) evaluated the effectiveness of commercially marketed products in teaching children about pedestrian safety. One group of children received pedestrian training with a play mat model. The experimenter guided children on journeys with the play mat, praised safe behaviors, and suggested alternate decisions to those that were unsafe. In a second group, children played in groups of four with a road safety board game that was sold in stores throughout Britain. The final experimental group participated in a discussion where the experimenter used posters and flip-charts and led an interactive session. All three interventions resulted in modest but significant increases in knowledge immediately after training and 6 months later. Unfortunately, when trained children were observed and compared with a control group, there were no differences between the groups in pedestrian safety behavior.

Unfortunately, one important problem with educational programs that rely on videos or a lecture format to teach children about traffic safety is that there is very little behavioral change even though there are knowledge gains. Indeed, in his review of the literature, Rothengatter (1981) found that, in general, video training improved children's knowledge of safety but did not change behavior. There are a number of reasons for this phenomenon based on cognitive and developmental theory.

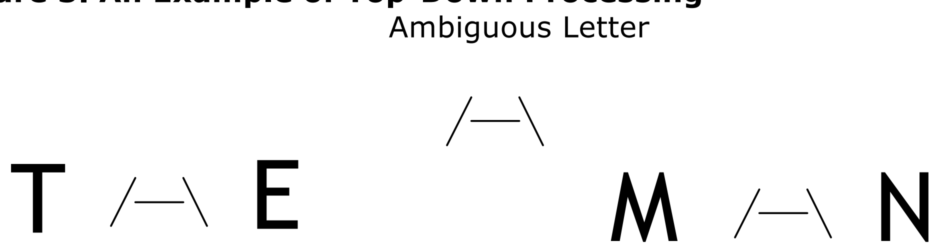
Psychological Theories of Learning

The human species lives in an ever-changing environment and, thus, must constantly learn to adapt to the environment. There is a long and detailed history of the development of learning theories that can be applied to learning safe street-crossing behaviors, but this paper will focus on the most relevant theories of learning that pertain to the learning of safe street-crossing behaviors. Learning can be defined as "the process by which relatively permanent changes occur in behavioral potential as a result of experience" (Anderson, 1995). Memory is an integral part of learning, whereby, the experience must be remembered in order for the learning to occur and last (Anderson, 1995). The theories and research that follow define the complex mental processes involved in learning.

Top-Down and Bottom-Up Theories of Processing

Most people are familiar with the experience of having difficulty recognizing a co-worker in a store on the weekend because the co-worker is out of context. More specifically, the identification of a stimulus or object occurs more quickly when it is in context. Cognitive psychologists make the distinction between top-down and bottom-up processing. Top-down processing (also known as conceptually driven processing) occurs when people's existing knowledge helps to make sense of incoming information (Matlin, 1989). For instance, for the average American person who sees a sloppy letter (see Figure 2), how that person interprets the letter depends on the context in which it appears. The letter can be seen as an "H" when between a "T" and an "E" and seen as an "A" between an "M" and an "N." Traditional classroom-type safety interventions utilize conceptually driven learning by teaching children the rules of crossing the road safely. Conceptually driven learning is best measured through tests involving recall or recognition of the information learned; in fact, children perform better on tests examining safety knowledge after safety interventions. Engaging in safe behaviors when crossing the street, however, is a motor skills domain which involves bottom-up learning.

Figure 3. An Example of Top-Down Processing



Bottom-up processing (also known as stimulus-driven processing) involves recognizing simple features of a stimulus to recognize complex patterns (Matlin, 1989). For instance, understanding the meaning of a sentence requires reading and processing the meaning of each individual word to understand the meaning of the sentence as a whole. Children and adults who learn a language begin by learning words and later use words to string together sentences. We can apply this bottom-up processing to learning how to cross the street safely. When children need to learn safe street-crossing behaviors, they need to learn and engage in the individual components of the task: stopping at the street, identifying a safe place to cross and moving to a new position if necessary, looking for traffic, identifying cues that mean it is safe to cross, crossing while walking, and continuing a search for traffic. Children can learn these steps, but in order for these steps to come to fruition, children must actively engage in each component a number of times to not only build the habit of doing them but to build on a conceptual understanding of what it means to cross safely.

The application of learned material, either through testing or real-world application, manifests differently depending on how the information was learned. For instance, a person who sits in a classroom lecture about new word processing software will remember the information differently if he or she participated in hands-on training as opposed to a classroom-type lecture format. The fact that children rarely show increases in behavior after pedestrian education is due to issues of levels of processing and transfer-appropriate processing.

Transfer-Appropriate Processing and Encoding Specificity

Transfer-appropriate processing is the principle that memory is best if the mental processes involved at study match the processes needed at recall. In an example of traditional cognitive research, Morris, Bransford, and Franks (1977) gave participants a list of words to learn. In one list, words were paired with the antonym thereby priming participants to process the words' meanings. The other list of words was paired with a rhyming counterpart thereby priming participants to process the phonetic aspects of the words. At test, participants who processed the meaning of the words recalled more words when a different antonym was present in the test than when a rhyming word was present in the test. Subjects who processed the phonetic aspects of the word recalled more words when a different rhyming word was present in the test than when the antonym was present in the test.

The issue of matching the test with the learning situation is also applicable to the type of test when it comes to levels of processing. Information learned through top-down processing is best measured with conceptual tests of knowledge such as recall and recognition tests, while information learned through bottom-up processing is best measured through data-driven tests (Blaxton, 1989). These differences in the learning process are typically studied using words lists. In Blaxton's study, participants studied lists of words where some words were presented as-is, with semantically related primes (e.g., *hawk* before *eagle*), and with a semantically related word and single letter clue (e.g., *hawk-e* for *eagle*). The theory was that when words are merely presented, learning takes place through bottom-up processing, and words presented with a semantically related word activate top-down processing.

The ability to remember words that are learned depends largely on the nature of the test. Words learned through a semantic association involving top-down processing would best be remembered through tests that tap into conceptual knowledge. However, words learned through bottom-up processing would be poorly remembered on conceptually driven tests but best remembered with tests that access the phonetic or perceptual features of the words. During the test phase, Blaxton had participants either answer general knowledge questions related to the words learned (e.g., What was the name of Armstrong and Aldrin's lunar module? Ans. Eagle), semantically cued recall test (*falcon* was a cue for *eagle*), or word fragment completion (e.g., E_G_E). Blaxton did find support for this inverse relationship because words learned through a semantic association were better remembered with the general knowledge test and semantically cued recall, while the words that were presented without context were best remembered with the word fragment completion test (see Table 1).

Table 1. Proportion Correct as a Function of Study Condition and Type of Test (Blaxton, 1989)

	Study Condition		
Type of Test	Generate	Context	No Context
Conceptually Driven			
General Knowledge	.50	.38	.33
Semantically Cued Recall	.67	.46	.51
Data Driven			
Word Fragment Completion	.46	.62	.75

This dissociation between the recall of the information learned during different levels of processing may explain why children who participate in pedestrian safety education show increases in knowledge but very little concurrent changes in behavior. Traditional child pedestrian safety education is often conducted in a classroom setting where children learn about the rules of the road and what to do when crossing the street. Occasionally, the program might involve children trying the behaviors a couple of times; but, for the most part, learning is expected to take place through conceptual understanding that will be applied to behaviors in traffic. The problem is that this model of education assumes that learning will be a top-down process, yet learning to behave in specific kinds of ways in specific situations is a bottom-up process. Therefore, in order to get children to increase their safe street-crossing behaviors, they need to engage in the specific behaviors a number of times in locations similar to where they will actually be performing them.

Another related issue is that information is better remembered if the physical situation at test and recall are the same, also known as encoding specificity (Tulving, 1975). For instance, people at times may find themselves leaving their bedroom with a goal in mind, only to completely forget it as they arrive in the kitchen. Often, going back to the bedroom helps jump start the memory process. Another possible reason why traditional child pedestrian safety education has not been effective in changing behaviors is that children learn in a classroom or miniature city which is far removed from the real traffic situation. Children are more likely to remember the safe street-crossing behaviors better if they learned near actual roads than had they learned in a classroom.[2] In fact, Rothengatter (1981) concluded that the real street with real traffic "seems to be the most promising instructional situation to train traffic behavior" (p. 251). Therefore, in order to get children to engage in safe street-crossing behaviors, children need to learn by engaging in the requisite behaviors in an environment similar to where they are expected to perform them (i.e., outside near streets). Building the behaviors requires repetition of the actions, suggesting that safe pedestrian behaviors are a motor skill.

Skill Acquisition

One important aspect that distinguishes between pedestrian education and traditional subjects taught in classroom-type settings is that pedestrian education involves the development of a skill while successful classroom type education involves the development of knowledge. A skill is defined as "proficiency, facility, or dexterity, that is acquired or developed through training or experience" (American Heritage Dictionary, 2000). The key part of this definition is that a skill is developed through practice. Riding a bike, learning to walk, and shooting a basketball successfully all require a proficient amount of practice to be executed well. Teaching children to behave safely in traffic is no different and requires active participation on the part of the child.

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[2] Clearly, there are several issues involved with training children near roads and in traffic and these will be addressed later on the paper.

Skill acquisition involves 3 stages (Anderson, 1995) of development. The first stage is the cognitive stage where the learner is given instructions or an example of how to perform the task. Pedestrian safety education techniques that employ videos, workbooks, and presentations would fall under this first stage of skill acquisition. Children are taught the rules of the road and these methods have proven effective in increasing children's knowledge (Rothengatter, 1981). This is known as declarative knowledge which is knowledge of facts (Anderson, 1995).

In the second stage of skill acquisition, called the associative stage, a transition occurs during which the skill moves from a declarative representation to a procedural representation. This transition occurs because practice of the skill not only helps to solidify the declarative knowledge gained but also begins to make the skill automatic. Therefore, if children are allowed to practice what they have learned through videos, workbooks, and demonstrations, then the skills themselves (stopping at a curb, looking for traffic, recognizing what makes it safe to cross) become ingrained in their behaviors. If programs include a simulation component but children are not given enough practice, the skill would not transition from the cognitive stage to the associative stage.

The final stage of skill acquisition is the autonomous stage. The execution of the skill becomes more automatic, and less cognitive effort is needed to execute the skill. This allows for increased problem-solving without having to spend mental resources on the execution of the actual skill. Once the skill to stop at the curb is ingrained, children can determine if that is the best place to see traffic and figure out a better position if it is not. The fact that a majority of child pedestrian crashes are due to dart-out behavior suggests that children do not have the habit of stopping at the edge of a street before venturing across. Child pedestrian education, therefore, must ensure that safe pedestrian skills have the chance to develop into full acquisition.

Reinforcement and Learning

Learning how to ride a bike, learning how to swim, and even learning how to work a computer all hold some intrinsic rewards that facilitate the repetition of these actions. For instance, learning the movements necessary for swimming keeps a person from drowning and gets the person from point A to point B. Learning how to swim does not occur in one single session but occurs though repeated practice and multiple lessons. While safely crossing the street has the intrinsic reward of not getting hit by a car, it is not a set of actions that have immediate, noticeable rewards that naturally reinforce the behavior. One can get from one side of the road to the other without engaging in safe behaviors and just hope for the best.

To build the habit of safe street-crossing behaviors, external rewards or positive reinforcement must be used to solidify the behavior. While there are a number of theories that explain how both positive and negative reinforcement facilitate learning (Anderson, 1995), the most basic level is that positive reinforcement elicits behavior and negative reinforcement extinguishes behavior. The most striking positive outcome of reinforcement can be seen in behavior modification programs for autistic children. Autistic children can learn language and positive social behavior through structured behavior modification sessions that provide positive reinforcement (Lovaas, 1987). An example of negative reinforcement can be seen when children learn not to touch a hot iron after the negative reinforcement of getting burned.

The most effective way to increase children's safety behaviors is to apply positive reinforcement for the target behaviors. Premack (1959, 1965) observed that the most effective positive reinforcement is when highly valued behaviors or rewards reinforce less valued behavior. Adcock, Thangavel, Whitfield-Gabrieli, Knutson, and Gabrieli (2006) conducted a study looking at the effects of varying levels of reward on memory and brain activation. Participants studied a list of words on a screen while in a functional magnetic resolution imaging (fMRI) scanner. Before the presentation of each word, a dollar amount appeared on the screen indicating the amount of money the participant would receive for remembering the word. Participants received a recognition test 24 hours later. Adcock et al. found that brain activation preceded the presentation of a high reward stimulus and activation continued during the presentation of the stimulation. In other words, the brain prepares itself to remember something if the reward is valuable. Therefore, in order to increase children's safety-related behaviors, meaningful positive reinforcements should be incorporated into a training program.

Developmental Theories

Another factor that must be considered in regard to developing appropriate pedestrian education for children is cognitive development. Some researchers have argued that children under the age of 9 or 10 do not have the cognitive skills necessary to learn the complex skills involved with crossing the street (Sandel, 1975; Vinje, 1981) because under Piagetian theory young children are not at the appropriate stage of development to allow them to master the pedestrian task. While developmental researchers have found that children know more than Piaget believed, Piaget's theory of cognitive development deserves a brief discussion because it is the foundation of more current developmental theories.

Piaget's Theory of Cognitive Development

Piaget's theory of cognitive development consists of four stages that children progress through, culminating in the final stage of formal operations or the level of adult thinking. At each stage children learn about the world within the constraints of their cognitive abilities. A child learning language will often simplify the language learning process by using one distinguishing feature to apply to all similar objects. For instance, a 1-year-old child hears his father refer to a creek when they go out walking in the woods. The young child discerns that his father is referring to the body of water they throw rocks into and begins to call all bodies of water "creek."

As children get older, the shift from one Piagetian stage to the next occurs when there is a conceptual shift in children's understanding of the world. With age, the 1-year-old child who referred to all bodies of water as a "creek" begins to distinguish differences between bodies of water a year later. Some bodies of water flow and take up space like a street or sidewalk, while others do not flow and are' more circular in shape. The young child begins to redefine his definition of "creek" and learns the appropriate words for the different bodies of water.

Piaget's four stages of cognitive development pertain to certain age ranges and each stage is associated with particular conceptual development.[3] Children begin at the sensory-motor stage of cognitive development until they reach approximately 2 years of age. At the sensory-motor stage, children develop motor skills, intention-directed behavior, object permanence, and explore the world through a sucking reflex. From ages 2-7, children are in the pre-operational stage of development. Children in this stage understand the use of symbols, focus on only one aspect of an object or situation, obtain the ability to believe in something without knowing why she or he believes in it, do not take the points-of-view of others, and are unable to conserve mass, volume, and number. The next stage of cognitive development is the concrete-operational stage from ages 7-11. At this stage, children can take into account multiple aspects of a problem to solve it; understand that numbers or objects can be changed and returned to their original state; can conserve mass, quantity, and length; can serially order objects; can categorize objects; and can view things from another person's perspective. The last stage of cognitive development is the formal operations stage which begins around 11 and continues through adulthood. This stage is characterized by the ability to think abstractly and draw conclusions from available information. Children at most risk for pedestrian-related injuries and fatalities are children ages 5-9 who, according to Piagetian theory, are in the pre-operational and concrete-operational stages of development.

There are several important conceptual developments that affect children's ability to comprehend the complex dangers of traffic. For instance, children ages 5-7, who are in the pre-operational stage of cognitive development, have difficulty taking another person's perspective. This becomes especially important in the road environment when young children decide to cross the road near a curve in the road. Because children this age see things from their perspective only, they fail to recognize that someone driving a car around the curve may see them when it is too late to avoid crash. Children this age, however, can be told that it is dangerous to cross at certain types of places (curves, hills, between parked cars, etc.) and to avoid crossing at those locations. Of course, children this age should not be crossing the street alone, but there is no guarantee that young school-age children will always be supervised.

One of the well known aspects of Piaget's distinction between children in the pre-operational stage of development and children in the concrete-operational stage of development is the ability to conserve matter. When children are shown two equal amounts of liquid in the exact same type of glass, children of all ages will agree that the amount of the liquid in both glasses are equal. One glass of liquid is then poured into a thinner but taller glass. Children in the concrete-operational stage of development will say that the amount of liquid between the two glasses remains

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[3] While the goal of this paper is not to discuss the complexities of each developmental stage, each stage will be briefly summarized and discussed later if it is relevant to the age that child pedestrian safety education targets.

the same while children in the pre-operational stage of development will say that there is more liquid in the taller glass.

The influence of this perceptually led thinking in the young child has serious consequences for the young child trying to cross the road. Ampofo-Boateng and Thomson (1991) prompted children to classify places as safe or unsafe using a model town. They found that 5- and 7-year-old children had a difficult time making correct judgments because they based their safety judgments solely on whether or not cars were present. At one level, these results suggest that children may be waiting a long time to cross the road if they need to wait until cars are no longer present. At a more dangerous level, this suggests that young children may be more likely to cross the road near a curve in the road or on a hillside because cars appear to be absent. In a second study, Ampofo-Boateng and Thomson tried to simplify the task by showing children pictures of the model town from a doll's perspective and removing the presence of traveling cars. Thus, children had to determine if a situation was unsafe if the doll was trying to cross between two parked cars thereby obstructing the doll's view of traffic. They found, however, that 5- and 7-year old children still categorized unsafe locations as safe because no cars were present.

Developmental research within the last 20 years has demonstrated that Piagetian stages of cognitive development are not rigid, inflexible stages. There are individual differences with regard to when certain types of thinking are applied to certain situations that Piaget did not take into account in his theory (Kreitler & Kreitler, 1989). For instance, there are times that children in the concrete-operational stage do not conserve while children and adults in the formal operations stage may think concretely (Flavell et al., 1993). An adult who has to work with a mathematical principle may need to diagram his thoughts and make the problem concrete to solve the problem.

The Contextual Approach

Another theory of cognitive development utilizes a more interactive approach between children and the environment. Vygotsky (1978) emphasized that cognitive development occurs within the context of social interactions. Children learn about the world not only through exploration but through speech, demonstration, and assistance from others. Development depends on what Vygotsky called the zone of proximal development where engagement in social behavior facilitates developmental advances. Adult guidance helps children move to the next developmental stage by building on what children already know. Developmental attainment occurs with adult guidance or peer interaction and exceeds what can be achieved alone. Language, for instance, cannot be learned if a child is isolated from society.

The theory and research that stems from Vygotsky's theory is based on the interaction between child and society (Flavell et. al, 1993). The behaviors, knowledge, attitudes, and perceptions a child learns are firmly rooted in the surrounding society. Likewise, parents and caregivers act as mediators between the child and culture. Children in the United States are encouraged by their parents to engage in a variety of activities that foster physical, creative, and intellectual stimulation while children in Japan are encouraged by their parents to focus heavily on science and mathematics (Flavell et al., 1993). Therefore, in order for children to develop the necessary skills to cross the street, parents must encourage and foster safe pedestrian skills and these skills must also be regarded as important among society.

Research on Improving Pedestrian Safety-Related Behaviors

Cognitive and developmental theories suggest that it is possible for young children to learn safe street crossing behaviors; however, any instruction has to reflect the various cognitive and developmental theories that underlie pedestrian skills. In the late 1990s, the Department for Transport in the United Kingdom undertook new research inquiries into developing new child pedestrian education based on child development. A number of these studies reveal that children as young as 5 years old can be trained to behave safely in traffic. The sessions train children in specific components of street-crossing and utilize active participation on the part of the child.

Identifying a Safe Place to Cross

Identifying a safe place to cross is essential in making a road-crossing decision, yet only 10% of parents reported teaching their children about finding a safe place to cross (MacGregor, Smiley, & Dunk, 1999). Schofer et al. (1995) found that a majority of child pedestrian crashes involved a sudden appearance of the child pedestrian where the child was moving quickly across the street, suggesting that children were crossing the road at unsafe locations. Schofer and colleagues conducted a pedestrian crash causation study where they collected information from parents, victims, police crash reports, and medical histories. They also visited the injury site at the same time of day and day of week that the crash occurred and measured, videotaped, and diagramed the location. Schofer et al. reconstructed the crashes to identify the main factors that contributed to each crash. They argued for the importance of teaching children not to run across the road, as well as the dangers of crossing in locations where their view is obstructed.

Parents and educators may assume that finding a safe place to cross is a relatively simple task when in fact it is not intuitive for young children (Thomson et al., 1992). In order to find a safe place to cross, children must be able to distinguish between safe and dangerous places. Dunbar, Lewis, and Hill (1999) asked children ages 4 to 10 and adults to identify pictures that depicted safe and dangerous situations. In the first study, children and adults had to sort a set of pictures and were not told that the pictures depicted safe and dangerous situations. While 90% of adults sorted automatically into the categories of safe and dangerous, they found that less than half of the children did so. After children were prompted to sort according to degree of danger, they did a better job of identifying dangerous situations with age; however, older children were more likely to classify safe pictures as dangerous. One complication of the study was that some of the pictures were drawings and other pictures were photographs. Children had a harder time categorizing a picture as safe or dangerous when it was the photograph because the photograph contained more relevant and irrelevant details. The more complex the picture, the more difficult it was for children to focus on what was relevant.

In an attempt to simplify the task, Dunbar, Lewis, and Hill (1999) conducted a second study with 4- to 8-year-old children where the children had to pick the dangerous picture from a set of four drawings. There were 24 sets of pictures: half depicted a child in a dangerous situation and the other half were controls where the target depicted the child sad or happy in a neutral situation. Among the dangerous targets, half of the situations were related to dangers around the home and the other half were related to dangers in the road environment. Children were significantly worse at identifying road dangers than they were at identifying home dangers and happy and sad situations. When they looked more closely at the data, the researchers found that young children were more likely to base their judgment about dangerous situations on the presence or absence of dangerous objects. These findings are consistent with Ampofo-Boateng and Thomson's (1991) study which found that young children identify places as safe if no cars are present. Both of these studies suggest that when young children cross the road, they may not automatically identify the scene as safe or dangerous and if they do, their decision is based on faulty reasoning.

While it has been shown that it is difficult for young children to identify safe and dangerous places, research suggests that young children can be trained to identify safe places to cross the street. Thomson et al. (1992) trained a group of 5-year-old children on identifying safe places to cross using either a table top model of a traffic environment or at the road side of an actual traffic environment. The pre- and post-tests involved taking children to several pre-selected sites on the roadside and children were instructed to imagine that they wanted to cross the road to reach a destination on the other side. Children pointed and described the route they would take and their choices were recorded and later scored as either very unsafe, unsafe, more safe, or safe.

The training sessions for both the table-top model condition and the roadside condition were designed to be interactive and discovery-based as opposed to having the children memorize a set of rigid rules. Children participated in six training sessions at a rate of two sessions per week in groups of five children and one adult. The training was designed to address two main types of errors that 5-year-old children made in previous studies. These errors were failing to recognize the danger of crossing near obstacles such as parked cars and selecting the most direct, and often diagonal, route which were the most dangerous. At each session, children were asked to describe the safe place to cross to reach a specified destination. Trainers used prompts, questions, and demonstrations to help the children discover the basic principles on their own in the hopes that this would aid in the conceptual development that would allow the children to deal with a wide range of situations.

Thomson et al. (1992) found that the training was effective in helping 5-year-olds identify safe places to cross. Children who received the table-top training and children who received the roadside training performed better than children who received no training at post-test 1 and post-test 2 which occurred 2 months later. In fact, this type of training can elevate a 5-year-old's performance to that of an 11-year-old child who had never taken training. In another study, Ampofo-Boateng et al. (1993) used a similar procedure with 5-, 7-, 9-, and 11-year-old children. Similar to Thomson et al. (1992), they found that children as young as 5 years of age improved in their ability to identify safe places to cross. In fact, trained 5-year-olds performed at the level of 11-year-old controls immediately after training and at the level of 9-year-old controls 2 and 8 months after training.

Roadside Search

After identifying a safe place to cross, children must be able to look for and attend to traffic. Tolmie, Thomson, Foot, McLaren, and Whelan (1999) tested children's ability to notice traffic-relevant scene features in a computer simulated street-crossing task. Children ages 5, 7, 9, and 11 and a group of adults saw a series of traffic scenarios on a computer screen that were presented for varying amounts of time, with varying complexity and different types and levels of distracters. Half of the participants were instructed to report anything they saw in the scene and the other half were asked to attend to information that would help the pedestrian in the picture cross the road safely. They found that when children were not directed to focus on traffic, children ages 5-11 tended to focus on traffic-irrelevant features such as the presence of a playground or a dog. When children were told that they were helping someone cross the street, 11-year-old children gave more relevant than irrelevant crossing features, 9-year-old children gave half relevant and half irrelevant features, and 5- and 7-year olds still provided a lot of irrelevant information.

Tolmie et al.'s results suggest that directing older children to focus on traffic led to a greater likelihood that they would attend to traffic-relevant information. A difficult issue to identify in this study is whether the same results would have occurred if children were told that they were walking to a friend's house or school, as opposed to helping someone cross the street. Children may have paid more attention to the traffic-relevant features in Tolmie et al.'s study because children became responsible for another person, and they may have paid less attention if that responsibility was removed.

Posner et al. (2002) found that more children were in pedestrian crashes when they were walking to a destination than when they were playing. Posner and colleagues interviewed children ages 4 to 15 who were patients involved in pedestrian collisions with motor vehicles. Children were asked about what they were doing prior to the collision and about their regular pedestrian activities. They found that 71% of children in the sample were engaged in walking to a destination. Of these children, 22% were walking to and from school when they were involved in the crash. The remaining 29% of children were engaged in play prior to the crash. Of these children, 28% were intentionally playing in the street and 72% were playing near the street and entered the road before they were struck. These findings suggest that it is at least important to get children into the habit of attending to traffic-relevant information when they are near the road.

Tolmie et al. (1999) focused intervention efforts on children ages 6-8 because this age group had difficulty attending to relevant features in the road. Tolmie and colleagues theorized that children at this age did not have the experience to know the relevant information in a street-crossing task. Children were randomly assigned to either a computer training task with adult guidance, a computer training task with peer guidance, or a control group. Children attended four sessions held once a week for four weeks. In each session, children worked on a computer program where they helped an animated figure cross the street in various traffic scenarios. Children could press either a "go" button when they felt it was safe to do so or press a "not safe" button if there was something about the situation that was not conducive to crossing the street. The computer program provided instructions and feedback about whether or not the response was correct. If the response was correct, children would move to the next problem. If it was incorrect, the children had to begin the scenario again. All children received pre and post evaluations.

Tolmie et al. found that children who had one-on-one computer sessions with an adult noticed more relevant features in the traffic environment than children who had computer sessions with peers and the control group. Children who worked with an adult increased their reporting of relevant information from 44% to 55%, while children who worked with peers went from 49% to 47% and the control group went from 52% to 50%.[4] In addition, children in the peer and control condition reported more irrelevant information post-test than the children who worked with adults. Children who were paired with adults also had a better understanding of why relevant features were important which led to improved judgments on crossing during traffic gaps in the computer program.

Identifying Safe Gaps in the Road

Crossing a street with traffic requires the pedestrian to make predictions about which gaps in traffic will allow for safe street-crossing. Children as young as 6 and 7 have been found to have difficulty in interpreting information on direction and speed of moving vehicles (Joly, Foggin, & Pless, 1991). Some traffic safety professionals argue that young children are developmentally unable to make decisions about traffic gaps because they have to attend to velocity and distance to predict arrival times. Research on the development of children's understanding of distance, speed, and time tend to explore more complicated concepts than determining a safe gap to cross the road (Siegler & Richards, 1979; Wilkening & Martin, 2004). However, by around 5 years of age, children have mastered the concepts of speed and distance (Siegler & Richards, 1979). In addition, research has shown that young children can be trained to make decisions that mirror adult decisions to cross during gaps.

Researchers have developed some innovative ways to evaluate and train children in identifying safe gaps in traffic. Lee et al. (1984) and Young and Lee (1987) used a

[4] The results are not based on the proportion of relevant items children reported as compared to the total number of relevant and irrelevant items in a picture. Researchers developed a ratio based on relevant and irrelevant items and thus the percentage changes are based on changes in the pre and post ratios.

roadside simulation to train children in road-crossing skills. A strip of land adjacent to a road was used as a pretend street. This pretend street was the same width as the target road and a barrier was set up between the real road and the pretend road. Children were asked to observe the traffic on the real road and cross the pretend road to the barrier when they thought it was safe to do so. Young and Lee (1987) found that 5-year-olds were capable of learning to cross safely through gaps in traffic at the level of adult performance. The one exception to this was that young children tended to have more missed opportunities (crossing when it was safe to do so) than adults. In fact, other studies that looked at the effectiveness of this particular roadside simulation have found that children exhibit a conservative approach to crossing the street resulting in safe crossings (Demetre et al., 1992; Hoffrage et al., 2003).

Another training method of gap crossing is through computer simulation. Thomson et al. (2005) developed a training program where children ages 7, 9, and 11 participated in four training sessions with an adult trainer and two other children. In the computer program, children would guide child characters on a variety of journeys involving a variety of road crossings through a small town neighborhood. When it was necessary to cross a street, children would press the go button when they thought it was safe to do so. If the gap between cars was adequate for a safe crossing, the character would cross the street. If there was insufficient time (also known as a tight fit), the scene would freeze, brake sounds would play, and the character's ghost would leave the body and go into the sky. Trainers used this feedback as a discussion point for the children and the crossing was repeated until the problem was solved. Each child had equal opportunity to make the decisions for the animated character and the children not making the decision at that time were discussants. The goal of the trainer was to listen to the children's reasoning on why they chose to make the incorrect decision, guide their thinking in the appropriate directions, and avoid imposing solutions. Children received pre- and post-tests at roadside locations. Children would stand at the road and raise their arm and yell "now" to indicate when they thought it was safe to cross the street.

Thomson et al. were able to positively influence children's gaps crossings. They found that training enhanced children's conceptual understanding of the crossing task and these improvements were associated with behavioral judgments at the roadside. Compared to controls, trained children crossed faster, accepted smaller traffic gaps with no effect on number of risky crossings, and missed fewer safe opportunities to cross. The most significant aspect of this training is that it displayed transfer of learning from a simulated environment to a real environment.

Practice and Behavior Modification

In order for children to develop pedestrian skills, they must practice the actions enough for the behavior to become automatic. Engaging in safe pedestrian behaviors is not intrinsically rewarding for children and so reinforcement must be coupled with the training process. Reinforcement can take the form of verbal praise, stickers, stars, tokens, or other small rewards. The most effective use of reinforcement to sustain behavior is when the behavior is reinforced irregularly (Anderson, 1995). Parents can play an enormous role after training because they can continue to provide reinforcement to their children until children are old enough to cross the street alone. By then, the habit and understanding of its importance should continue children's engagement in safe pedestrian behavior. While no programs have looked at the long-term effects of behavior modification in pedestrian skills training, programs that incorporate positive reinforcement or are solely based on behavior modification have shown dramatic increases in safe pedestrian behavior.

In 1973, Reading implemented a child pedestrian safety training for children ages 5-9 using behavior modification. The education portion was administered in a 20- to 30-minute assembly which included a short lecture, question and answer period, and role play from several students chosen from the audience. Children were observed crossing streets near the school for several days before the assembly and several days after the assembly. After the assembly, children were reinforced through verbal praise, candy, smiles, and a "good pedestrian citation" for safe street-crossing behavior at particular intersections while walking home from school. Reinforcement continued throughout the project implementation. Reading used a staggered start design where one group of children attended the assembly 6 days into the observations, the second group of children attended the assembly 2 days later, and the third group of children attended the assembly 2 days after the second group. In each case, baseline levels of correct crossing behavior ranged from 4% to 12% and jumped to over 60% after the assembly when reinforcement occurred continually.

The dramatic increase in safety behavior in Reading's study is promising, yet there are certain limitations with reinforcement that must be considered when using reinforcement as part of a training program. When behavior is reinforced continually, the behavior ceases with the removal of the reinforcement (Anderson, 1995). So, in all likelihood, once Reading's project ended and the reinforcement ceased, children's safety behaviors probably returned to baseline levels. There are different schedules of reinforcement that lead to different levels of behavioral response (Anderson, 1995). The best way to maximize children's use of safety behaviors is to provide reinforcement at irregular times. Parents can continue the reinforcement schedule since young children should not be left unsupervised near roads.

Another issue to bear in mind with Reading's study is generalization. Children were reinforced for their safety behaviors when they crossed one of three predetermined intersections. The remainder of the children's walk to school may have exhibited baseline levels of behavior because children were never reinforced for their behavior at other street crossings on their journey home. This is another instance where parental participation is invaluable. Parents can reinforce their children for safe street-crossing behaviors while crossing many different kinds of streets. This can ensure generalization of the learned skill.

Dueker (1975) developed a more structured training program for children using behavior modification in a school setting. He evaluated the effectiveness of three programs on changing children's safety behaviors and on ease of implementation. The Basic Program involved teacher instruction of safe pedestrian behaviors. Children then practiced the behaviors in class through games and simulated streets using mock-up automobiles while teachers reinforced correct behaviors. The Simulator Program followed the same format as the Basic Program except that the simulation included two synchronized rear-projection systems to simulate left and right approaching traffic in a simulated street in the classroom. Instead of teacher instruction, the Film Program used a film of Captain Kangaroo teaching safe street-crossing behavior and followed the Basic Format in reinforced practice in games and in-class simulation with mock-up automobiles. In addition, the film was unique in that Captain Kangaroo explained why it was important to cross the street safely and showed children in the film the award they will receive when they learn how to safely cross the street. The children in the film practiced as Captain Kangaroo watches and the children received safety tokens for correct behavior. When a child in the film made an error, the film action froze and Captain Kangaroo asked the children in the audience what the child did wrong thereby eliciting involvement of the children watching the film. At the end of the film the Captain gives the children in the film their awards and explains to the children watching the film that their teacher will tell them how they can earn an award.

Each program involved eight very structured sessions. In the first session, the program was introduced and children were shown a Street Safety Award patch and certificate that could be earned from the accumulation of tokens received for safe street-crossing behaviors. After children learned the crash-avoidance sequence, they practiced the behaviors until 95% of the class had correctly performed the sequence twice. In the second session, children were reminded of the safety sequences, practiced during the in-class simulation, and received tokens for safe street-crossing behaviors. The session ended when 95% of the children correctly performed the sequence three times. In sessions 3 through 5, children participated in games that involved crossing the simulated street and the teacher reinforced safe street-crossing behavior. Sessions 6 through 8 occurred outside where children engaged in the same games near closed-off roads. Teachers continued to provide reinforcement for correct behavior.

Children were observed crossing the street before the program, several days after the program, and a month after the program. Children were excused from class individually and told to get a book from a truck located outside and return to class. The truck was located across the street and an experimenter called the child over. After the child selected a book, the experimenter encouraged the child to hurry back to class. The roads were closed off but a plant car drove up and down the street so that the child had to wait and attend to the car. Each child was observed independently by two experimenters during the whole process. Each time a child crossed the street he or she was scored on how many times he/she performed the sequence of safety behaviors taught in the program without error. For example, if a child crossed the street to pick up a book and executed the safety sequence but did not execute the entire sequence on the return to school, she received a 1. If a child executed the entire sequence to the van and back to school, she received a 2.

All children in the three programs showed improvement in behavior after the program with the Simulator and Film programs showing the best improvements in behavior. Before the training program children rarely exhibited the entire sequence of safety behavior which included stopping at the curb, searching for traffic by looking left-right-left, crossing the road if no vehicles are detected, or repeating the sequence if a child has to wait for a car to pass. In order for children to receive a score of 1 or 2, children had to engage in all actions of the sequence. Any omission of the sequence would result in a score of 0 resulting in a strict scoring system. In a comparison of pre-test scores and the first post-test score, 20% of the children in the Basic Condition improved their scores, 50% of the children in the Simulator Condition improved their scores, and 51% of the children in the Film Condition improved their scores. Girls improved with training more than boys by 14%.

In a field test, Dueker (1981) found some support for these programs; however, they were not as strong as the initial pilot test. Schools received either the Simulator or the Film Program. Teachers were provided with manuals that explained the curriculum and the training session, which occurred over one semester and was followed up with refresher courses during the following two semesters. Children were observed in the experimental sites and control sites in the same way as was done in the pilot study, during which children were sent to retrieve a book from a van outside the school. The number of crashes before and after the program implementation were also compared among the experimental and control sites. Dueker found that compared to the control group, the Film Program and the Simulator Program significantly reduced the number of unsafe street crossings. The Film Program showed a 40.1% reduction compared to the Simulator, which showed an 11.7% reduction. Both groups did not show as large of an improvement as they did during the pilot study. In terms of crash reductions, only the Film Program was associated with a 17% crash reduction of dart-out first-half crash types.

While the pilot program showed a lot of promise in increasing children's safe pedestrian behaviors, the field test did not result in as dramatic behavior change. Several important differences in methodology could have accounted for this difference (Dueker, 1981). The sites where the programs were implemented were chosen based on crash data availability and the school districts' voluntary participation. The schools in the Film Program came from a high-income school district while the schools in the Simulator Program came from a low-income school district. Schools from low-income areas are often overburdened, and in this study, did not have the time necessary to correctly implement the Simulator Program. Teachers in the pilot study had researchers available to help with the setup and implementation of the complicated Simulator Program when needed. In contrast, teachers were on their own in the field test. The most crucial deviation from the programs was that the positive reinforcement was not properly or consistently administered as explained in the Instructor's Guide. In order for behavior modification to occur, the method of positive reinforcement has to be properly administered.

In a smaller and more controlled study, Yeaton and Bailey (1978) were able to demonstrate dramatic behavior change through behavior modification. They conducted a pedestrian training program among a small group of children in two different schools. Children were recruited based on whether or not they ordinarily walked to school and whether they walked along a predetermined route. Children then received roadside training over several days during which children were taught to engage in safe street-crossing behaviors. The adults present in the training sessions would administer positive, verbal reinforcement for correct behaviors and children gave each other feedback on correct behaviors and mistakes. Children displayed baseline safety behaviors 50% of the time. After training, this increased to 90%. Children were also observed on a generalization street and although the percentages were in the 80% range, they were still significantly above baseline. One year later, children's behaviors decreased; however, the behavior was still above baseline levels and jumped back up to post-test levels after brief refresher training.

A program that involves practice and positive reinforcement is going to be time-intensive and will require vigilant observation from the person providing the reinforcement. However, it is a key component in getting strong behavioral change and is worth considering for pedestrian training. For instance, in their training of finding safe places to cross the road, Ampofo-Boateng et al. (1993) gave children positive verbal reinforcement and gold or silver stars for appropriate behavior. They were able to increase 5-year-old children's performance to that of untrained 11-year-old children.

Parental Involvement
Researchers recognize that parental involvement is critical to children's behavior change (Rothengatter, 1981). Children consider their mothers and fathers as significant safety role models (Quraishi, Mickalide, & Cody, 2005). Both children and parents reported engaging in safe behaviors more often when they were in each other's presence. Unfortunately, there are limitations in getting parents to participate in safety programs and perform them correctly (Rothengatter, 1981).

Some recent work suggests parents are willing to be involved depending on the level of commitment. DeFrancesco et al. (2003) surveyed parents and found that they were willing to get involved to increase child pedestrian safety but were unsure of what kinds of strategies would work well to get changes in their community. In addition, there were very few differences across parents in their survey responses when parents were grouped according to family income level and injury risk level. Overall, the strongest predictor of parental contribution was the perception of neighborhood solidarity. An interesting finding was that most parents believed that engineering countermeasures (i.e., speed bumps) were the best solutions to protecting child pedestrians. Very few parents thought that teaching parents about traffic safety and better traffic enforcement were effective strategies to reduce child pedestrian crashes. This suggests that it is important to educate parents in the interaction of child development and traffic safety so that they are more informed.

Bishai, Mahoney, DeFrancesco, Guyer, and Gielen (2003) surveyed parents using a method known as "contingent valuation to quantify what parents are willing to do to make their neighbourhoods [sic] safe" (p. 951). Parents were asked if they would either pay or contribute a certain amount of hours for a particular safety countermeasure for child pedestrian safety. They found that parents were least likely to volunteer as a crossing guard and more likely to participate in a neighborhood meeting regarding safety. Only 15% of parents thought that pedestrian injury in their neighborhood was very likely. Future programs need to recognize these limitations regarding parental involvement and creatively work to increase parental participation.

In the 1970s, West Germany created a very effective training program for children using children's parents as their instructors. Limbourg and Gerber (1981) conducted a number of pilot studies to develop and evaluate a training program in which parents taught their children ages 3 to 7 pedestrian safety. The program was based on behavior modification and social learning theories where parents positively reinforced children and modeled correct street-crossing behaviors. Limbourg and Gerber created a number of road-training objectives and ordered them into four levels of difficulty (see Table 2). Parents were encouraged to observe and analyze their children's behavior in traffic using a reference sheet provided by the program. Parents then selected the appropriate learning objectives that their child needed. Parents were also instructed to always demonstrate the correct pedestrian behavior to their children and clearly explain to their children what they are doing. Lastly, and most importantly, parents were instructed to reward their children for correct behavior in traffic situations.

Table 2. Limbourg and Gerber (1981) Training Objectives (p. 259)

Training Stage I	1. Walk at the inner side of sidewalk 2. Stop at curb
Training Stage II	3. Look to the left and to the right at the curb 4. Cross the road straight ahead 5. Cross the road quickly but without running 6. Cross over at traffic lights while the light is green 7. Crossing over at zebra crossing for pedestrian; give a signal by extending the arm 8. Crossing over at zebra crossing for pedestrian; wait until the cars stop before crossing over 9. Select zebra crossing for pedestrian or traffic light to cross the road
Training stage III	10. Stop at the line of vision 11. Look to the left, to the right, and to the left at the line of vision
Training stage IV	12. Walk alone to school

Limbourg and Gerber consistently found substantial increases in children's correct street-crossing behavior. In every pilot study, children in the experimental group were compared to a control group and all children received pre- and post-observations. One important distinction they made when evaluating the programs was the extent to which training influenced children's behavior when they were distracted because children are more likely to act impulsively when distracted. They found that even when children in the experimental group were distracted, they were more likely to engage in safe street-crossing behaviors than controls.

Gielen et al. (2004) found that parents may develop a false sense of security after teaching their children pedestrian skills. Through a survey of elementary school parents, they found that all parents reported that they teach their children pedestrian safety skills. However, 30% of parents said they let their child under 10 years of age walk to school alone and 47% did not supervise their children when they were playing outdoors. While parental involvement in pedestrian education is important in developing children's pedestrian skills, it is equally important that parents understand that while children can learn how to safely cross streets, their lack of impulse control makes it dangerous to be alone near traffic.

Comprehensive Approaches to Safety Education

In their review of the literature, Bruce and McGrath (2005) evaluated research on safety interventions conducted with children under 6 years of age. While the evaluation included several different types of safety interventions (road crossing, car restraint, spinal cord safety, poison safety, and "911/stranger-danger/street-crossing" (p.144)), the authors discussed what aspects of the intervention made it successful. Key to the success of an intervention was the ability for children to practice the safe behaviors. Children need to be exposed to opportunities that will develop problem-solving skills instead of only developing knowledge. Successful programs included interactive learning in group sessions and rehearsal opportunities.

Hotz et al. (2004) evaluated the effectiveness of a training program that utilized traditional classroom-type education and outside simulations. Children in kindergarten through grade 5 from schools at risk for pedestrian injury received daily 30-minute sessions for 1 week for a total of 2.5 hours of educational training. Children received classroom education and videos on days 1 and 3, participated in outside simulations in days 2 and 4, and participated in a poster contest on day 5. Pre- and post-test evaluations revealed that WalkSafe improved children's safety knowledge immediately after the intervention and this increase in knowledge was sustained 3 months later.

The WalkSafe program did result in improvements in safe pedestrian behavior. Hotz et al. observed children by setting up cameras near busy intersections near schools that received the intervention. They found that 12.5% of children stopped at the curb and looked left-right-left before crossing prior to the implementation of WalkSafe. Immediately after the intervention, 19.5% of children exhibited these behaviors. The 7% increase in safety behaviors was statistically significant, however, the fact that 80% of the children observed did not engage in safe street-crossing behaviors is alarming. While children were given the opportunity to practice safe pedestrian skills, two 30-minute sessions in 1 week may not have been enough to allow for the behaviors to become ingrained in children. In addition, this study did not use control groups for comparison so it is difficult to say if the 7% increase would have happened without the intervention.

Rivara, Booth, Bergman, Rogers, and Weiss (1991) developed a pedestrian training program that utilized reinforcement, practice, peer/adult interactions, and parental involvement. Children in kindergarten through grade 3 participated in six 30- to 40-minute sessions; however, the report did not describe when the sessions occurred over time. The program included a variety of activities to accommodate differences in learning styles. Children saw pedestrian cartoon characters, used maps, sang songs, and participated in role-playing and contests. In the first four lessons, children were taught basic skills which included learning to recognize and avoid pedestrian hazards; making eye contact with the driver; crossing at a blind spot; crossing at corners; and identification of traffic signs, signals, and safe walking zones. Children practiced the basic skills during the final two lessons. They were videotaped so peers could critique their performance. Workbooks were sent home so that parents could complete the workbooks with their children. The workbooks were designed to increase parent awareness of children's pedestrian abilities and limitations and encourage parents to model safe pedestrian behavior.

Rivara et al. measured children's behavior in traffic before and after the training program. They chose not to examine changes in pedestrian crashes because they would have had to train a much larger group of children to see a difference at the injury level. Children who participated in the training program wore a visible number to and from school so that observers could identify which children participated in the study. Children were told that they were wearing the number for a variety of reasons and the researchers noted that the children seemed to forget about the number as the observation week went on. Children who participated in the program in 1989 were treated as a separate group than children who participated in the program in 1990 because the parent workbooks were not added until 1990.

Children showed significant increases in their safety behavior only after the parents were encouraged to complete the workbooks. Before the implementation of the workbooks, the only significant improvement in behavior was that 17.2% of children in grades K-1 searched for traffic while crossing the street before the implementation of the program and 36.8% of the children did so after the program. Among grades 2-4, 14% of children searched for traffic while crossing the street before the program and 32% of children did so after the program. After parents completed the workbook with the children, there were improvements in looking for traffic before crossing the street as well as continued looking while crossing the street. Among children in grades K-1, 42.2% of children searched for traffic before crossing and 61.8% did so after the program. Among children in grades 2-4, 20% of children searched for traffic before crossing and 46.6% of children did so after the program.

There are a number of issues with this study that make it difficult to make conclusions about the effectiveness of this intervention. First, it is unclear how the training sessions were planned. While students learned basic pedestrian skills, Rivera et al. did not report if children learned everything in one lesson and received repeated exposure to the material for the remaining lessons or if the basic skills were spread out over each lesson. Repeated exposure over time to the same principles is more likely to have an impact than a single exposure over time (Matlin, 1989). Secondly, the training lessons consisted of a variety of activities to accommodate different learning styles. However, this may have been too much variation to keep children focused on the content rather than the process. This may explain why no differences were seen before and after the implementation of the program when the parents were not involved. In addition, while the post-test percentages of children searching for traffic before and during a street-crossing were higher when parents were involved, both groups (parent involvement and no parent involvement) increased 20 percentage points from baseline. Lastly, there was no control group to make sure that improvement did not happen by chance. A control group is especially important in young children because they can make substantial cognitive gains within several months.

In Australia, Cross, Hall, and Howat (2003) developed and evaluated a child pedestrian education program called the Child Pedestrian Injury Prevention Project (CPIPP). The CPIPP used school- and home-based instruction of safe pedestrian behaviors for children ages 7 to 9. The focus of the school and home activities was to teach pedestrian skills in a "real" road environment using school roads and local traffic roads. The educational materials had applications in science, language, art, math, and physical education. The home-based materials actively involved students' families by linking them to classroom lessons, school newsletters, fact sheets, and memorabilia with safety messages. After 3 years of the intervention, Cross et al. found that there was a significant difference between the intervention and comparison groups for crossing the road and playing on or near the road. Students in the intervention group were more likely to cross the road with an adult and less likely to play near a road.

Thomson et. al (2002) explored a 2-year computer-based training program for children. The training program consisted of four modules each training the children ages 5 to 11 on finding safe places to cross, roadside search, gap timing, and perceptions of other's intentions. A module was taught in the fall and spring of each year and each module was cumulative such that the beginning of each module required children to apply the knowledge they gained in previous modules. For instance, in the first year, finding safe places to cross was taught in the fall, followed by roadside search in the spring. Part of the roadside search task was to first identify a safe place to cross and then children could make a computer animated character cross the road. The second year of training began with gap timing in the fall and ended with perceptions of other's intentions in the spring. Each module consisted of 30-minute training sessions that were held once a week for 4 weeks. Children participated in the training sessions in groups of three with an adult trainer. The goal was to maximize Vygotsky's zone of proximal development by having modules that built upon each other, adult guidance to prompt more advanced ways of thinking, and peer discussion to further solidify the concepts.

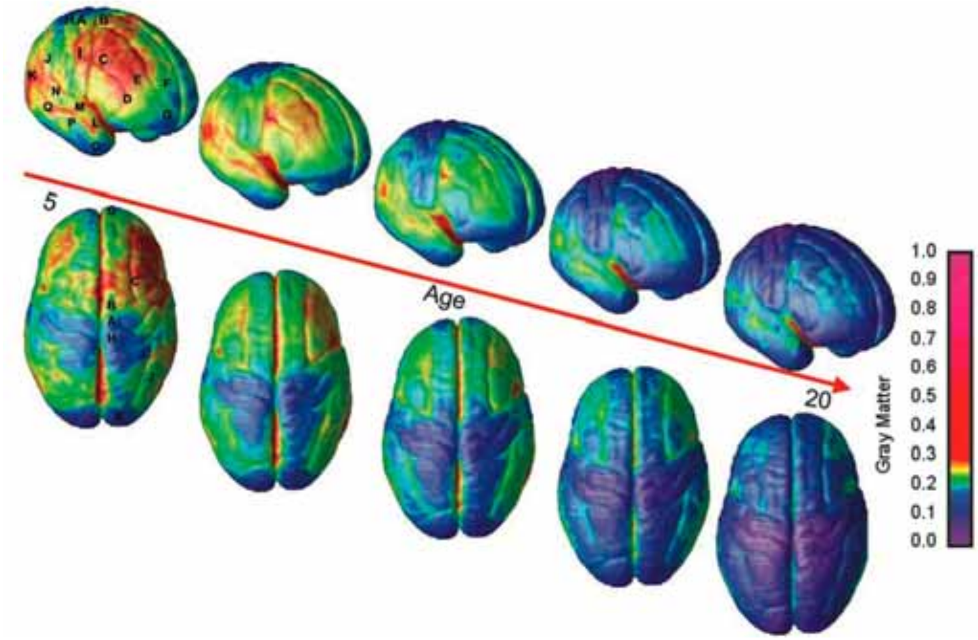
Thomson et al. found that the program increased both children's roadside safety behavior and knowledge for all age groups. The program was most effective for 7- to 10-year-old children. In the training on finding safe places to cross, 8- and 10-year-olds increased their number of safe-place judgments by 100% and were better able to offer insightful justification for their judgments than prior to the training and to controls. While this training module did not increase 6-year-old children's ability to find safe places, the data suggest that it did help them with the following roadside search module. All children in the roadside search training performed better than controls on picking up information on vehicle movements and explaining its significance. Similarly, after the training in gap timing, all children in the training sessions showed an improved ability to estimate crossing time and were better able to anticipate upcoming gaps in traffic compared to their pre-test scores and to controls. After the final module of perception of intentions, trained children were better able to predict driver behaviors and explain why they came to those predictions compared to controls.

This study suggests that a cumulative training program that breaks down the street-crossing task can be taught through computer simulations with roadside applicability. Thomson et al.'s program was most effective for children ages 7 to 10 and argued that a combination of roadside and computer training would be most effective for 5- to 6-year-old children. These young children had difficulty making the connection between the computer simulation and actual roadside, which kept the computer-based training program from reaching its full potential as it had with the older children. Although children were tested at the roadside, the program demonstrated increases in conceptual understanding but did not address the effect it had on children's everyday behavior. The ability to cross the street safely is a motor skill that cannot develop without repeatedly engaging in the motor skill over time. An effective pedestrian training program for children has to incorporate this important aspect of the street-crossing task.

WHERE DO WE GO FROM HERE?

The last 30 years of research in child pedestrian safety education reveals that it is possible to teach young children to behave safely in traffic. However, even with training, children under the age of 10 should not be unsupervised when in or near roads largely because their ability to control their impulses and base decisions on long-term consequences is still immature (Gogtay et al., 2004). Researchers at the National Institute of Mental Health and the University of California at Los Angeles conducted a 10-year longitudinal study with participants ages 4 to 21 using magnetic resonance imaging (MRI) to asses normal brain development (Gogtay et al., 2004). They found that the parts of the brain that mature first are those involved with basic functions such as processing the senses and movement. Areas with more advanced functions like the ability to control impulses and weigh long-term consequences are the last to mature (see Figure 3).

Figure 4. Phases of the Developing Brain (Gogtay et al., 2004)



Note: 1.0 is least mature and 0.0 is mature.

Unfortunately, while children under age 10 should not cross the street alone, they may sometimes find themselves crossing a street unsupervised; therefore, it is important that they know how to cross the street safely. Research has shown that the most effective interventions that produce behavioral change are often time-intensive and costly. However, it is important to develop a successful pedestrian education program for children because children's exposure may increase as a result of the increasing national concern of childhood obesity and the rise of Safe Routes to School (SRTS) programs. In the early 1970s, 4% of children ages 6-11 were overweight. Thirty years later, the percentage of overweight children rose to 18.8% (CDC, 2005). Walking and biking are healthy activities for children; therefore, it is important for children to know how to safely negotiate traffic.

While we do not have a sense for the level of pedestrian exposure, Smeed's law suggests that an increase in pedestrian activity will lead to decreases in pedestrian fatality rates, that is, fatalities per number of pedestrians (Smeed, 1949). Smeed statistically showed that there were fewer road fatalities per vehicle as the number of vehicles increased. This exponential function has been shown to fit traffic data in the 1980s and in Australian states where greater levels of cycling were associated with fewer injuries per kilometer cycled (Robinson, 2005). This suggests that increases in pedestrian activity may lead to lower pedestrian crash rates.

One study suggests that an increase in pedestrian exposure may not lead to an increase in crashes. Johnston, Mendoza, Rafton, Gonzalez-Walker, and Levinger (2006) evaluated the implementation of a walking school bus[5] in an inner-city, low-income public school and compared it with control schools that had similar demographic profiles. The school with the walking school bus showed an increase in the number of children walking to school while the control schools showed a decrease in the number of children walking to school. Even though there were more children out on the street after the implementation of the walking school bus, there were no child pedestrian injuries during the school year. While the inverse relationship between exposure and fatality rates may hold true for adults who are experienced in dealing with traffic, it may not be true for children who are more physically vulnerable and significantly less experienced with traffic.

Other research suggests that an increase in walking is related to increases in injury rates. Rao, Hawkins, and Guyer (1997) examined the number of street crossings of children whose parents owned a car and a home compared with children whose parents did not own both a car and home.[6] Children whose parents did not own a car or home crossed significantly more streets than children whose parents did own a car and home. Rao et al. found that injury rates were negatively correlated with the proportion of children who were driven home from school. In areas of Baltimore where children are driven home, the rates of pedestrian injury are lower than areas of Baltimore where children walk home. While there were no child pedestrian injuries in the implementation of the walking school bus, Johnston et al. (2005) did note that children showed very few safe street-crossing behaviors. Less than 50% of the children were observed to look for traffic before crossing and to continue to look while crossing the street. Increased numbers may make children more visible to drivers. However, if children do not know how to safely engage in street-crossing behaviors, there may be a large number of children engaging in erratic behavior making it more difficult for drivers to avoid collisions.

The most effective means of implementing safety programs is to target children who are at risk for pedestrian fatalities. While it is important that pedestrian safety training is universal, interventions might begin with a more targeted approach by starting first with children from low-income urban areas and then expand the program to other groups. Although more boys are involved in pedestrian crashes than girls, both boys and girls should receive training since exposure is the same

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[5] A walking school bus is a group of children walking to school with one or more adults (NCSRTS, 2007).

[6] The ownership of a car and home was used as an indirect measure of SES.

for both. Future research should identify why boys are more susceptible than girls to pedestrian injury and develop an extra component for boys in the pedestrian skills training.

Based on learning theory and the research that has been conducted thus far on child pedestrian safety, there are three components to a successful safety education program. First, the material must incorporate active involvement by having children engage in the behaviors they learn and positively reinforce correct behaviors. Second, there should also be an interactive component where children are urged to think about their decisions and reevaluate them if necessary. In studies training children to identify safe traffic gaps to cross the road (Ampofo-Boateng et al., 1993; Thomson et al., 1992; Thomson et al., 2005), children explained their decisions and were prompted to think them through if they were dangerous. Each of these studies found that trained children performed significantly better than controls and that these results often lasted beyond the first post-test. The final important component is parental participation in training. Parents should be actively involved in their children's pedestrian safety education, positively role model appropriate pedestrian skills, and positively reinforce their children's correct behavior. Although little research has been conducted concerning parental involvement, parents can positively influence children's safety training.

Ideally, traffic safety education should span childhood and adolescence. Pedestrian education would be the first component children are exposed to. Children ages 5 to 9 would learn the basics of traffic safety through pedestrian education. As they get closer to adolescence, children would then learn about bicycle safety at a time when they are independent enough to be on their own but not yet old enough to drive a car. What they learned as pedestrians would serve as the foundation for more advanced traffic safety skills as road users on bicycles. The final component would be driver education where the skills children learned and developed as pedestrians and cyclists would be further advanced as drivers. Ultimately, through a more comprehensive approach to child pedestrian safety education we can begin to make some important gains in keeping children safe in traffic.

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