Children's Road Crossing

A Window Into Perceptual–Motor Development

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ABSTRACT—*Most research on perceptual–motor development has focused on changes occurring during infancy and toddlerhood. In this paper, we describe our work on the development of perceptual–motor development during late childhood and early adolescence in the context of an important applied problem: bicycling across traffic-filled roads. Specifically, we have examined the gaps between cars that children and adults accept when bicycling across intersections, using an immersive, interactive bicycling simulator. This work highlights both methodological advances in using immersive, interactive virtual environments to study perceptual–motor functioning as well as theoretical advances in understanding the problem of moving the self in relation to other moving objects. We conclude with ideas for future research and practical implications of this work.*

KEYWORDS—*perceptual–motor development; road crossing; virtual-environment technology; bicycling*

Moving the self in relation to other objects is a central problem faced by children and adults alike. We cross traffic-filled roads, walk along crowded sidewalks, and catch fast-moving balls. On the perceptual side, this requires learning to perceive information specifying relevant properties of objects and surfaces in the environment (e.g., speed, distance, angle). On the motor side, this requires learning to control critical components of one's own movements (e.g., posture, balance, force). But adaptive movement within the environment involves more than just perceiving the relevant information or controlling physical movement; one must also synchronize motor movements with perceptual information. When crossing busy roads, for example, motor movements must be closely timed to perceptual information specifying the speed and distance of the traffic.

To date, much of the work on perceptual–motor development has focused on infancy and toddlerhood, because this is when visual perception and motor skills are undergoing dramatic change (Adolph & Berger, 2006). Our work, however, clearly shows that perception–action coupling continues to undergo change even in late childhood and early adolescence. This is particularly obvious when children and adolescents are faced with the problem of coordinating the movement of a complicated mechanical device (e.g., a bike or car) in relation to other fast-moving objects in the environment. In this article, we describe our work on the development of perception–action coupling during late childhood and early adolescence in the context of an important applied problem: bicycling across traffic-filled roads.

Bicycling injuries are a significant public health problem in the United States (Rivara, Thompson, & Thompson, 1997). Approximately 600,000 bicycle-related injuries are treated in emergency rooms each year. Five- to 15-year-old children represent a particularly vulnerable segment of the population, having the highest rate of injuries per million cycling trips. Motor vehicles are involved in approximately one third of all bicycle-related brain injuries and in 90% of all fatalities resulting from bicycle crashes (Rivara & Aitken, 1998). A critical first step in developing programs to prevent collisions between bicycles and motor vehicles is to understand why such collisions occur. Our work focuses on how immature perceptual–motor functioning may put children at risk for car–bicycle collisions when crossing roads. The overarching aim of this research is to bring together the study of basic and applied issues into a single program of research (Schwebel, Plumert, & Pick, 2000).

PERCEPTION–ACTION COUPLING

Research on perception–action coupling has focused on two broad classes of problems facing all organisms with self-produced movement. The first is effectively moving the self in relation to stationary objects such as stairs and furniture. In this case, perceivers must judge their action capabilities relative to static properties (e.g., angle, height, and size) of objects and surfaces. The second problem is effectively moving the self in relation to moving objects such as balls, cars, and people. This problem is much more complex because perceivers must scale their actions with respect to both static (size and shape) and

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dynamic (velocity and acceleration) information about objects. When catching a fly ball, for example, perceivers must use information about the size, trajectory, and speed of the ball to time their interceptive actions appropriately (Peper, Bootsma, Mestre, & Bakker, 1994; van der Kamp, Savelsbergh, & Smeets, 1997).

Another situation in which children and adults must coordinate their actions with dynamic information about objects is crossing roads. To determine whether a gap between two vehicles affords crossing, perceivers must judge the temporal size of the gap in relation to the time it will take them to cross the road. Thus, both overestimation of gap size and underestimation of crossing time can contribute to errors in judging whether a gap is sufficiently large to afford safe crossing.

Walking Across Traffic-Filled Roads

How good are children at judging whether a gap is large enough for safe crossing? Virtually all research to date has examined children's road-crossing judgments while walking (e.g., Connelly, Conaglen, Parsonson, & Isler, 1998; Lee, Young, & McLaughlin, 1984; te Velde, van der Kamp, Barela, & Savelsbergh, 2005). Lee et al. (1984), for example, devised a road-crossing task in which 5- to 9-year-old children attempted to safely cross a "pretend road" set up parallel to an actual road (i.e., reach the other side of the pretend road before the vehicle on the real road crossed their line of travel). Although children were generally cautious, they sometimes accepted gaps that were too short. Likewise, Connelly et al. (1998) found that 12-year-olds selected safe crossing-gap thresholds much more often than 5-year-olds did, suggesting that younger children are more likely than older children to overestimate their ability to walk through traffic gaps.

Bicycling Across Traffic-Filled Roads

These studies of children's road-crossing judgments in the face of real traffic have yielded important findings. There are limitations of studies conducted at the roadside, however. First, for obvious safety reasons, none of these studies involve children crossing actual roads. Thus, we are left with an incomplete picture of road-crossing behavior, because the relation between gap choice and crossing behavior is largely unknown. Second, traffic flow in the real world is highly variable, leading to variation in the kinds of crossing problems children face. Without control over the timing and location of traffic, it is very difficult to systematically examine children's road crossing.

To fill this gap, we have developed an immersive, interactive bicycling simulator to examine the gaps children and adults accept when bicycling across traffic-filled intersections in a virtual environment (http://www.cs.uiowa.edu/~hank/). Participants ride an actual bicycle mounted on a stationary frame that is positioned in the middle of three 10-foot by 8-foot screens (Fig. 1). High-resolution, textured graphics provide participants with 270 degrees of nonstereoscopic, immersive visual imagery. The bicycle is instrumented to sense steering angle, hand braking, and pedaling torque applied by the rider. Real-world dynamics are simulated through a torque motor that actively drives the bicycle's rear wheel. The bicycle dynamics model that controls the torque motor accounts for rider and bicycle mass and inertia, terrain slope, ground friction, wind resistance, and so on.

Fig. 1. The bicycling simulator. Note that the visual angles are correct from the viewpoint of the rider.

Our initial work addressed two basic questions (Plumert, Kearney, & Cremer, 2004). First, are there age differences in the size of traffic gaps that 10- and 12-year-old children and adults accept? And second, how do gap choices relate to crossing behavior? We addressed these questions by examining age differences in gap choices and how much time children and adults left to spare between themselves and the approaching car when they cleared the path of the car. Ten- and 12-year-olds and adults rode the bicycle through our virtual environment consisting of a straight, residential street with six intersections. Their task was to cross the intersections without getting "hit" by a car. Participants faced cross traffic from their left-hand side and waited for gaps they judged were adequate for crossing (Fig. 2). The cross traffic traveled at continuous rates of either 25 or 35 miles per hour, with varying-sized gaps between vehicles.

Relative to adults, children's gap choices were less well matched to their road-crossing behavior. Children and adults chose the same-size gaps and yet children ended up with less time to spare when they cleared the path of the approaching car. At this point, the margin for error was very small, particularly for 10-year-olds. Interestingly, our later work has also revealed that 10- and 12-year-old girls end up with less time to spare than their male counterparts do, suggesting that girls are less skilled in coordinating their movement with that of the cars. This gender difference in our task disappears by college age, however.

An important question these findings raise is how does the mismatch between gap choices and crossing behavior occur?

Fig. 2. A child waiting to cross an intersection in the virtual environment.

Our studies have repeatedly shown that children delay in getting started relative to adults, leading to pronounced age differences in the time left to spare between the bicyclist and the approaching car. This mismatch between children's gap choices and their crossing ability is consistent with other research showing that children often overestimate their physical abilities and, further, that ability overestimation in simple laboratory tasks is significantly related to injury proneness in the real world (Plumert, 1995; Plumert & Schwebel, 1997). More generally, these results suggest that errors in perceiving affordances (i.e., the fit between one's own abilities and the properties of the environment) may play an important role in childhood injuries.

Our more recent work has explored how children and adults adjust their gap choices in response to changes in traffic density (Plumert, Kearney, & Cremer, 2007). Two questions were of particular interest. First, how willing are children and adults to choose risky gaps to avoid long waits at busy intersections? And second, do risky gap choices at busy intersections lead to risky gap choices at later intersections? We addressed these questions by presenting 10- and 12-year-olds and adults with a set of four intersections in which they encountered many uncrossable gaps before minimally acceptable gaps appeared. This set of "long wait" intersections was sandwiched between two sets of four "random" intersections in which children and adults encountered randomly ordered gaps ranging from 1.5 to 5 seconds. As in the earlier work, children and adults were instructed to stop at each intersection and to cross without getting hit.

Both children and adults were willing to accept much smaller gaps when they had to wait for a long time before a minimally acceptable gap appeared. The end result was that participants had less than a second to spare when they cleared the path of the approaching car. This risky crossing behavior is consistent with recent work on sighted and blind pedestrians' gap choices in high-density traffic (Guth, Ashmead, Long, Wall, & Ponchilla, 2005). Children and adults were also more willing to accept very tight gaps during the last four intersections than during the first four intersections, suggesting that the intervening experience with waiting for a long time for an acceptable gap to appear led to riskier gap choices at the later intersections. We directly tested this hypothesis in a second study by having new groups of children and adults participate in either the "long wait" condition described above or a control condition in which the gaps at all 12 intersections were randomly ordered. Children and adults in the long-wait condition were more likely to accept very tight (3-second) gaps during the last four intersections than were participants in the control condition. Thus, experience with risky bicycling in high-density traffic led to risky gap choices at subsequent intersections, even when larger gaps were readily available.

FUTURE DIRECTIONS

The work described above indicates that there is considerable perceptual–motor development occurring after infancy and toddlerhood, particularly in moving the self in relation to other moving objects. A major question for future work is why do children delay initiation of movement when crossing roads? One possibility is that children have immature movement-preparation strategies. Anecdotally, we have observed that children (especially 10-year-olds) do not always have their feet in a forward diagonal position on the pedals. As a result, they have to expend additional time and effort to get the bike moving once they have chosen a gap to cross. A second possibility is that children take longer to arrive at "go/no-go" decisions than do adults. This may leave them with less time to translate their decisions into action. A third possibility is that children have more difficulty synchronizing their movements with those of the cars. Adults fairly quickly learn to tune their motor movements to perceptual information to achieve very stable solutions to problems such as bouncing a ball up and down on a racquet or balancing a pole upended on one hand (Warren, 2006). Although there are very few direct comparisons between children and adults, we suspect that children would take longer than adults to achieve these stable solutions, indicating that children's ability to bring their actions tightly in line with perceptual information is less well developed than that of adults.

A second question for future research is how are individual differences in temperamental characteristics such as impulsivity, aggression, and effortful control related to risky bicycling behavior? Numerous studies have implicated temperament as a major contributor to unintentional childhood injuries (Plumert & Schwebel, 1997; Schwebel & Plumert, 1999). In our current work, we are examining whether temperamental characteristics such as aggression and low effortful control predict risky gap choices in high-density traffic (a situation likely to elicit individual differences in gap choices). Preliminary analyses indicate that 10- and 12-year-old boys who were rated higher on aggression (by mothers) chose smaller gaps, stopped less often at intersections, and waited for less time before crossing. These findings are consistent with research showing that injury-prone children are more aggressive, overactive, and poorly disciplined (Davidson, 1987). Additional work is underway to examine how longitudinal measures of temperament are related to risky bicycling behavior in our virtual environment. We expect that this work will extend our previous work on basic age differences in road-crossing skills by identifying individual-difference variables that put some children more at risk than others for car–bicycle collisions.

PRACTICAL IMPLICATIONS

What implications might our findings have for pedestrian and bicycling safety? First, what looks like a good gap to a child may actually be too small for safe crossing. This suggests that children should be taught either to choose larger gaps or to better time their movements. We might be able to facilitate the development of this latter skill by providing children with training on "getting ready to go." Essentially, this involves learning to exert better prospective control over movement, a critical component of adaptive perceptual–motor functioning (von Hofsten, 2007). Concentrated practice with producing the motor movements necessary to get the bike moving might also be helpful. A second implication of our work is that aggressive bicycling (or driving) in high-density traffic may lead to unnecessarily aggressive road-crossing behavior in subsequent low-density traffic. This hypothesized "double whammy" effect of high-density traffic represents a previously unknown but potentially significant risk factor for car–bicycle collisions. Successful intervention in this case will most likely require engineering the traffic environment to provide safe crossing places in high-density traffic areas, or perhaps implementing "traffic calming" devices such as lowered speed limits or added speed bumps.

In closing, there is rich potential for research on children's perceptual–motor development in the context of complex, real-world problems. Not only can such work further elucidate the basic principles of perceptual–motor learning and development—it can also further the development of interventions to enhance children's well-being and safety.

Recommended Reading

Adolph, K.E. (2002). Learning to keep balance. In R.V. Kail (Ed.), *Advances in child development and behavior*. San Diego, CA: Academic Press, pp. 1–40.

Plumert, J.M. (1995). (See References)

Plumert, J.M., Kearney, J.K., & Cremer, J.F. (2004). (See References)

Schwebel, D.C., Plumert, J.M., & Pick, H.L. (2000). (See References)

Warren, W.H. (2006). (See References)

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REFERENCES

Adolph, K.E., & Berger, S.A. (2006). Motor development. In W. Damon & R. Lerner (Series Eds.) & D. Kuhn & R.S. Siegler (Vol. Eds.), *Handbook of child psychology, Volume 2: Cognition, perception, and language* (6th ed., pp. 161–213). New York: Wiley.

Connelly, M.L., Conaglen, H.M., Parsonson, B.S., & Isler, R.B. (1998). Child pedestrian's crossing gap thresholds. *Accident Analysis and Prevention*, *30*, 443–453.

Davidson, L.L. (1987). Hyperactivity, antisocial behavior, and childhood injury: A critical analysis of the literature. *Developmental and Behavioral Pediatrics*, *8*, 335–340.

Guth, D., Ashmead, D., Long, R., Wall, R., & Ponchilla, P. (2005). Blind and sighted pedestrians' judgments of gaps in traffic at roundabouts. *Human Factors*, *47*, 314–331.

Lee, D.N., Young, D.S., & McLaughlin, C.M. (1984). A roadside simulation of road crossing for children. *Ergonomics*, *12*, 1271–1281.

Peper, L., Bootsma, R.J., Mestre, D., & Bakker, F.C. (1994). Catching balls: How to get the hand to the right place at the right time. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 591–612.

Plumert, J.M. (1995). Relations between children's overestimation of their physical abilities and accident proneness. *Developmental Psychology*, *31*, 866–876.

Plumert, J.M., Kearney, J.K., & Cremer, J.F. (2004). Children's perception of gap affordances: Bicycling across traffic-filled intersections in an immersive virtual environment. *Child Development*, *75*, 1243–1253.

Plumert, J.M., Kearney, J.K., & Cremer, J.F. (2007). *Pushing the perceptual–motor system to the limit: Child and adult cyclists' responses to high traffic density*. Manuscript in preparation.

Plumert, J.M., & Schwebel, D.C. (1997). Social and temperamental influences on children's overestimation of their physical abilities: Links to accident proneness. *Journal of Experimental Child Psychology*, *67*, 317–337.

Rivara, F.P., & Aitken, M. (1998). Prevention of injuries to children and adolescents. *Advances in Pediatrics*, *45*, 37–72.

Rivara, F.P., Thompson, D.C., & Thompson, R.S. (1997). Epidemiology of bicycle injuries and risk factors for serious injury. *Injury Prevention*, *3*, 110–114.

Schwebel, D.C., & Plumert, J.M. (1999). Longitudinal and concurrent relations between temperament, ability estimation, and accident proneness. *Child Development*, *70*, 700–712.

Schwebel, D.C., Plumert, J.M., & Pick, H.L. (2000). Integrating basic and applied developmental research: A new model for the twenty-first century. *Child Development*, *71*, 222–230.

Te Velde, A.F., van der Kamp, J., Barela, J.A., & Savelsbergh, G.J.P. (2005). Visual timing and adaptive behavior in a road-crossing simulation study. *Accident Analysis and Prevention*, *37*, 399–406.

van der Kamp, J., Savelsbergh, G.J.P., & Smeets, J.B. (1997). Multiple information sources in interceptive timing. *Human Movement Science*, *16*, 787–822.

von Hofsten, C. (2007). Action in development. *Developmental Science*, *10*, 54–60.

Warren, W.H. (2006). The dynamics of perception and action. *Psychological Review*, *113*, 358–389.