Bicycle Safety Education for Children From a Developmental And Learning Perspective

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16. Abstract

When children ride bicycles in and near traffic, they engage in a complicated task of combining motor skills and cognitive skills. In addition to developing bicycle-handling skills, bicycle safety education programs teach children how to ride safely in and near traffic. However, to what extent are bicycle education programs effective in improving safe, bicycle-riding behavior and reducing injuries? The purpose of this literature review is two-fold. First, this report describes the nature of children and adolescents' bicycle injuries in addition to understanding the types of programs that exist and their effectiveness. Second, this report explores the psychological domains related to riding a bicycle in childhood and adolescence such as motor skill development, cognitive development, brain development, and risk-taking and social influences. Understanding how each of these interacts with children's abilities to learn and ride a bicycle safely in traffic allows researchers and safety practitioners to design more effective bicycle education programs to teach children and adolescents how to safely negotiate traffic as bicyclists.

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Executive Summary

The purpose of this report is to act as a companion piece to the report, *Child Pedestrian Safety Education: Applying Learning and Developmental Theories to Develop Safe Street-Crossing Behaviors* (Percer, 2009), by explaining how current theories of child development and learning can guide educational programs that teach children how to safely ride bicycles in traffic.[1] While bicycle riders 45 to 54 years old have the highest fatality rate of 3.51 per million population (NHTSA, 2013a), children are more likely to have emergency department visits due to bicycle-related injuries. For instance, in 2010, non-fatal, bicycle-related injuries were 39% of all transportation-related injuries among 5- to 15-year-olds (CDC, 2012). Therefore, it is appropriate to also explore how current theories of child development and learning can be used in bicycle-safety education programs as was done in the NHTSA report on child pedestrian-safety education.

The focus of this literature review is to (1) understand the factors associated with bicycle crashes in relation to traffic; (2) describe the different types of bicycle education and their effectiveness; and (3) explore how children's learning and development might interact with their bicycle riding skills. While the literature review will discuss the developmental level of younger elementary school children 5 to 7 just learning to ride a bike, the review will focus more on the developmental level of children 8 to 16, when the likelihood that children are riding near and in traffic increases with age. This literature review also explores ways that bicycle education programs can be more effective when considering children's developmental and learning abilities.

Errors Children Make

In order to understand how to improve children's bicycle-safety education, it is important to understand the types of errors they make by looking at the types of crashes they are likely to be in. For instance, children are likely to be involved in crashes midblock, where they are likely entering a road from a driveway or alley; at intersections with stop signs; and while traveling in the same direction as an overtaking car (Hunter, Stutts, Pein, & Cox, 1996). One thing that most of these crashes have in common is the child most likely did not conduct a proper search before executing their move that resulted in a crash.

Bicycle Education and Effectiveness

Bicycle education programs can help children stay safe while bicycle riding. Education programs can teach children how to ride safely in traffic, how to handle their bicycles, the importance of wearing safety gear, and even bicycle maintenance. Bicycle education programs vary in content, length, and even

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[1] While it is important to choose safe places to ride that are away from traffic (e.g., bicycle trails and paths, bicycle lanes), feasible alternatives are not always available. Thus, it is important that children learn how to ride in and near traffic.

target audience making it difficult to know what is the most effective form of bicycle safety education for keeping children safe.

Evaluations of bicycle education programs can reveal what aspects of the program are important in changing behavior. For instance, short, lecture-based programs are effective in improving children's knowledge (Greene et al., 2002; McLaughlin & Glang, 2010). This is the first step to injury prevention because children have to know and understand the rules of the road first and foremost. The second step, however, is ensuring that children engage in the concomitant behaviors to reduce the likelihood of injury. The evaluated programs that have shown behavioral improvement tend to be more in-depth programs offering five or more hours of on-bicycle training in road environments (Rivara & Metrik, 1998). Programs that show crash reductions have several hours or more of classroom instruction in addition to several hours or more of on-bicycle training (Rivera & Metrik, 1998).

Child Development, Learning, and Risk-Taking

Bicycle training programs may be more effective if additional factors related to children and bicycle riding are considered. For instance, understanding physical and cognitive development can guide what children can be taught at different ages. In addition, factors related to risk-taking and social influences also have different impacts at different ages.

Most of a child's physical development occurs before the age of 7 and is further refined through adolescence. However, it is important to consider that bicycle riding is a motor skill. Developing a motor skill involves a large amount of practice to make the movements efficient and automatic. Bicycle riding in traffic involves two types of motor skills:

1) Basic bicycle handling skills,
    - balancing, pedaling, steering, and braking, and
2) Physical safety skills,
    - searching for traffic (moving the head),
    - quickly moving through the chosen traffic gap,
    - engaging the brakes to stop at lights and stop signs, and
    - engaging in the physical behavior of signaling when turning.

In order for children to become proficient at both these skills, both skills must be practiced frequently and together so that the skills become automatic (Clark, 2007).

Another area of physical development to consider when designing bicycle education programs is how the brain changes during childhood and adolescence. The pre-frontal cortex gradually matures in the early to mid-20s (Casey, Giedd, & Thomas, 2000). This means that children gradually get better at using working memory, inhibiting responses, controlling impulses, planning, weighing consequences, and self-regulation (Casey et al., 2000; Steinberg, 2007). In addition, the onset of puberty results in changes in the socio-emotional center of the brain making it a more dominant part of the brain (Steinberg, 2007). This means that not only do emotional reactions occur easily in adolescence, but that emotionally positive situations are intensely rewarding. As a result, risk-taking is heightened during adolescence because risk-taking behaviors tend to be exhilarating. For instance, risk-taking while riding a bicycle would become more prevalent in early adolescence because it is emotionally rewarding. Because the pre-frontal cortex is still maturing during adolescence, it has difficulty regulating behavior under emotional situations during adolescence (Steinberg, 2007). The pre-frontal cortex can regulate impulses from the socio-emotional center when it is fully developed during one's early to mid-twenties. Researchers argue that this is why adolescents are more likely to take risks than adults.

Understanding certain aspects of children's perceptual development can help guide the development of bicycle safety programs. Children have the same visual abilities as adults (Cohen & Haith, 1977); they do not have limited peripheral vision as some researchers and safety program managers previously believed. However, one important thing to consider is that there does seem to be a period around 7 to 8 years old where children stop using peripheral cues to help maintain balance (Nougier, Bard, Fleury, & Teasdale, 1998). This means that children this age have to use their central vision to help maintain balance and cannot use their peripheral vision as effectively to scan for traffic hazards. If they do use their peripheral vision to scan for hazards, they may compromise balance.

In the area of cognitive development, there are important areas to consider when working with children and bicycle safety. For instance, while children have fully developed spatial and temporal abilities allowing them to choose the same gap sizes to cross in traffic as adults, they are slower to execute their actions once their decision is made (Plumert, Cremer, & Kearney, 2004). Children have slower response times that gradually improve with age and are adult-like by approximately 14 years old (Kail, 1991). This means that children have a delay from the moment they make their decision to the moment they begin to act on their decision, which can be dangerous for them during normal riding conditions and emergency situations. Finally, changes in knowledge do not necessarily lead to changes in behavior (e.g., learning that one must stop at a stop sign does not mean that a child will actually do it). Each domain needs to be taught separately and in environments similar to where they will be executed (Percer, 2009; Tulving, 1975).

Riding a bicycle involves the simultaneous execution of motor skills and cognitive skills. While children are able to perform two tasks at once, they often sacrifice cognitive performance for motor skill performance (Wierda & Brookhuis, 1991). Research suggests children begin to handle dual-tasks like adults where they show some decrement in both tasks but good performance overall during adolescence. It may be possible to train children to perform well in dual-tasks of cognitive and motor performance (Pellecchia, 2005).

Social influences also affect children's decisions to take risks. The presence of peers makes children and adolescents take more risks (Gardner & Steinberg, 2005; Miller & Byrnes, 1997; Morrongiello & Sedore, 2005), but some research suggests that peers can also serve as models for safe behaviors (Babu et al., 2011). Therefore, it may be beneficial for parents to know the peers their children ride with and have children and peers participate in a bicycle-safety education program together.

Parents can also play a crucial role. The more vigilant a parent is (providing supervision at young ages, knowing where teenage children are, etc.) the more likely they will have a child who takes fewer risks and experiences fewer injuries (Arnett & Balle-Jensen, 1993; Morrongiello & Hogg, 2004). Parents who also model safe behavior have children who not only engage in safe behavior but intend to continue safe behavior in adulthood (Bandura, 1991; Morrongiello, Corbett, & Bellissimo, 2008).

Given the risk for injuries from bicycle riding, it is important that efforts to protect children while bicycle riding consider these developmental issues. In addition, ongoing interest and increases in Safe Routes to School programs, national and community interest in increasing physical activity for children, and the development of communities that promote more walking and bicycling may increase children's bicycle riding exposure. Therefore, now is the time to ensure that safety programs are adequately preparing children for increased exposure to traffic and potentially lay the foundation for safe riding over their lifetime.

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INTRODUCTION

In 2009, NHTSA published a report on child pedestrian safety that updated the field by explaining how new theories of child development and human learning can guide educational programs that teach children how to cross the street safely (Percer, 2009). Since that report came out, a number of children's bicycle safety advocates asked NHTSA for a similar report in relation to child bicyclist safety. The purpose of this report is to act as a companion piece to the report titled, "Child pedestrian safety education: Applying learning and developmental theories to develop safe street-crossing behaviors" by explaining how current theories of child development and learning can guide educational programs that teach children how to safely ride bicycles in traffic.

We recognize that children are not the most at-risk age group when it comes to traffic-related fatalities. Bicycle riders 45 to 54 years old are the most at-risk for fatalities. Bicycle riders 45 to 54 have a fatality rate of 3.51 per million population while children 5 to 9 and 10 to 15 have fatality rates of 1.28 and 1.41 per million population, respectively (NHTSA, 2013a). In addition, bicycle injuries and fatalities among children have steadily decreased over the last 20 years. (See Figure 1 for the fatality and injury rates per million population for children 5 to 15 years old).

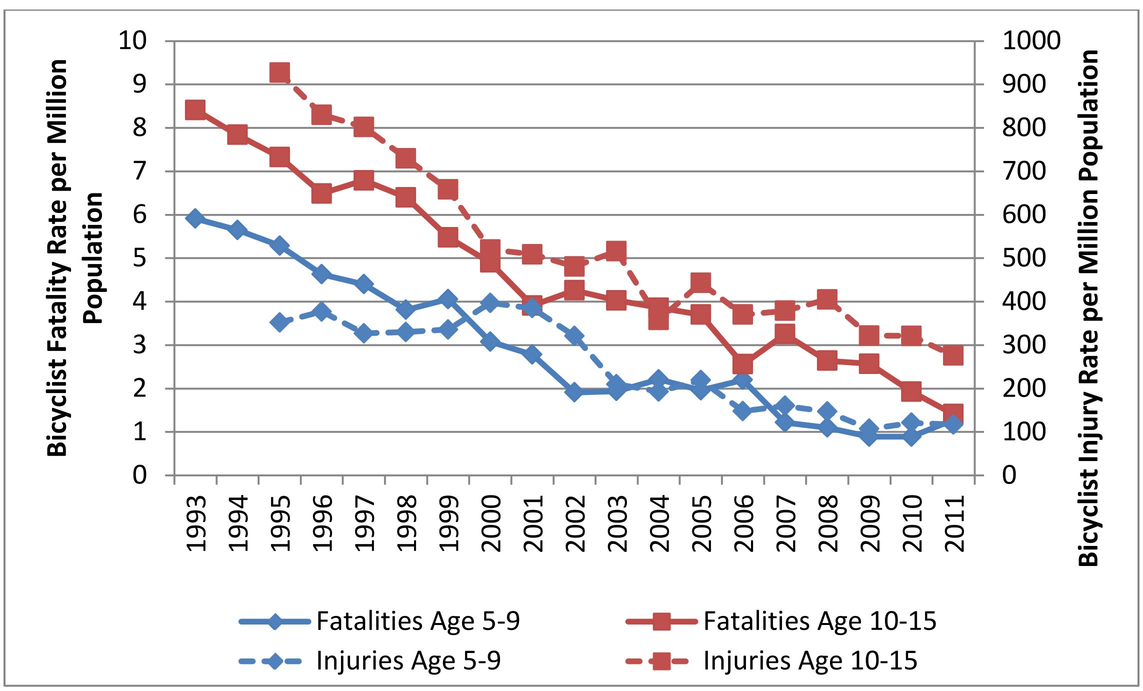

Figure 1. Bicyclist Fatality and Injury Rates for Children 5 to 15 From 1993 to 2011
Source: NHTSA FARS

However, it is important to keep in mind that NHTSA's data is based on police reported crashes and sometimes it is helpful to look at other data sources to get a more comprehensive understanding of the issue or problem. For instance, the Centers for Disease Control and Prevention's (CDC) Web-based Injury Statistics Query and Reporting System (WISQARS) is a national estimate of injuries treated in U.S. hospital emergency departments. WISQARS collects data on 20 specific ways people of all ages can be unintentionally injured (e.g., dog bites, cutting/piercing, drowning, falls, fire/burn, gunshot, motor vehicle occupant, etc.). In 2010, there were 4,512,353 unintentional, non-fatal injuries among children 5 to 15 (CDC, 2012). Of these injuries, 5% were bicycle-related. More specifically when looking at non-fatal, bicycle-related injuries for all ages in 2010, children 5 to 15 represented 27% of non-fatal, bicycle-related injuries that occurred on public highways and roads (CDC, 2012), making them the largest age group of traffic-related, bicyclist injuries when comparing similar age spans.[2] When looking at all bicycle-related injuries that occurred in 2010 (traffic-related and non-traffic- related[3]), children 5 to 15 accounted for 40% of all bicycle-related injuries (CDC, 2012). (See Figure 2 for a comparison of injuries from WISQARS and fatalities from NHTSA FARS.)

While NHTSA's injury and fatality rate data show that children's bicycle-related crashes are on the decline, bicycle-related injuries reported to emergency departments consist of a large proportion of children 15-years-old and younger. Therefore, the emergency department data suggest that it is useful to have a companion report to children's pedestrian safety (Percer, 2009) that is focused on bicycle safety. A companion report ensures that bicycle programs are designed to teach children how to ride their bicycles safely using current developmental and learning perspectives just as the report for NHTSA on child development, learning, and pedestrian safety (Percer, 2009) does.

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[2] According to the 2010 U.S. Census, the population has relatively equal numbers of people from birth to age 60 (Howden & Meyer, 2011); there are approximately 20 to 22 million people in the U.S. for each 5-year age group (birth to 5, 5 to 9, etc.). Therefore, the age ranges used for the non-injury data span equal length age ranges so that the number of people in each age group is relatively similar across all ages when looking at injuries compared to 5- to 15-year-olds.
[3] The CDC defines "non-traffic-related" for its data as "Any vehicle incident that occurs entirely in any place other than a public highway, street, or road" (CDC, 2007).

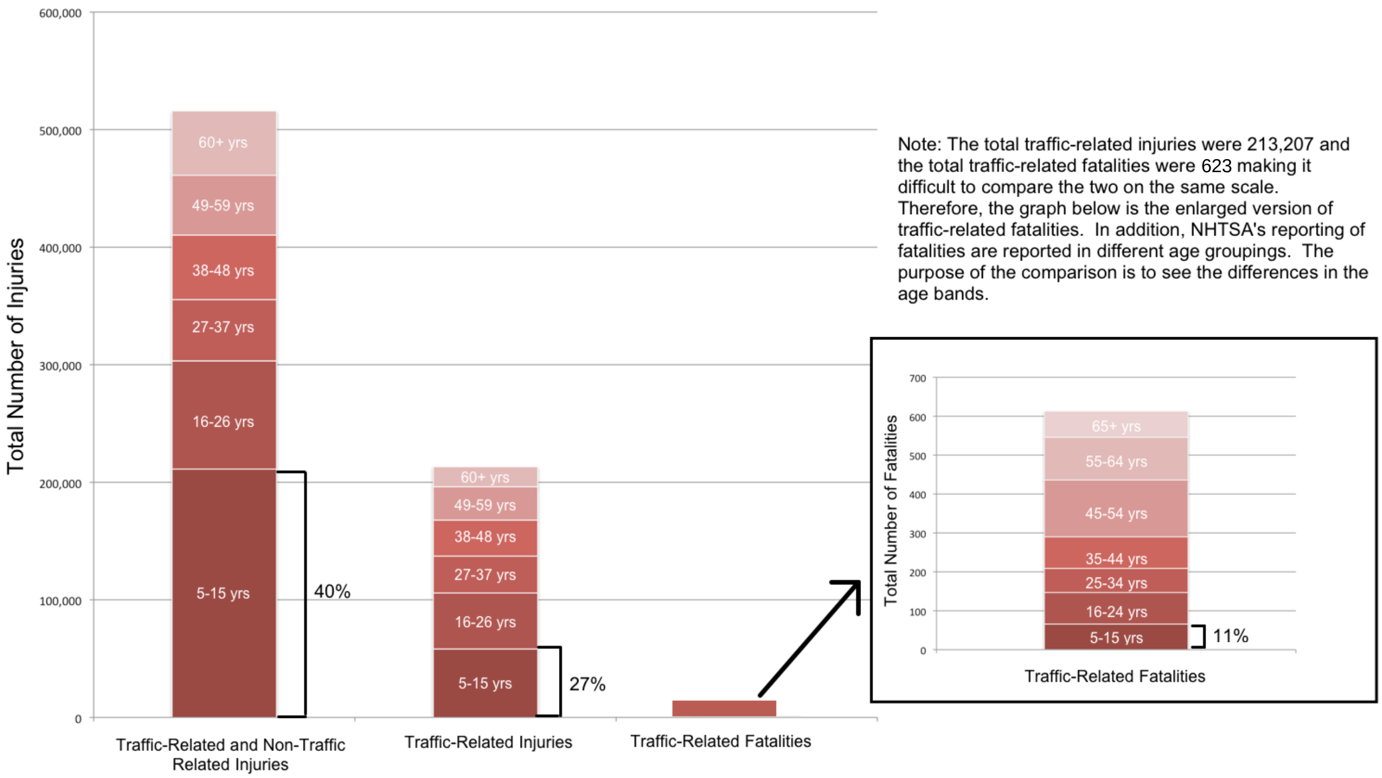


Figure 2. Comparison of WISQARS Bicycle-Related Injuries and FARS Bicycle-Related Fatalities by Age Group in 2010

The purpose of this literature review is to:

1. Understand the factors associated with bicycle crashes;
2. Describe the different types of bicycle education and their effectiveness; and
3. Explore how children's learning and development interact with their bicycle riding skills.

While the literature review will discuss the developmental level of younger elementary school children (5 to 7) just learning to ride a bike, the review's focus will be more on the developmental level of children 8 to 16 when the likelihood that children are riding near and in traffic increases. This literature review also explores the possibility that current programs may not be effective in improving safe riding behavior because they lack the appropriate focus on children's developmental and learning abilities.

ERRORS CHILDREN MAKE

Because the latest NHTSA fatality data (NHTSA, 2013a) shows that children are not the most at-risk for bicycle fatalities, this section focuses on understanding the types of errors children make. This is important to understand in order to create a companion piece to the report on children's pedestrian safety education.

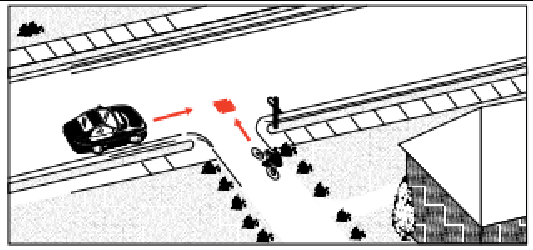
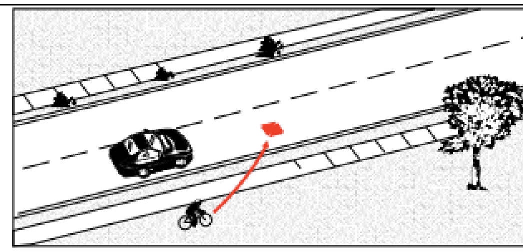
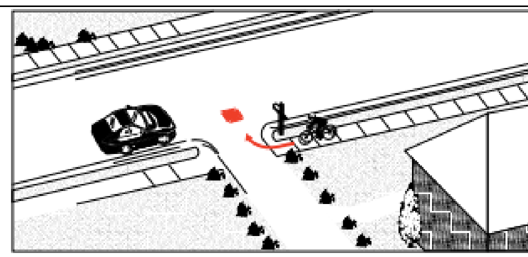
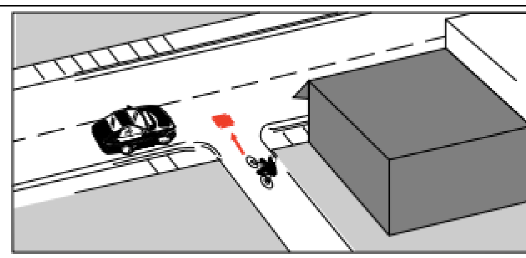
Several studies have found that bicyclist error is often cited as the cause of children and adolescents' bicycle-motor-vehicle collisions (Hunter, Stutts, Pein, & Cox, 1996; Rowe, Rowe, & Bota, 1995; Spence, Dykes, Bohn, & Wesson, 1993). In a seminal study, Cross and Fisher (1977) examined the data on the causes of bicycle-motor-vehicle crashes in order to identify potential countermeasure approaches. Data were collected by interviews and on-site investigations for non-fatal crashes and fatal crashes. Thirty-six unique problem types emerged based on the characteristics of the crashes. In some problem types, children and adolescents were more likely to be involved than adults. Hunter et al. (1996) found these problem types to be relatively robust 20 years later when children continued to be overrepresented in similar problem types. While this type of study has not been updated on a large representative sample since Hunter et al., the purpose of the following paragraphs is to give the reader a sense for the types of errors children have made when riding bicycles while looking at the types of crashes they are in.

Children and adolescents often are involved in crashes where the bicyclist enters the road from a residential driveway, midblock, sidewalk, or commercial driveway (Hunter, Pein, & Stutts, 1997). (See Table 1 for a description of the crashes.) A more recent study also found that children and adolescents were often involved in collisions where they were struck by vehicles when they entered the roadway from an adjacent sidewalk (Boufous, De Rome, Senserrick, & Ivers, 2011).

There were several crash types that young children (0 to 9) were more likely to be involved in than adolescents (10 to 14) (Hunter et al., 1997).[4] For instance, young children were often in crashes where the bicyclist turned in front of an approaching vehicle making up 30% of the crashes. Young children represented 40% of the crashes that occurred at an intersection that did not have a stop sign or a traffic signal. They also represented 27% of the crashes where the bicyclist lost control of the bicycle and swerved into the path of a moving vehicle. Finally, young children represented 36% of the crashes where a motor vehicle backed up into the street and struck the bicyclist.

[4] There are no illustrations for these findings.

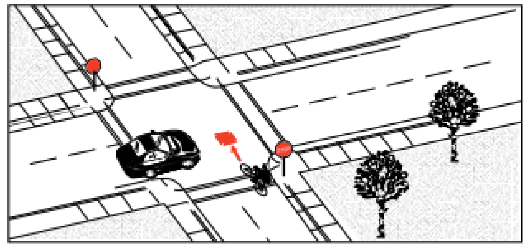
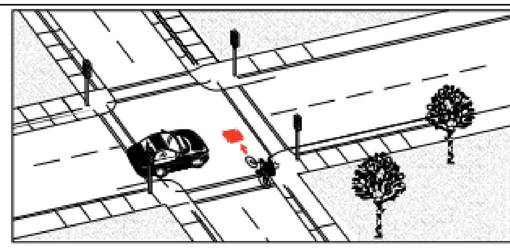
Table 1. Roadway Entry Crashes Where Children 0 to 14 Are Overrepresented

Type of Crash	Ages and Approximate Percentages	Crash Illustration
Ride Out at Residential Driveway	**0-9**	
	55% of crashes	
	10-14	
	30% of crashes	
Ride Out at Midblock	**0-9**	
	39% of crashes	
	10-14	
	32% of crashes	
Ride Out from Sidewalk	**0-9**	
	38% of crashes	
	10-14	
	38% of crashes	
Ride Out at Commercial Driveway	**0-9**	
	24% of crashes	
	10-14	
	45% of crashes	

Source: Hunter et al. (1997)

Children and adolescents were often in crashes at intersections (Hunter et al., 1997). However, adolescents 10 to 14 comprised a larger percentage of these crashes. For instance, children 0 to 14 were more likely to be in crashes at intersections where the bicyclist was facing a stop sign, flashing red light, or signal, but children 10 to 14 represented a larger percentage of these crashes than those 0 to 9 (see Table 2 for the percent).

Table 2. Crashes at Intersections Where Children 0 to 14 Are Overrepresented

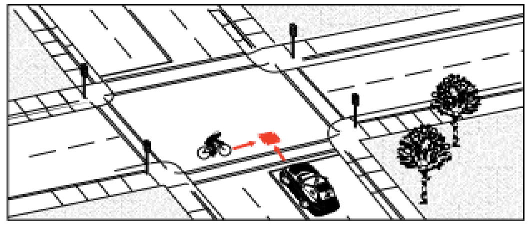
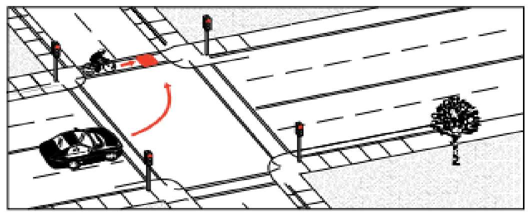
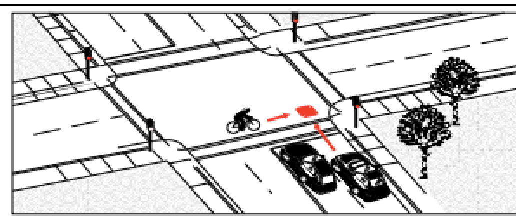
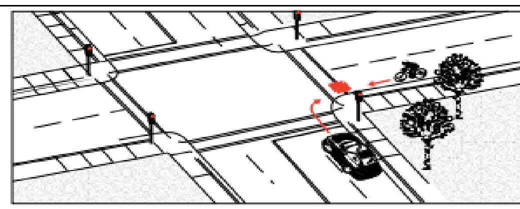
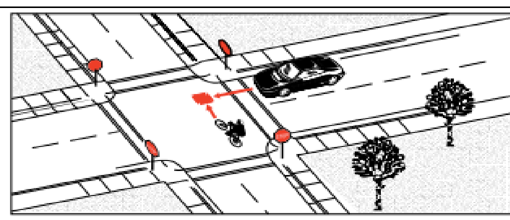
Type of Crash	Ages and Approximate Percentages	Crash Illustration
Ride Out at Stop Sign	**0-9** 31% of crashes **10-14** 37% of crashes	
Ride Out at Intersection - Other	**0-9** 22% of crashes **10-14** 35% of crashes	

Source: Hunter et al. (1997). Note: "Other" is described in Hunter et al. as "the crash occurred at an intersection, signalized or uncontrolled, at which the bicyclist failed to yield" (p.88).

Hunter et al. (1997) found that adolescents 10 to 14 were more likely to be involved in certain types of crashes at intersections than children 0 to 9. (See Table 3 for percentages and descriptions of the crashes). For instance, 50% of the crashes where the bicyclist did not clear the intersection before the traffic signal turned red (called "Trapped") consisted of adolescents 10 to 14 while there were no children 0 to 9 represented in this type of crash. Similarly, 30% of the crashes that occurred where both parties were traveling in the same direction and the motorist turned left in front of the bicyclist consisted of adolescents 10 to 14 while there were no children 0 to 9 represented in this type of crash. Other crashes where adolescents 10-14 were overrepresented are multiple threat, where the bicyclists did not clear the intersection before their light turned red and the motorist's view was obstructed by standing traffic; the motorist turned right at a red light and struck the bicyclist; and the motorist struck the bicyclist at an intersection controlled by a stop sign or traffic signal and did not conform to any of the other crash types.

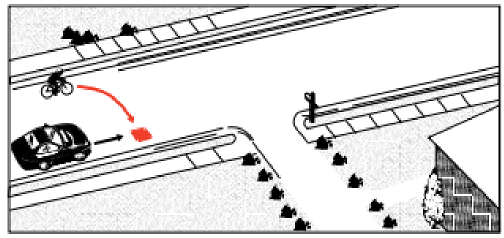
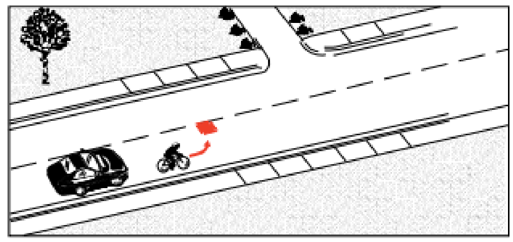
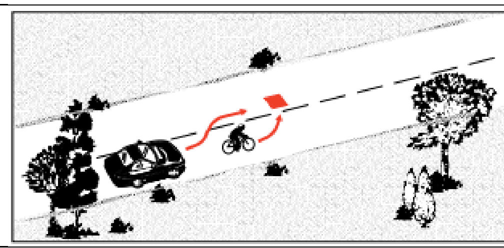
Additional crash types that children 10 to 14 were more likely to be in occurred when both the bicyclist and motorist are on the same road traveling in the same direction. These include crashes where the bicyclist turns right while riding on the left side of the motor vehicle it crashes with; the bicyclist turns left in front of traffic traveling in the same direction; and the motorist was overtaking the bicyclist when the bicyclist swerved into the motorist's path. (See Table 4 for percentages and descriptions of the crashes.)

Table 3. Crashes at Intersections Where Adolescents 10 to 14 Are Overrepresented

Type of Crash	Ages and Approximate Percentages	Crash Illustration
Trapped	**10-14** 50% of crashes	
Motorist Left Turn in Front of Bicyclist	**10-14** 30% of crashes	
Multiple Threat	**10-14** 30% of crashes	
Right on Red	**10-14** 33% of crashes	
Controlled Intersection - Other	**10-14** 30% of crashes	

Source: Hunter et al. (1997). Note: "Other" is described in Hunter et al. as "the crash occurred at an intersection that was controlled by stop sign or traffic signal, and did not conform to any of the other crash types" (p. 96).

Table 4. Additional Crashes Where Children 0 to 14 Are Overrepresented

Type of Crash	Ages and Approximate Percentages	Crash Illustration
Bicyclist Right Turn	**0-9**	
	26% of crashes	
	10-14	
	37% of crashes	
Bicyclist Left Turn in Front of Traffic	**0-9**	
	19% of crashes	
	10-14	
	45% of crashes	
Motorist Overtaking – Counteractive Evasive Actions	**0-9**	
	21% of crashes	
	10-14	
	44% of crashes	

Source: Hunter et al. (1997)

Section Summary

The purpose of this section was to explain the types of bicycle crashes involving motor vehicles children are likely to be in to better understand the errors they make. One common theme of most of these crashes is that children most likely did not conduct a proper search before executing their move that resulted in a crash whether it was entering a roadway, entering an intersection, or changing direction while traveling on a road. In a later section titled, *Making Education Programs More Effective: Developmental Considerations*, we explore some reasons why children may not be making a proper search while riding their bicycles.

BICYCLE EDUCATION AND EFFECTIVENESS

A brain injury is the leading cause of death and permanent disability in bicycle crashes. Bicycle helmets, particularly hard-shell helmets, have a protective effect against head, face, and neck injuries (Elvik, 2011).[5] Twenty-one States and the District of Columbia and at least 201 municipalities or counties have child helmet laws, mostly for children under 18. Thirteen States have no state or local helmet laws (Bicycle Helmet Safety Institute, 2012). While bicycle helmets are the best way to protect children on bicycles from head injuries in the event of a crash, it is also important to prevent crashes from happening in the first place. One way to prevent crashes is to provide bicycle safety education that includes knowledge and on-bike skills. The purpose of this section is to focus on the types of bicycle safety education programs for children that exist and the extent to which they have been evaluated.

Types of Bicycle Education Programs

Bicycle education (including cycling skills clinics, bike fairs, and bike rodeos) for children can teach children about traffic laws as bicyclists, how to ride on streets with traffic present, safe riding maneuvers, proper helmet use, and how to conduct bicycle safety checks and maintenance (NHTSA, 2013b). The purpose of bicycle safety-training programs is to teach children how to ride their bikes safely thereby reducing injuries and fatalities.

Bicycle safety-training programs can vary in content, duration, and format. For instance, some bicycle education programs consist of a single, lecture-based presentation lasting up to one hour in school classrooms (FHWA, 2002; McLaughlin & Glang, 2010; Rivara & Metrik, 1998). Other programs combine a single on-bike training session with a single lecture-based presentation (FHWA, 2002; Rivara & Metrik, 1998; van Schagen & Brookhuis, 1994). Finally, some programs offer a more in-depth learning experience covering several hours of classroom-based instruction and several hours of on-bicycle instruction (FHWA, 2002; Savill, Bryan-Brown, & Harland, 1996). Classroom or lecture-based instruction can cover topics such as bicycle traffic laws and signs, helmet fitting, maintenance and repairs, and bicycle safety checks. The on-bicycle instruction can develop skills such as braking, turning, road positioning, riding with one hand, right-of-way intersections, and interactions with other vehicles.

The critical question is do these programs reduce children's crashes with motor vehicles? This question can be difficult to answer because programs are typically evaluated in small settings (e.g., several schools or several community centers) and with such a small sample size there usually is not enough statistical power to

[5] There is a debate in the literature regarding the level of bicycle helmets' protective effect; therefore, an exact percentage is not reported. However, there is agreement that helmets reduce the likelihood of injury. See Elvik (2011) for the latest meta-analysis and discussion on the effectiveness of bicycle helmets.

determine if the program reduces crashes. Sometimes, programs are implemented citywide or in large enough areas that an impact on crashes can be evaluated. Often, evaluations where a crash reduction cannot be assessed will use changes in safety knowledge and behavior as a proxy for potential crash reductions. The assumption is usually that improved safety knowledge will lead to improved behavior which will in turn lead to fewer crashes.

The Effectiveness of Bicycle Education Programs

While the goal of injury reduction may be part of many bicycle education programs, it is difficult to know the extent to which programs achieve their goals without an evaluation of the program. Considering the variety in length, format, and even content that bicycle education programs can have it can be difficult to know if the shorter in-class sessions are as effective as the longer more in-depth sessions. A number of studies have been conducted to determine how effective bicycle education programs are at changing children's behaviors and reducing crashes and injuries. The purpose of this section is to identify any specific aspects of programs that might be effective in improving knowledge, changing behaviors, and reducing crashes.

Knowledge Gains

A number of evaluations have found that bicycle education programs increase children's safety knowledge in comparison to pre- and post-tests and controls (Greene et al., 2002; Gresham et al., 2001; McLaughlin & Glang, 2010; Nagel, Hankenhoff, Kimmel, & Saxe, 2003; Rivara & Metrik, 1998; Savill et al., 1996; van Schagen & Brookhuis, 1994). Rivara and Metrik (1998) evaluated a program that was known at the time as the Travis County Super Cyclist program.[6] This program consisted of a single, one-hour session for 5- to 8-year-old children and a five-class course for 9- to 14-year-old children (Rivara & Metrik, 1998). The course structure was mainly lecture-based presentations, although the version for the older children ends with an on-bicycle training course. The program's coordinators reported to Rivara and Metrik that students showed an improvement in knowledge based on changes in the pre- and post-test scores.

The program THINK FIRST for KIDS (TFFK) has also been shown to improve children's knowledge. TFFK is a six-week curriculum teaching six safe-behavior units, two of which include motor vehicle, pedestrian safety, and bicycle safety. The curriculum is based on applied learning and behavioral theories that suggest that varied messages introduced over time improve understanding, knowledge, retention, and sustained behavior. Gresham et al. (2001) conducted an evaluation of TFFK in California. First, second, and third graders were either in the intervention schools or the control schools. Without the intervention, children often lacked basic knowledge regarding bicycle safety and did not recognize behaviors considered high risk for injury while bicycling. The researchers found a

[6] This program is currently known as the Super Cyclist project that uses the Neighborhood Adventures in Bicycle Safety curriculum and is used throughout Texas.

significant increase in knowledge among intervention participants than controls. The program had the greatest impact among minority students who showed the largest knowledge gains. Greene et al. (2002) conducted a similar evaluation of the TFFK program in Oregon. They also found improvement in knowledge compared to controls with the greatest gains among students from low socio-economic status backgrounds.

McLaughlin and Glang (2010) found knowledge gains with the Bike Smart program, an eHealth software program that teaches bicycle safety to young children (grades kindergarten through third). The Bike Smart program can be completed in two class periods and navigated independently by most students using interactive learning and individualized feedback for the user. Students participating in this study and were randomly assigned to either the intervention group or the control group. They took a written pre- and post-test on their knowledge and were evaluated on their ability to correctly wear a helmet. McLaughlin and Glang found that, overall, children who took the Bike Smart program showed greater improvement from pre- to post-test scores than the controls. Children also demonstrated an improvement in knowledge and behavior when it came to correctly putting on a helmet.

Behavioral Improvements

Other evaluations have found behavioral improvements in children's bicycle safety after participating in a bicycle education program. Programs that found behavioral improvements used an on-bicycle training format giving children hands-on experience in the target behaviors.

Savill, Bryan-Brown, and Harland (1996) conducted a study to assess whether bicycle-training programs in the U.K. resulted in improved, safer cycling skills. The U.K. had a National Cycle Proficiency Scheme (NCPS, superseded by Bikeability) that provided training to children 9 and 10 since 1947. The bicycle-training course took place in four to eight sessions each lasting one to one and a half hours and included on-bicycle training. At the time of the Savill et al. (1996) study about 40% of each annual cohort of children received training by their 12th birthday. They recruited children who had taken training and a control group who had not, matched on sex and experience from local schools. Children received a knowledge test and an on-road test that was conducted according to NCPS test procedures. Children performed a variety of maneuvers, including making left and right turns and overtaking parked cars. A retired road safety officer, blind to whether or not the children had taken the training, evaluated their performance giving children a "safe" or "unsafe" rating for each maneuver. Savill et al. found that 75% of the children who were trained were given an overall "safe" assessment, compared to 53% of the untrained children. The two groups also had similar levels of exposure which means that amount of riding could not influence the difference between the two groups.

Van Schagen and Brookhuis (1994) conducted a study to evaluate the effectiveness of two training methods developed to teach young cyclists 8 to 9 years old how to behave in important traffic situations.

- One method they evaluated was based on a modeling principle. In this training method, children participated in a single 1.5-hour on-bicycle session. During that time they watched the instructor demonstrate the target behaviors. Afterwards, children practiced the target behaviors with the instructor, and then the children performed the behaviors with the instructor watching. During children's solo performance, the instructor would verbalize the target behaviors to the children and give them feedback on their performance.
- In the other training method, children received instruction on the theoretical basis for various cycling rules. For instance, children received explanations on the purpose of signaling and conducting a visual search with an emphasis on the consequences for this behavior. The theoretical portion of the training occurred in a classroom-based setting and was followed by on-bicycle training a week later.

Two groups of children were trained with one of these methods and a control group did not receive traffic-related training. The behavioral training and behavioral testing occurred on a traffic training ground which was very much like a real traffic intersection but closed to traffic and with an experimental car, bicyclist and pedestrian. Both types of training resulted in an overall improvement in correct, safe-cycling behaviors over no training and this remained one-month later.

For specific situations, children were not always consistent in their decisions. For instance, children were more likely to yield the right of way even if they had the right of way. However, in about 30% of situations, children took the right of way when it was not theirs to take. Van Schagen and Brookhuis (1994) noted that just because children responded correctly in one situation did not mean they responded in the same way in a similar situation. They suggest this may occur because children developed their own rules prior to the training that were difficult to override with training. In addition, they argued that ideally children should be taught correctly when they first learn how to ride a bike. Unfortunately, children typically learn to ride a bicycle at 5 years old when they are too young for the complicated rules of the road as a bicyclist.

Crash Reductions

Some evaluations of bicycle education programs have reported crash reductions. Rivara and Metrik (1998) discussed an evaluation of the *Florida Traffic/Bicycle Safety Education Program*,[7] which provided children with 3 to 5 hours of classroom instruction and 3 to 5 hours of on-bicycle training for grades 3 through 5. They found "an 80% decrease in bicycle-related mortality and a 68% decrease

[7] Updated information on this program can be found at http://legacy.hhp.ufl.edu/safety/

in bicycle-related morbidity" (p. 24); however, details on these findings were not provided. Rivara and Metrik also discussed the evaluation of Safe Moves in California, which provided on-bicycle skills training combined with a lecture-based presentation. Between 1993 and 1996, one million school children participated in the program. The Los Angeles County Department of Public Works reported a 25% reduction in bicycle-related fatalities and a 34% reduction in bicycle-related injuries. At the time it was evaluated, the *Travis County Super Cyclist Program*, which consisted mainly of lecture-based presentations and a course for the older children that ended with on-bicycle training, reported an 88% decrease in the number of bicycle crashes with motor vehicles among children 5 to 14 (Rivara & Metrik, 1998).

The Basics of Bicycling developed in North Carolina is another program that showed a crash reduction (Rivara & Metrik, 1998; Stutts & Hunter, 1990). Stutts and Hunter (1990) developed and evaluated this program for fourth and fifth graders. The program consisted of seven lessons. The first two lessons were lecture-based instruction, and the remaining five lessons were on-bicycle in a simulated road environment on school grounds. In a follow up survey, the authors found that six months later program participants were less likely than the controls to have been injured while riding their bicycles over the summer. [8]

Similarly, Durkin, Laraque, Lubman, and Barlow (1999) found a crash reduction from the program they evaluated. They conducted a study to examine the incidence of severe traffic injuries before and during the implementation of a comprehensive, hospital-initiated injury prevention program. The Safety City Program was designed to prevent traffic injuries to school-aged children in Manhattan. The program provided instruction in safe-street crossing behavior to third grade elementary students in Northern Manhattan. The program also had a traveling puppet theater that provided safety information to children in kindergarten through fourth grade and to parks and community centers on motor vehicle occupants, bicyclists, and pedestrians. Prior to the intervention among school-aged children, average annual rates of severe injuries per 100,000 children (younger than 17) were 127.2 for pedestrian, 37.4 for bicyclist, and 25.5 for motor vehicle occupants. The peak incidence of pedestrian injuries was among 6- to 10-year-old children, of bicyclist injuries were among 9- to 15-year-old children, and of motor vehicle occupant injuries were among adolescents 12 to 16 years. The incidence of traffic-related injuries among school-age children was increasing before the program was implemented; and during the intervention, the incidence of traffic injuries among school-aged children

[8] Stutts and Hunter (1990) conducted a behavioral evaluation of children who took the course and of controls. However, the evaluation for the trained group was not the same as the controls. They wrote, "We usually tended to give the [trained] child 'the benefit of the doubt' if we knew that we had seen him/her successfully execute a particular maneuver on several previous occasions." (p. 27) This "benefit of the doubt" could not be given to controls whom they had never seen on the course previously and so the behavioral results of this study are not reliable and therefore, not discussed.

decreased.[9] Durkin et al. (1999) also found a decline in the incidence of major head trauma by 73%, a 52% decline in minor head trauma, and a 42% decline in all other injury incidence during the intervention.

No Effect of Training

Studies finding no significant effect of training showed no behavioral changes, no differences in injuries, or no reduction in crashes (Carlin, Taylor, & Nolan, 1995; Colwell & Culverwell, 2002; Macarthur, Parkin, Sidky, & Wallace, 1998). Macarther et al. (1998) evaluated the Kids CAN-Bike Festival in Canada, a 90-minute playground course for children 8 to 13. Children went to six stations where they were taught about bicycle equipment and bicycle handling. The four bicycle-handling skills taught were based on crash risk factors noted in previous studies. The skills were taught because they emphasized the dangers of weaving on the road, swerving into traffic without looking, not signaling, and riding through stop signs. Macarther et al. found the training was not effective in changing behaviors. However, they did note that the festival served as an introductory course in bicycle safety, and after the festival, children were encouraged to attend the 10-hour bicycle course that provided more detailed instruction and skills practice.

Carlin, Taylor, and Nolan (1998) evaluated the effectiveness of *Bike Ed* in reducing bicycle crashes in Victoria, Australia. *Bike Ed* covered safe riding skills, traffic knowledge and skills, and basic bicycle mechanics. The course progressed through three types of sessions including a classroom component, practice riding their bikes on the school grounds, and lastly, a supervised group ride on local streets. Children who were injured while riding a bicycle were recruited through hospital emergency departments to participate in the program. The control group included children of the same age range as the injured children and who rode bicycles. They were recruited by calling randomly selected telephone numbers. If training reduces injury, one would expect to see more children among the controls who took *Bike Ed* than the injured children. However, the proportion of children who participated in *Bike Ed* was similar in both groups.

Similarly, Colwell and Culverwell (2002) found that the U.K.'s bicycle training program had no effect on reducing children's bicycle crashes. They recruited children 13 to 16 from local schools and gave them a questionnaire that asked about riding and crash history. About half of the sample had taken the cycling course that was offered in London and half of those children had taken the course on public roads. At least one cycling injury had been sustained by 58.3% of respondents, requiring hospital treatment in 19.1% of cases. Colwell and Culverwell found no difference in crashes between trained and untrained children. However, it is important to note that the researchers asked children for

[9] Durkin et al. (1999) acknowledge that without a control group it is difficult to ascertain the magnitude of the intervention's effect. They do note that the rest of New York City (excluding northern Manhattan) showed a decline in children's traffic-related injuries during the same period but the decline was not as great as Northern Manhattan.

the total number of lifetime crashes meaning that any crashes that happened before the training may have diluted any differences in crashes after training.

Section Summary

While the evaluations discussed in this report examined different kinds of bicycle programs, some consistent trends did emerge suggesting that different types of training can affect knowledge, behavior, and crashes. For instance, short, lecture-based programs are effective in improving children's knowledge. Knowledge is the first step to injury prevention because children have to know and understand the rules of the road first and foremost. The second step, however, is ensuring that children engage in the concomitant behaviors to reduce the likelihood of injury. The evaluated programs that showed such behavioral improvements were generally the more in-depth programs offering 5 or more hours of on-bicycle training in road environments. Programs that showed crash reductions tended to have several hours or more of classroom instruction in addition to several hours or more of on-bicycle training, although at this point it is not clear what specific aspects of programs lead to crash reductions.

Bicycle training programs may be more effective if additional factors related to children and bicycle riding are considered. For instance, understanding cognitive development can guide what children can be taught at different ages. In addition, factors related to risk-taking and social influences also have different impacts at different ages. The following sections review important areas in child development and learning that can guide the development of more effective bicycle education programs.

Making Education Programs More Effective: Developmental Considerations

Understanding how to bring about changes in humans is a complex process. With respect to learning how to ride a bicycle in traffic, motor skills, vision, learning and memory, cognitive development, and the social environment can all influence how and what people learn. In addition, the brain is not fully developed until the early to mid-twenties and so it is important to understand how the developing brain influences children's ability to learn safe bicycle riding skills. The purpose of this section is to discuss the various factors that can help or hinder children's abilities to learn safe bicycling skills. When possible, these factors will be discussed in the context of what we know about children's errors in riding bicycles. Because developmental psychology covers a wide range of topics, the purpose of this section is not to give the reader a mini course in developmental psychology but to provide bicycle safety program managers with essential pieces of information that can help guide bicycle program development.

Physical Development

The purpose of this section is to discuss physical development as it relates to helping children safely ride bicycles. In particular, it is important to understand that learning to ride a bicycle involves the development of specific motor skills related to bicycle riding. In addition, the maturation of the brain through early adulthood affects how and what children and adolescents learn and understand.

Motor Skill Development

Motor development in children typically refers to a group of behavioral milestones related to postural development; locomotion such as walking, running, jumping, and climbing; stability movements such as bending, turning, and rolling; and manipulative movements such as throwing, catching, and writing (Vasta, Haith, & Miller, 1999). These fundamental skills develop between the ages of 2 and 7 and are further refined through adolescence. However, learning to ride a bicycle can be considered a motor skill because it involves a specific set of behaviors developed through repeated practice and use. Motor skills must be "nurtured, promoted, and practiced…. Motor skills take years to develop and require specific experiences and instruction" (Clark, 2007, p. 43). Through practice, a motor skill develops because the movements are fine-tuned to become smooth and efficient (Thelan, 1995).

When a motor skill is developed, the movements have what Whitall (2003) calls optimal coordination and optimal control. Optimal coordination is being able to efficiently move the various parts of the body to execute a certain behavior at an advanced level. Control is important because one needs to adjust the speed, timing, and direction of his or her movements depending on the situation. The combination of optimal coordination and control allows a person to easily adapt to environmental changes.

When applying optimal coordination and optimal control to riding a bicycle on roads, children not only have to develop the bicycle riding skill (balance, pedaling, adjusting speed, braking, controlling the handlebars, etc.), but they must also develop the traffic-safety skill that consists of sufficient behaviors needed to correctly and safely maneuver through traffic (moving the head to search for traffic, engaging the brake pedals or levers to stop at lights and stop signs, slowing down to yield, etc.). Both types of skills, the bicycle-riding skill and the traffic-safety skill, will only occur through frequent practice. Practice will produce a skillful bicyclist; and a skillful bicyclist can smoothly and efficiently maneuver the bicycle, whether it is steering, swerving, stopping, starting, and looking around for other moving objects, or adjusting roadway positioning to avoid roadway obstacles. The skillful bicyclist also has sufficient control over his or her actions such that he or she is able to alter his or her movements quickly and efficiently to avoid or minimize crashes.

As stated in an earlier section on evaluated programs in this report, Macarthur et al. (1998) found that the training they evaluated did not change children's behaviors. The program they evaluated was similar to bicycle skills training (bike rodeos) consisting of a single, 90-minute session on a playground where each of six stations taught varying bicycle handling skills. Given that it takes a significant amount of practice to develop a skill, it is not surprising that behavior changes were not found after a one time training activity. Bicycle skills training such as cycling skills clinics[10] may be a good way to introduce children to bicycle handling skills; however, this activity alone is not the best source for producing behavioral change.

Brain Development

With advances in technology, scientists continually develop a more thorough understanding of how the brain functions and changes through the life span. Changes in the brain affect how children and adolescents learn and what they understand. An understanding of these changes can better guide prevention efforts. Neuroscience studies often involve the use of functional magnetic resonance imaging (fMRI) to see what parts of the brain are activated during certain kinds of tasks.

Based on fMRI studies, the prefrontal cortex is the last part of the brain to mature (Casey et al., 2000; Giedd et al., 1999). The prefrontal cortex involves working memory, response inhibition, planning, weighing consequences, and self-regulation (Casey et al., 2000; Steinberg, 2007). The gradual maturation of these abilities has direct implications for children and adolescents with traffic safety. For instance, response inhibition is the ability to not respond during the presentation of a particular stimulus such as not running into the road when your ball enters the road or refraining from choosing a gap that is too small to cross

[10] www.nhtsa.gov/Driving+Safety/Bicycles/CyclingSkillsClinic

because you are in a hurry. Therefore, for some traffic-related skills, children's performance will improve as their brains mature.

Researchers have also found that changes in the brain are related to risk-taking during adolescence (Bjork et al., 2004; Steinberg, 2007). Some adolescents take more risks because of the competing demands between the prefrontal cortex and the socio-emotional center of the brain[11] (Steinberg, 2007; Steinberg et al., 2008). The socio-emotional center is sensitive to social and emotional stimuli and is important for processing rewards. The socio-emotional center becomes increasingly sensitive and easily aroused during early adolescence because of the hormonal changes in puberty and as a result becomes a more dominant part of the brain during adolescence. Because the prefrontal cortex matures gradually into young adulthood, it cannot keep up with the demands of the now active socio-emotional center until it reaches maturity. This means that under emotionally arousing situations, including situations that involve risk-taking, the socio-emotional network becomes so activated that the cognitive-control network cannot regain control of the emotional centers. As the cognitive-control network matures over time, it gradually gets better at moderating risk so that by the early to mid-twenties it can do so even under heightened emotional arousal.

Perceptual Development

It is also important to understand how perception interacts with children's ability to ride a bicycle. Vision and the interaction of vision and balance have important implications for children riding a bicycle in traffic. Similarly, children's ability to estimate speed and distance are another perceptual ability that is important when riding a bicycle.

Vision[12]

Vision is obviously important in riding a bicycle, not only to see where to ride but to also search for obstacles and moving vehicles. Often cited in the child pedestrian and bicycle literature is Sandels' (1975) conclusion that elementary school children have limited peripheral vision, and because of this, children have difficulty seeing motor vehicles approaching in their peripheral vision. It is not surprising that she came to this conclusion, given that the research at the time was inconclusive. Shortly after Sandels' theories were published, there was a shift in developmental psychology as researchers developed simple and innovative ways to understand what children are capable of. Because potential confounds with previous studies on children's peripheral vision involve differences in reaction times between adults and children and tasks too difficult for children, Cohen and Haith (1977) examined children's ability to identify

[11] Gender differences are discussed in "Making Education Programs More Effective: Considerations of Risk-Taking During Childhood and Adolescence" of this report.
[12] In the academic world, the debate that children can use their peripheral vision is settled. However, because program managers still reference Sandal's research that children cannot use their peripheral vision, it is important to reiterate the research findings on children's peripheral vision.

shapes in their visual periphery. Five- and 8-year-old children and adults judged either the similarity (Study 1) or the identity (Study 2) of geometric forms as they were presented in various positions in the visual field (including the peripheral field). They found no age differences in the ability to use peripheral vision, challenging the idea of tunnel vision in elementary school aged children.

Vision, especially peripheral vision, is also important for balance while stationary and during locomotion (Assaiante & Amblard, 1992; Nougier, Bard, Fleury, & Teasdale, 1998). Nougier et al. (1998) conducted a study where children balanced on an apparatus under different conditions of vision. They analyzed postural oscillations[13] in 6-, 8-, and 10-year-old children in four conditions of vision (complete vision, peripheral vision, central vision and no-vision). They found that children were more stable with than without vision. This occurred whether children had complete or partial vision (central only or peripheral only). Overall, there was no effect of age.

There does appear to be a transition period around 7 or 8 years old in the use of peripheral vision for motor tasks. Nougier et al. (1998) did find a subtle difference between 8-year-olds and the 6- and 10-year-olds. In their study, 6- and 10-year-olds' central and peripheral vision contributed equally to postural control, but for 8-year-olds central vision helped them to have a more stable posture than peripheral vision. This is consistent with other findings such as Assaiante and Amblard's (1992) findings that around age 7, children stop using peripheral cues for balance but then begin using them again at 8 or 9 years old through adulthood. What this may mean in terms of bicycle riding is that children 7 to 8 may place more focus on their central vision to maintain their balance on a bicycle making them less able to notice important traffic-related information in their peripheral vision. Alternatively, if they do pay attention to traffic-related information in their periphery, they may compromise their balance on their bicycle.

Estimating Speed and Distance

It is important to understand to what extent children can use visual cues to estimate speed and distance because finding a safe gap to cross in traffic is dependent on it. Hoffman, Payne, and Prescott (1980) wanted to compare children and adults on their ability to estimate vehicle arrival time. They recruited participants from four age groups (5 to 6, 7 to 8, 9 to 10, and adults) and showed them a series of film clips of an approaching vehicle along a roadway.[14] Participants estimated how long it would take each vehicle to reach them. Hoffman et al. found that all age groups underestimated the time to arrival, and participants' estimates became more accurate as they got older. Males were more accurate than females. Based on a regression analysis, Hoffman et al. predicted that children would be at adult performance by about 12 years old.

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[13] Nougier et al. (1998) measured how much children's backs moved from a central point. Fewer oscillations or movement meant better balance and control.
[14] This was set up as if participants were standing on a curb looking at traffic.

However, Hoffman et al. noted that in the 5- to 6-year-old age group, there was a "considerable proportion" (p. 239) that were capable of scaling time, even though they were more likely to underestimate.

However, just because the children under 12 were less accurate than adults, does not necessarily mean that they were incapable of judging the speed and distance of moving vehicles. Children have mastered the concepts of speed and distance by 5 years old (Siegler & Richards, 1979). One reason the younger children were more likely to have difficulty with vehicle estimation time may have been due to the two-dimensional nature of the task. The younger children may have had difficulty in estimating time to arrival in the absence of depth cues, and estimating from a three-dimensional environment may have resulted in a larger proportion of younger children having closer estimates to adults. In addition, because other studies have found that young children can be trained to make decisions that mirror adult decisions to cross the road during gaps (Young & Lee, 1987), it may be that increased exposure to similar situations (e.g., more practice at estimating speed) may improve younger children's performance.

Plumert and colleagues have found that older children choose the same gap sizes as adults while in an immersive, interactive bicycle simulation (Plumert, Cremer, & Kearney, 2004; Plumert, Kearney, Cremer, Recker, & Strutt, 2011). Plumert and colleagues had 10-year-olds, 12-year-olds, and adults ride a bicycle mounted on a stationary trainer through a virtual environment (see Figure 3). In the virtual environment, they traveled down a street and crossed a pre-determined number of intersections with traffic. At each intersection, participants had to choose the safest gaps to cross the street and continue to the next intersection. In their first study, Plumert et al. (2004) had participants face continuous cross traffic that was traveling at 25 mph or 35 mph and wait for gaps they judged were adequate for crossing. The researchers found that 10-year-olds were less likely to stop at intersections when cars were traveling 25 mph than when cars were traveling 35 mph. However, there were no differences between 10-year-olds, 12-year-olds, and adults on their chosen gap sizes. Ten-year-olds, 12-year-olds, and adults also make similar choices under high-density traffic conditions (Plumert et al., 2011). Because children and adults chose the same gap size, these findings suggest that older children and adults have similar perceptions of temporal information.

Figure 3. Simulated Environment for a Bicyclist Crossing the Road
Source: Plumert, reprinted with author's permission.

Cognitive Development

Understanding what children know is the hallmark of cognitive developmental psychology. For many years, Jean Piaget's theories of cognitive development led the way in explaining how children's understanding of the world changes over time. However, advances in developmental research in the last 30 years have shown that children know more than researchers once believed and other theories have evolved to explain children's cognitive development.

One major modern theory is the information processing approach, which draws from computer science to formulate and test theories (Perkins & Salomon, 1989; Vasta et al., 1999). Because the purpose of this section is to help bicycle program managers understand how bicycle safety education can be improved based on developmental principles, only a basic description of this theory is provided. As explained through the information processing approach, people take information from their environment and then process the information, such as attending to important information, making comparisons with past memories, or selecting a response. One important thing to understand about this theory is that changes in cognition are understood from a domain specific perspective as opposed to broad level changes. In other words, instead of understanding general rules that explain how children understand the world, there are specific rules for specific situations. Therefore, the following sections discuss specific aspects of cognition that are relevant to children learning how to ride safely in traffic.

Speed of Processing

Speed of processing is how fast a person can execute a cognitive operation to solve a problem. Case (as discussed in Vasta et al., 1999) theorized that children use an operating space and a short-term storage space to solve problems. The operating space is the area where cognitive operations occur to solve a problem. The short-term storage space is the area that stores the results from previous cognitive operations while carrying out new ones. Children's ability to solve problems changes with age and becomes faster because as their short-term storage space increases they have more room to combine previous cognitive operations that could only be done individually when the short-term storage space was smaller. Children's short-term storage capacity increases as they get older because children become more efficient with their cognitive operations. As a result, the cognitive operations space uses less capacity thereby giving more space to the short-term storage area.

What this means is that children's ability to solve a problem and do it quickly is very much dependent on their cognitive operations becoming automatic (and thereby efficient) and biological maturation (Vasta et al., 1999). In a traffic situation, it is critical for road users to act quickly in the event of an emergency. Delayed response times can make the difference between a near miss and a crash. Studies have found that children are significantly slower at reacting than adults, but children's reaction time improves with age (Kail, 1991, 1993). Kail (1991) conducted a study that demonstrated the developmental trend associated with reaction times. Participants were 7.5 to 43 years old and were tested on several different tasks that involved releasing a button in response to a stimulus. They found that reaction times declined with age, or in other words, children became faster at responding in the tasks as they got older. Children 7.5 to 8.5 were 73% slower than adults in responding to stimuli. Children became more adult-like in their response times around 14 years old. Kail (1993) proposed that children have slower reaction times than adults because they are slower to process information.

Children's slow processing abilities affect their bicycle riding abilities. In the bicycle simulation studies, one significant age difference Plumert and colleagues (Babu et al., 2011; Chihak et al., 2010; Plumert et al., 2004, 2011) did find was in what they called time-to-spare: how much time riders left between themselves and the approaching car when they cleared the lane. Ten-year-olds left less time-to-spare between themselves and the approaching car than 12-year-olds and 12-year-olds left less time-to-spare than adults. Plumert et al. (2004) reasoned that this was most likely due to the additive effects of children being slower to initiate movement and slower to cross the road which is consistent with the findings that children are slower to respond than adults (Kail 1991, 1993).

To minimize children's slower speed at initiating movement and crossing the intersections, Chihak et al. (2010) conducted a follow up study where participants did not come to a complete stop at the intersections. In their study, 10-year-olds, 12-year-olds, and adults rode through 12 intersections where they attempted to pass through a gap between two moving, car-sized blocks by slowing down or speeding up to make it through the gap. They found that 10-year-olds and 12-year-olds continued to have significantly less time to spare than adults, despite the fact that they did not come to a complete stop at the intersections. In Experiment 2 where participants had to cross with more traffic on the simulated roads, the 10-year-olds continued to have less time to spare than adults, but the 12-year-olds and adults were no different. While Chihak et al. attempted to minimize children's slow responses by keeping participants from coming to a complete stop during the experiment, there was still a moment of decision and reaction to that decision when participants chose their gap to cross. It is possible that the difference in time to spare between children and adults is due to their slow information processing.

At this time, no studies have been conducted to determine if children's responses to unexpected stimuli or decision-making while bicycle riding can be improved through training. Therefore, an important point for traffic safety professionals to keep in mind is that young children will be slower than adults to respond in an emergency situation. Consequently, it might be prudent to define safe environments for young children to ride in that minimize the need for quick responses.

Multi-tasking[15]

Riding a bicycle in traffic involves engaging in motor and cognitive skills at the same time. It involves physically manipulating the bicycle and attending and responding to the traffic environment. In their bicycle simulation study, Chihak et al. (2010) discuss the possibility that children have difficulty multi-tasking (e.g., steering and watching for cars at the same time). Research has shown that while children are capable of multi-tasking, it is often to the decrement of one task. Wierda and Brookhuis (1991) conducted a study where participants of varying ages and bicycling experience rode a bicycle while simultaneously completing a cognitive task of pressing a button in response to a buzzer sound. All participants also completed the cognitive task while standing next to the bicycle to compare single task with multi-task performance. When engaged in the cognitive task only, they found that 6- to 8-year-old children were about 100 ms slower than the 9- to 11-year-olds, 125 ms slower than 12- to 18-year-olds and about 75 ms slower than 19- to 59-year-olds. With the addition of the cycling task, the 6- to 8-year-olds had the slowest reaction times. They were about 250 ms slower than the 9- to 11-year-olds, 300 ms slower than the 12- to 14-year-olds, 350 ms slower than the 15- to 18-year-olds, and 300 ms slower than the 19- to 59-year olds. Kail's (1991, 1993) research on reaction times shows that reaction times improve with age from childhood to adolescence, but for young children reaction times are greatly impaired when engaged in more than one task. Wierda and Brookhuis (1991) also found that 6- to 8-year-olds missed more than 13% of the

[15] While the current technical term is "cognitive load," the word "multi-tasking" is used because it is more familiar to a non-technical audience.

stimuli while cycling, while 9- to 11-year-olds missed 4%, 12- to 14-year-olds missed 1%, 15- to 18-year-olds about 0.5%, and 19- to 59-year-olds missed a little over 1%.

Other studies have also found that children show performance decrements in the cognitive skill when they engage in a cognitive task and a motor task concurrently (Krampe, Schaefer, Lindenberger, & Baltes, 2011; Schaefer, Krampe, Lindenberger, & Baltes, 2008)**.** Krampe et al. (2011) investigated dual-task performance, or multi-tasking with two tasks, in children and adults from four age groups: 9-year-olds, 11-year-olds, young adults, and older adults. The two tasks consisted of a cognitive task (saying members of a category like four-legged animals) and a walking task. For single task performance (cognitive task only or walking task only), performance improved with age through young adulthood and then declined for older adults. For all ages, cognitive performance was impaired while engaging in both tasks at the same time, but the children showed the biggest impairment compared to the older age groups. More specifically, 9-year-olds had the worst performance in the cognitive task and young adults performed the best. When looking at the walking task during dual-task performance, distance covered was less for all age groups when performing both tasks at the same time, with young adults covering the largest distance overall and older adults and 9-year-olds covering the shortest distance.

Schaefer et al. (2008) found similar cognitive impairments during dual-task performance. They compared dual-task performances of 9- and 11-year-old children and young adults engaging in a cognitive task and a motor task. The motor task required balancing on an ankle-disc board and the two cognitive tasks measured different types of memory.[16] Schaefer et al. found that children were more likely than adults to prioritize balance performance over cognitive performance when their balance was challenged. Adults showed performance decrements in both task domains under dual-task conditions. In contrast, children showed impaired performance only in the cognitive tasks. They showed improved motor performance by swaying less while engaging in both tasks than when only engaged in the motor task. Children continued to reduce their body sway even when instructed to focus on the cognitive task during the multi-task condition.

These findings suggest that when children engage in a concurrent cognitive and motor task like riding a bicycle and navigating traffic, children's cognitive capabilities are compromised making their ability to negotiate traffic problematic. The research studies just discussed found that children place a priority on balance over cognitive tasks when engaging in both at the same time. This can be problematic when riding in traffic.

There is evidence that performance can be improved with training, although the

[16] Difficulty levels were individually adjusted during the course of extensive training so that all age groups were at 75% correct prior to the multi-tasking.

training occurred with adults and not children. Pellecchia (2005) investigated the effect training had on performing a cognitive task and a motor task at the same time. Adult participants were assigned to no-training, single-task training, or dual-task training groups. Single-task training consisted of three sessions in which the motor task (standing on a dense foam pad that makes balance somewhat challenging) and the cognitive task (counting backward by 3's) were practiced separately. Dual-task training consisted of three sessions of practicing counting backwards by three's while standing on the foam pad. Pellecchia found that at test time, maintaining balance while counting backwards by 3's was difficult for participants who were in the no-training and single-task training groups but not for those in the dual-task training group. Results suggest that dual-task practice improves dual-task performance. While no studies have been conducted with children on the effect of training on dual-task performance, it is likely that children will have the same training need. In other words, children may need to practice both riding and attending to and dealing with traffic at the same time, numerous times in a safe environment before riding on their own in traffic.

Expertise can also have an effect on a person's ability to engage in a cognitive and motor task simultaneously. Expertise is essentially the culmination of a significant amount of practice and the automaticity of related behaviors. Smith and Chamberlin (1992) recruited adolescent participants who were novice, intermediate, or expert soccer players. In the study, participants first ran as quickly as possible through a slalom course. Next, they ran through the slalom course while dribbling a soccer ball. Last, participants had to identify geometric shapes projected on a screen at the end of the slalom course while dribbling the ball through the slalom. While the addition of the cognitive task caused a decrement in performance for all three experience levels, the amount of decrement decreased as level of expertise increased. Expertise made it easier for players to engage in both cognitive and motor tasks at the same time. Similarly, Ward and Williams (2003) found that expert soccer players can demonstrate superior perceptual and cognitive skills compared to their sub-elite counterparts. Therefore, it seems that combining cognitive and motor skills may be more costly for novices but that sufficient practice to make skills automatic helps dual-task performance.

Taken together, these studies suggest that while children have difficulty engaging in a cognitive and motor task at the same time, training and practice might make this combination easier. It is important to keep in mind that children are still developing their information processing abilities as evidenced by their gradually improving reaction times. This means that in normal and emergency situations, younger children will take more time to respond, thereby, increasing their chances of injury.

Transfer Appropriate Processing and Encoding Specificity

It is important to consider transfer appropriate processing when designing safety education programs for children. Transfer appropriate processing refers to the phenomenon that information is best remembered if the mental processes involved at study match the processes needed at recall (Percer, 2009). Blaxton (1989) found that information learned through top-down processing[17] was better remembered through tests that tap into conceptual knowledge. Words learned through bottom-up processing[18] were better remembered with tests that accessed the phonetic or perceptual features of the words.

The assumption of any prevention program is that improving knowledge leads to behavior changes that will reduce the likelihood of injury. However, traffic safety professionals have acknowledged that a change in knowledge does not necessarily lead to changes in behavior (Schieber & Vegega, 2002). Based on transfer appropriate processing, this may be because learning and understanding traffic rules is conceptual knowledge, or top-down processing, while the behavioral actions of riding a bicycle are learned through bottom-up processes. This means that conceptual knowledge and behavioral skills have to be learned separately through lecture presentations for conceptual learning and on-bicycle training for behavioral skills.

Another related and important principle of memory is that information is better remembered if the physical situation during the learning period is the same at test time. This is known as encoding specificity (Tulving, 1975). For instance, information learned in the classroom is better remembered in the classroom and remembered less well if it has to be applied in a different context. To increase the likelihood that children will engage in the safe riding behaviors they learned during training, it is important that the training occurs in an environment similar to where they will use the safe riding behaviors such as closed off roads as opposed to school gyms or playgrounds.

Section Summary

There are a number of important factors to consider in designing children's bicycle safety training programs. Development and learning can impact a child's ability to learn how to ride safely in traffic. When designing children's bicycle education programs, it is important to consider children's physical development, perceptual development, and cognitive development.

When considering physical development, one must understand the distinction between children's motor development and the development of specific motor skills for specific activities. Children's motor development usually refers to a set of behavioral milestones that typical healthy children achieve such as walking, running, jumping, climbing, bending, turning, rolling, throwing, catching, and writing. These fundamental skills develop through the age of 7. Alternatively,

[17] Top-down processing happens when existing knowledge helps to make sense of incoming information (Matlin, 1989).
[18] Bottom-up processing involves recognizing simple features of a stimulus to recognize complex patterns (Matlin, 1989).

specific behaviors that are learned in response to the requirements of a specific activity are motor skills. For instance, riding a bicycle encompasses a variety of discrete motor actions or skills specific to riding a bike that become automatic through repeated practice and use.

There are essentially two types of motor skills children have to learn when riding a bicycle.

- One is a basic bicycle handling skill (balancing, pedaling, steering, braking, etc.), and
- The other is a safety-behavior skill (moving the head and eyes to search for traffic, quickly moving through the chosen traffic gap, engaging the brakes to stop at lights and stop signs, using body motions to signal when turning, etc.).

In order for children to become proficient at these skills, both skills must be practiced repeatedly and together so that the skills become automatic.

The development or maturation of the brain is one critical aspect of physical development to consider when designing bicycle education programs. Changes in the brain due to maturation affect how children and adolescents learn and what they understand. For instance, the onset of puberty results in the changes in the socio-emotional center of the brain making it a more dominant part of the brain. This means that not only do emotional reactions occur easily in adolescence, but that emotionally positive situations are intensely rewarding. As a result, risk-taking is heightened during adolescence because risk-taking behaviors tend to be exhilarating. Risk-taking while riding a bicycle could become more prevalent in early adolescence because it is emotionally rewarding (risk-taking is discussed in the next section). In addition, the pre-frontal cortex, which would normally be able to regulate behavior under emotional situations, gradually matures into young adulthood. This makes it difficult for the pre-frontal cortex to regulate outcomes from the socio-emotional center until full maturity in adulthood.

Vision and estimating speed and distance are important components of perceptual development. While children have the same visual abilities as adults, it is important for bicycle safety practitioners to know there does seem to be a period during 7 to 8 years old where children stop using peripheral cues to help maintain balance. This means that children may pay less attention to what is happening in their periphery to maintain balance and if they do pay attention to objects in their peripheral vision, they may compromise their balance. Children also have the same ability as adults to estimate speed and distance and choose the same gaps in traffic as adults.

In cognitive development, important areas to consider involve speed of processing, multi-tasking, transfer appropriate processing and encoding specificity. Children are slower to process information than adults. This means that children have a delay from the moment they make their decision to the moment they begin to act on their decision, which can be dangerous for them during normal riding conditions and emergency situations. Some studies suggest that children become more adult like in their speed of processing during mid-adolescence.

Riding a bicycle involves engaging in a motor task and cognitive task at the same time, or multi-tasking. While children are able to perform two tasks at once, they often sacrifice cognitive performance for motor skill performance. It may not be until adolescence that children begin to handle dual-tasks like adults where they show some decrement in both tasks but good performance overall. It may be possible to train children to perform well in dual-tasks of cognitive and motor performance based on a study with adults, but no studies have been conducted with children at this time. However, the research on expertise and multi-tasking suggests that children can be trained to perform cognitive and motor tasks at the same time.

Finally, it is also important that bicycle safety practitioners understand the effects of transfer appropriate processing and encoding specificity. Because changes in knowledge do not necessarily lead to changes in behavior (e.g., learning that one must stop at a stop sign, does not mean that a child will actually do it), knowledge improvements and behavioral improvements need to be treated separately and taught in environments similar to where they will be executed. Improvements in knowledge are best achieved through classroom-based instruction that focuses on conceptual knowledge. However, improvements in behavior are best achieved through engaging in and practicing the target behaviors. Because information is best remembered when it is learned in an environment similar to where it will be remembered (encoding specificity), it is equally important that training that focuses on behavior change occurs in environments that are very similar to where children will be riding.

Making Education Programs More Effective: Considerations of Risk-Taking in Childhood and Adolescence

Risk-taking during childhood and adolescence can take the form of reckless bicycle riding, either by how the child rides the bicycle or interacts with traffic while riding. Moreover, taking risks is related to injuries. Dong et al. (2011) found that children who had high scores on cycling risk behaviors were more likely to have suffered a traffic-related injury. Previous studies have found that many bicycle crashes occur because children engaged in reckless bicycle riding: riding too fast and doing wheelies (Acton et al., 1995; Cushman, Down, MacMillan, & Waclawik, 1990). The purpose of this section is to better understand the factors related to risk-taking among children and adolescents.

The Influence of Emotion

Emotion, particularly fear and excitement, is a significant factor in the extent to which risks are taken. Increased fear is often associated with reduced risk-taking, while increased excitement is often associated with increased risk-taking. Cook, Peterson, and DiLillo (1999) conducted a study to determine if children's affect influenced their decisions to take risks. Fourth-grade children reported on their current typical levels of fear and excitement in response to common play situations, including those involving play in the water. A week or more later, the same children were observed during their turn at free play on the diving board of a local swimming pool. Cook et al. rated the frequency of going on the diving board and how the children acted when jumping off the diving board including being cautious or refusing to jump. They found that the more fearful children rated themselves, the fewer risky behaviors they exhibited during free play. The more exhilarated or excited they reported being, the more risks they took on the diving board. Similarly, Morrongiello and Sedore (2005) found that children who experienced fear were less likely to take risks and those who reported feeling excitement were more likely to take them.

Age Differences

The experience of fear and excitement for risky situations vary by children's ages. In their bicycle simulation studies to assess perceptions and emotions (Peterson, Brazeal, Oliver, & Bull, 1997; Peterson, Gillies, Cook, Schick, & Little, 1994; Peterson, Oliver, Brazeal, & Bull, 1995), Peterson and colleagues had participants (second graders, fifth graders, eighth graders, undergraduates and adults) ride a stationary bicycle while they watched two-minute video presentations recorded from a bicyclist's perspective (e.g., as if the participant was riding on a road). Each video ended with a frozen frame just after the presentation of an obstacle (garden hose, wheelbarrow, the back of a slow moving car, railroad timbers, a turning car, and a head-on-car). The film endings suggested but did not confirm a collision with the object. After each video ended, participants were asked what they thought would happen next in the scenario and to rate the extent to which they felt scared and excited. After answering the series of questions, participants then saw the endings of each of the videos again but this time heard a narration of the collision that occurred including how the bicyclist's body interacted with the hazard. Participants then rated levels of tissue damage, pain, fear and excitement. Peterson et al. (1994, 1997) found that with increasing age, children and adolescents showed decreases in fear and increases in excitement in situations where they did not know how the story ended. When participants were told a collision was the outcome in the simulation, younger children anticipated more tissue damage (e.g., more severe injury), more pain, and more fear than older participants.

In another study, Morrongiello and Matheis (2007) were interested in how cognitions and emotions affect children's decisions in a real injury-risk situation. They had children 7 to 12 walk across a balance beam because it posed some threat of injury if the child fell off. In addition, through extensive pilot testing, this task was found to be one where all children had comparably low experience with the task. Children chose the height of the balance beam before walking across it, and their height choice was used as a measure of risk-taking. Morrongiello and Matheis found that older children experienced more excitement and less fear than the younger children and took significantly more risks than younger children.

These age differences in the experience of fear and excitement are consistent with the changes in the socio-emotional center of the brain when children enter puberty as discussed in the previous section on brain development.[19] The increased activation in the emotional center coupled with the increased activation in the reward center of the brain means that excitement and exhilaration are more rewarding and risk-taking becomes appealing as children move into adolescence.

Gender Differences in Risk-Taking

Neuropsychological research has shown that risk-taking peaks in early adolescence as a result of changes in the socio-emotional center of the brain during puberty. If increased risk-taking in adolescence is due to the socio-emotional center's more dominant role, why is it that boys continue to take more risks than girls during adolescence (Bijttebier, Vertommen, & Florentie, 2003; Jelalian et al., 1997; Kontos, 2004; Morrongiello & Matheis, 2007; Morrongiello & Sedore, 2005)?

There are several possible additional influences that may mediate risk-taking among girls during adolescence. Girls perceive things differently than boys and

[19] Sensation seeking is a personality construct that is related to low levels of fear, high levels of excitement, and increased risk-taking. Studies discussed later in this report look at changes in sensation seeking as it relates to puberty through adulthood in addition to sensation seeking and risk-taking.

this difference may explain the gender differences in risk-taking. For instance, teenage girls have safer attitudes than teenage boys with regard to bicycle riding (e.g., concentrating properly when riding) based on a bicycle safety attitude scale (Colwell & Culverwell, 2002). Girls are also more likely than boys to have high levels of perceived risk (Irwin, Cataldo, Matheny, & Peterson, 1992; Kontos, 2004). Finally, risk-taking may be more closely tied to boy's self-concept than girls (Jelalian et al., 1997).

Another factor that may mediate girls' risk-taking is the experience of fear in risky situations. For instance, Morrongiello and Matheis (2007) found that girls were more scared than boys and boys were more excited than girls just before walking across a balance beam. Peterson et al. (1997) found similar gender differences in their bicycle simulation. Female participants of all ages (second graders, fifth graders, eighth graders, undergraduates, and adults) reported more fear than male participants and anticipated more pain than male participants. Female participants also experienced more fear than males during a near miss and braked more rapidly during the simulated collisions.[20]

Sensation Seeking

Sensation seeking is a construct that is directly tied to both exhilaration and risk-taking (Zuckerman, 1991). Sensation seeking is a preference for different, unique, and highly stimulating experiences and a willingness to take any risks to achieve them (Zuckerman, 1979). For instance, adolescents and young adults who are high in sensation seeking are more likely to get involved in risky behaviors that pose potential injury (Arnett & Balle-Jensen, 1993; Everett & Palmgreen, 1995). Similarly, children 6 to 10 who are high in sensation seeking are more likely to take risks[21] (Morrongiello & Sedore, 2005; Potts, Martinez, & Dedmond, 1995).

Sensation seeking is influenced by the changes in the socio-emotional center of the brain during adolescence (Steinberg et al., 2008). In parallel with the changes in the socio-emotional network during puberty and the gradual maturation of the prefrontal cortex, changes in sensation seeking (influenced by the socio-emotional center of the brain) and impulsivity (controlled by the prefrontal cortex) follow a similar trend. Steinberg et al. (2008) examined age differences in sensation seeking and impulsivity. They found that sensation seeking peaks during puberty and declines with age and impulsivity declines gradually with age, which correlates with the gradual maturation of the prefrontal lobe that controls impulsivity.

Social Influences

Peers and parents are highly influential regarding the extent to which children and adolescents are willing to take risks. Peers are the strongest predictors of

[20] Gender differences in fear may also be due to culture, biology, and evolution.
[21] Risk-taking in this study was based on questionnaires designed to assess level of risk taking.

risk-taking. Studies have found that children are more likely to take risks when peers are present, even if they are peers that the children do not know (Gardner & Steinberg, 2005; Miller & Byrnes, 1997; Morrongiello & Sedore, 2005). However, parents can have a protective effect on the number of injuries children sustain during childhood (Morrongiello & Hogg, 2004; Arnett & Balle-Jensen, 1993). While both peers and parents can influence children's and adolescents' risk-taking, peer influence is much stronger (Otis et al., 1992). For instance, Otis et al. (1992) conducted a study where students in the fourth through sixth grades completed a self-administered questionnaire concerning their beliefs about helmet use. They were asked about their perceptions of the risk of riding bicycles unprotected, the severity of possible head injuries, and about other bicycle-safety related behaviors. Otis et al. found that what peers think was a very strong predictor of whether or not participants would wear a helmet and what mothers thought came in second as a predictor.

The Influence of Peers

The preference for peers during adolescence is related to the changes in the brain that occur in the socio-emotional center of the brain during adolescence (Gardner & Steinberg, 2005; Steinberg, 2007; Steinberg et al., 2008). "Risk-taking may be heightened in adolescence because teenagers spend so much time with their peers, and the mere presence of peers makes the rewarding aspects of risky situations more salient by activating the same circuitry that is activated by exposure to nonsocial rewards when individuals are alone" (Steinberg, 2007, p.56). Gardner and Steinberg (2005) had adolescents (13 to 16), youths (18 to 22), and adults (24 and older) complete two questionnaires assessing risk preference and risky decision-making and then completed a behavioral task measuring risk-taking. Participants in each age group were randomly assigned to complete the measures either alone or with two same-aged peers. They found that all participants took more risks, focused more on the benefits than the costs of risky behavior, and made riskier decisions when in peer groups than alone. However, peer effects on risk-taking and risky decision-making were stronger among adolescents and youths than adults.

Children and adolescents consistently show an increase in risk-taking when peers are present. Miller and Byrnes (1997) found that third through eighth grade boys were more likely to choose the very risky condition when peers were present. Peers had a negative effect for the oldest students such that they were less likely to choose the optimal choice in the tasks. Morrongiello and Sedore (2005) conducted a study with 9- and 10-year-olds who either made decisions about risk-taking with an unknown same-sex peer watching them or while alone. They found that in the presence of a same-age peer, all children were more likely to take risks.

Peers can also serve as co-conspirators or models. Jelalian et al. (1997) conducted a study to examine the importance of peer injury in understanding reported injuries among adolescents. They conducted a survey with 1,426 adolescents aged 14 to 18. The biggest predictor of adolescent injury was knowing a friend who had been injured in the same way. The authors suggest either both the participants and their peers were injured at the same time doing the same activity, or the participant copied their peer who was injured for the same activity.

It is clear from the research that children will take more risks with peers present. However, there is some hope. One study found that children also model a safe peer (Babu et al., 2011). Babu et al. used a virtual environment (the paradigm developed by Plumert and colleagues discussed earlier) to programmatically control a peer to ride with the participant while participants rode a stationary bike. The purpose of the study was to use a virtual peer to study social influences on children's bicycling behavior. The children in the study were 10- and 12 years old. Babu et al. (2011) found that children who had the safe peer were more likely to come to a complete stop (78% of the time) than children who had the risky peer (56% of the time). Children in the risky peer condition were more likely to accept intermediate-sized 3.5 second and 4.5 second gaps than children in the safe peer condition. In another study, Lajunen and Rasanen (2004) found that a favorable opinion of helmet use from peers and parents was the strongest predictor of future helmet use among adolescents.

The Influence of Parents

Research has found that parental involvement can have a protective effect from injury in general throughout childhood and adolescence. Morrongiello and Hogg (2004) found that parents who left their children without constant supervision at a younger age[22] had children who experienced the most injuries. Likewise, children who had a history of fewer injuries had mothers who did not leave them alone to play until they were older. Mothers who focused on discipline as opposed to safety as a reaction to their child's misbehavior were more likely to have children who had many injuries regardless of the child's sex. In adolescence, the more monitoring a parent demonstrated (i.e., knowledge about the adolescents' whereabouts) the less likely adolescents were to engage in risky behaviors (Arnett & Balle-Jensen, 1993).

Safety rules are one of the primary preventative tactics used by parents to avoid childhood injury. Peterson and Saldana (1996) examined families of 8-year-old children for one year. They assessed the extent to which the parents taught a set of safety rules taken from the injury prevention literature, actually adhered to the rules, and the relationship between having rules and childhood injuries. Of the 718 injury events reported by the mothers, only 31% could be associated with safety rules. The majority of injury events were a result of novel risk-taking such as "riding a bicycle with one's coat zipped over one's face" or "running into a pole" (p. 324). Mothers tended to impose rules consistently more often than inconsistently and the more rules mothers enforced, the fewer injuries children

[22] Specific ages that define "younger age" were not given in Morrongiello and Hogg (2004).

tended to have. Mothers enforced safety rules equally with boys and girls and boys and girls were equally likely to obey safety rules.

Another important role parents play involves the extent to which parents practice what they teach. Morrongiello, Corbett, and Bellissimo (2008) examined the impact of parental safety practices and teachings on children's current behaviors and their intended future behaviors when they reached adulthood. Children 7 to 12 were interviewed and asked to report on their parents' practices and teachings (discussions, expectations for children's behavior) regarding five common safety behaviors (wearing a seat belt, wearing a helmet when biking, wearing a helmet when rollerblading, wearing sunscreen when in the sun, and crossing streets at the corner). They found that children reported their parents as not practicing what they preached, and children perceived themselves as engaging in more safety-related behaviors than their parents. Children also reported that they would engage in fewer safety-behaviors as adults. Children were more likely to attribute the difference either to adults not needing to be as concerned about safety as children or parents were more skilled in the activity and did not need to engage in the proper safety behaviors. Predictors of children's safety-behavior were parents' teachings (either discussion or expectation). Children intended to use safety behaviors as adults if their parents engaged in the safety behaviors (such as wearing a safety helmet).

While parents can have a big impact on children's injury and risk-taking, many parents need education about why safety practices are important. For instance, Lohse (2003) found that parents of first and second graders in a Midwestern State believed that helmets were not needed for their children or that their children would not wear them.[23] Peterson, Farmer, and Kashani (1990) found that parents were unworried about most injuries and believed most injuries could not be prevented. Parents were fairly confident in their knowledge of safety rules and their ability to teach them. The more parents felt they knew about safety, the more competent they felt to intervene. The more effective they believed an intervention to be, the more teaching efforts they reported. Unfortunately, if parents believe their children are not likely to be injured and that most injuries cannot be prevented, then there is little motivation for parents to teach and promote safety.

Parents are also affected by risk compensation theory when it comes to the use of safety gear. Risk compensation theory states that increased risk-taking occurs because of the protective effects of safety equipment (Morrongiello & Major, 2002). Morrongiello and Major (2002) conducted a study to examine whether risk compensation theory applied to parents' judgments about school age children's permissible risk-taking in either non-safety gear or safety gear conditions for seven common play situations. A telephone interview was used to obtain each parent's ratings of permissible risk-taking by their child (e.g., speed at which the

[23] Specific percentages for this finding were not provided.

child is allowed to cycle, the height the child is allowed to climb) in both the safety gear and no gear conditions. Parents also rated the level of their children's experience with each activity and their beliefs on the efficacy of safety gear. Parents were more likely to permit greater risk-taking by their child if their child had safety equipment. The highest permissible risks occurred with cycling and sledding. Morrongiello and Major also found that mothers who believed their children had a lot of experience with an activity were more likely to let their children take greater risks even if they were not wearing safety gear. In addition, if mothers believed in the efficacy of the safety gear, they were also more likely to tolerate greater risk-taking.

Parents, and even peers, are an important factor in keeping children safe while riding. Children are more likely to imitate peers who demonstrate safe riding (as they are likely to imitate peers who are engaging in reckless behavior). And they are more likely to wear a helmet if their peers think it is important. Parents however, can also play an important role. Parents who supervise children when they are young, who use and enforce rules, and who know where and what their adolescents are doing are more likely to have children who take less risks and sustain less injuries. And finally, children are more likely to become safety conscious adults when their parents practice what they preach.

Optimism Bias

Optimism bias is the belief that one is less susceptible to injury than others (Weinstein, 1987). Morrongiello and Rennie (1998) conducted a study to look at the contribution of cognitive-based factors to health relevant decisions, specifically, elementary school children's beliefs about their personal vulnerability to injury and if optimism bias existed among this age group. The study was conducted with children ages 6, 8, and 10. Using a structured interview, they found that as children got older, their optimism bias increased and boys had a greater optimism bias than girls. High risk-taking was greatly predicted by attributions to luck for injuries, optimistic beliefs that they were less likely than peers to get injured, and low perceived risk (gender did not contribute to this prediction).

Section Summary

There are a number of important factors related to risk-taking and injury to consider in designing children's bicycle safety training programs. For instance, positive emotions like exhilaration and excitement are often associated with increased risk-taking. In addition, exhilaration and sensation seeking increase as children move into adolescence making risk-taking more prevalent as children move from childhood to adolescence. Fear is often related to reduced risk-taking and females of all ages often experience more fear in risky situations than males.

Social influences are also related to children's and adolescents' risk-taking. For instance, the presence of peers makes children and adolescents take more risks, but peers can serve as models for safe behaviors. Parents can also have an impact on children's and adolescents' risk-taking. The more vigilant a parent is (i.e., providing supervision at young ages, knowing where teenage children are, etc.) the more likely they will have a child who experiences less injuries. Parents, who also model safe behavior, have children who not only engage in that behavior but intend to continue using that behavior in adulthood. Finally, children's social comparisons change with age. As children get older, they are more likely to perceive themselves as less likely than their friends to have an injury.

SUMMARY

Bicycle education programs should consider developmental factors and children's risk-taking as they ride bicycles. Bicycle crashes often occur because children engage in risky behaviors on their bicycles and fall off of their bikes as opposed to colliding with a moving vehicle. However, when children do collide with a moving vehicle, they tend to be more seriously injured. Prevention should focus on handling skills, risk-taking, and traffic-safety skills.

Learning to ride a bicycle and doing so safely in and near roads involves developing both motor and cognitive skills.
Motor Skills: Successfully riding a bicycle involves proficiently developing the motor skills of handling the bicycle and safely riding on roads including:

- maintaining balance and control,
- stopping and starting at intersections,
- stopping when entering the road,
- riding in a straight line, and
- riding in a straight line while signaling and searching for traffic before changing lanes, etc.

Cognitive Skills: The cognitive skills needed to ride a bike safely with moving vehicles include, but are not limited to:

- searching for potential hazards and remembering where they are,
- choosing safe gaps to cross or turn,
- reacting quickly in emergency situations, and
- remembering and applying the rules of the road.

In order for anyone to become proficient in all of these, extensive practice must occur. "It requires at least 100 hours of learning and practice to acquire any significant cognitive skill to a reasonable degree of proficiency" (Anderson, 1982, p. 369). Therefore, learning to ride a bicycle in traffic should be no different than training for a sport, especially when children's lives are at stake. Just like a typical sport, consistent and regular practice should precede performance time or riding in traffic. If parents are willing to spend time and money giving children experience and eventually expertise in soccer, football, softball, dance, etc. they should make the same kind of investment for learning to ride a bicycle in traffic.

It is also important that bicycle safety practitioners understand that children have a difficult time doing a cognitive task and a motor task at the same time. Recall earlier in this report, Wierda and Brookhuis (1991) had children and adults press a button when they heard a buzzer while standing next to a bicycle and while riding the bicycle. Compared to their own performance (see Figure 4), children ages 6 to 8, 9 to 11, and 12 to 14 were significantly slower at the detection task while cycling than while stationary. When looking at the reaction times while cycling across the age groups, children 12 to 14 respond more similarly to the 15- to 18-year-olds and the 19- to 59-year-olds. While it is certainly possible that bicycle training programs may help children improve at dual task performance based on Pellecchia's (2005) research on dual-task training, children will still be slower to react during all road situations until early adolescence.

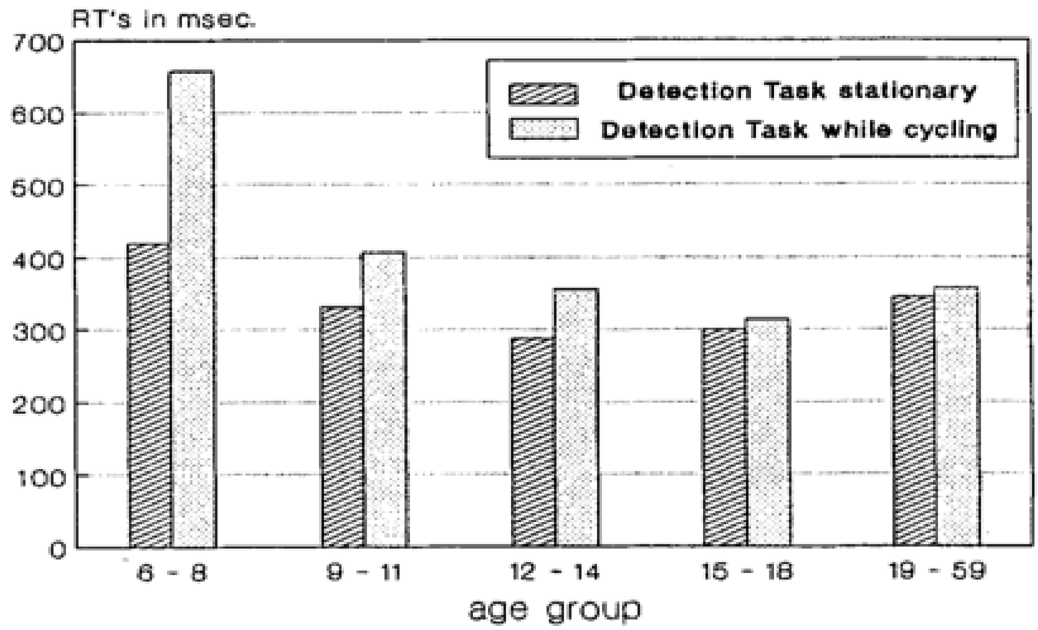

Figure 4. Average Reaction Times for the Participants in Wierda and Brookuis (1991), p. 118
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Risk-taking increases with age. However, there are some important elements a bicycle safety program can include to mitigate risk-taking among children. For instance, bicycle-safety education programs can be peer focused where two or more peers take the class together. In addition, if children know their parents are interested and involved in what they are learning, they may be less likely to engage in risky behavior. Bicycle education programs can include parents in either taking the class with their children or having parents ask their children to demonstrate what they've learned at home.

It is important to know when promoting and conducting bicycle safety education training that studies have found that training can increase children's confidence and put them more at-risk. Carlin et al. (1998) found that the Bike Ed Program had a negative effect on boys and families of lower educational status leading the authors to conclude that the course may inadvertently lead "susceptible" children to take risky behaviors on their bikes. Stutts and Hunter (1990) found that students who had completed the program rode more frequently than they had prior to the program suggesting that a bicycle program increases confidence thereby increasing exposure. However, Dong et al. (2011) found that children who knew more about road safety were less likely to have a road-traffic injury. Therefore, it is important to stress and explain to children what they can and cannot do at each age to improve the chances that they will stay within the boundaries of their experience and ability level.

Given the risk of injuries from bicycle riding, it is appropriate that efforts to protect children while bicycle riding consider these developmental issues. In addition, the increase of Safe Routes to School programs and the development of communities that promote more walking and bicycling may increase children's bicycle riding exposure. Therefore, now is the time to ensure that safety programs are adequately preparing children for increased exposure to traffic.

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