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ARTICLE

Effect of Cell Phone Distraction on Pediatric Pedestrian Injury Risk

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What's Known on This Subject

Two observational studies with adults found slightly increased risk-taking while crossing streets talking on a cell phone. To our knowledge, no published research in the English language has investigated this subject among children.

What This Study Adds

This study is the first, to our knowledge, to find links between distraction while talking on a cell phone and pedestrian risk-taking among children.

ABSTRACT

OBJECTIVE. Early adolescents are using cell phones with increasing frequency. Cell phones are known to distract motor vehicle drivers to the point that their safety is jeopardized, but it is unclear if cell phones might also distract child pedestrians. This study was designed to examine the influence of talking on a cell phone for pediatric pedestrian injury risk.

PARTICIPANTS AND METHODS. Seventy-seven children aged 10 to 11 years old completed simulated road crossings in an immersive, interactive virtual pedestrian environment. In a within-subjects design, children crossed the virtual street 6 times while undistracted and 6 times while distracted by a cell phone conversation with an unfamiliar research assistant. Participants also completed several other experimental tasks hypothesized to predict the impact of distraction while crossing the street and talking on a cell phone.

RESULTS. Children's pedestrian safety was compromised when distracted by a cell phone conversation. While distracted, children were less attentive to traffic; left less safe time between their crossing and the next arriving vehicle; experienced more collisions and close calls with oncoming traffic; and waited longer before beginning to cross the street. Analyses testing experience using a cell phone and experience as a pedestrian yielded few significant results, suggesting that distraction on the cell phone might affect children's pedestrian safety no matter what their experience level. There was some indication that younger children and children who are less attentive and more oppositional may be slightly more susceptible to distraction while talking on the cell phone than older, more attentive, and less oppositional children.

CONCLUSION. Our results suggest that cell phones distract preadolescent children while crossing streets. *Pediatrics* 2009; 123:e179–e185

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Key Words
pedestrian, vehicular injury, safety, traffic, cell phones, distraction

Abbreviations
VE—virtual environment
EATQ-R—Early Adolescent Temperament Questionnaire-Revised
DBRS—Disruptive Behavior Rating Scale

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UNINTENTIONAL PEDESTRIAN INJURY is a leading cause of pediatric mortality.[1] One reason preadolescent children might have particularly high risk for pedestrian injury is because crossing a street is a highly complex cognitive and perceptual task. Preadolescents may not have developed the cognitive and perceptual skills necessary to simultaneously perceive and process the distance, speed, and acceleration patterns of at least 2 vehicles, as well as the distance across the street and the speed within which they can cover that distance.

The cognitive task of judging street-crossing safety is likely to become even more challenging when children multitask while negotiating street environments. A substantial literature suggests cell phone use interferes with safe automobile driving,[2] and 2 observational studies suggest adult pedestrians might be more distracted while talking on the cell phone,[3,4] but there is very little known about how talking on a cell phone while crossing a street might influence child pedestrian safety.

The influence of cell phones on child pedestrian safety is particularly concerning because cell phones, an oddity just a decade ago, are quickly becoming ubiquitous among American schoolchildren. Commercial interests actively market cell phones for children and marketing research firms estimate that 54% of 8- to 12-year-olds will have cell phones by 2009, double the 2006 rate.[5] Cell phones clearly offer convenience and safeguards to families, but they also may pose risk, particularly when children attempt to multitask while conversing on the cell phone and have reduced cognitive capacity to devote to potentially dangerous activities such as crossing streets.

FIGURE 1
Screenshot of the virtual reality environment.

Given the public health prominence of child pedestrian injury, the very active marketing of cell phones for use by children, and the fact that cell phones are believed to cause significant distraction in motor vehicle drivers, the present study was designed to examine the effect of cell phone use on pediatric pedestrian injury risk. We focused on novice pedestrians (those aged 10 to 11 years old) for 4 reasons: (1) they are at the developmental stage when most children have recently learned to behave safely in street environments; (2) they would typically be safe pedestrians without distraction but potentially much less safe while distracted on the cell phone; (3) they are being actively targeted in cell phone marketing campaigns; and (4) they cross streets without adult supervision with great frequency.[6]

Methodologically, we conducted our research within an interactive, immersive virtual reality environment.[7] This environment validly represents real-world behavior[7] and offers the dual advantages of a safe environment for research but one which simulates real-world risks. We hypothesized children would behave in a riskier manner when crossing the street while engaged in a cell phone conversation than when not distracted. We also had a secondary aim to examine individual difference factors that might predict particularly risky behavior while distracted. We hypothesized younger age, poorer attentional skills, higher levels of oppositionality, less experience using a cell phone, and less frequent exposure to walking on streets would each be related to increased distraction and riskier pedestrian behavior while on the cell phone.

PARTICIPANTS AND METHODS

Participants

Seventy-seven children aged 10 to 11 years old were recruited (average age: 10.88 years; SD: 1.53). The sample included 37 girls (48%) and 40 boys, and was culturally representative of the surrounding area (60% white, 32% black, 8% other races/ethnicities). The median household income of families was in the $60 000 to $79 000 range. Exclusionary criteria included only visual or motor disabilities that would prohibit valid participation in the experimental protocol.

The protocol was reviewed and approved by the university's institutional review board. Children's parents provided signed informed consent; children provided assent, as developmentally appropriate. Families were monetarily compensated and children received toy prizes.

General Protocol

Families participated in a single 1-hour session. Parents completed several questionnaires, as detailed below. Children engaged in 3 successive activities. First, they participated in a familiarization virtual reality session. Next, children completed a series of experimental tasks, including a behavioral measure of attention (a trailmaking test) and other tasks unrelated to the present hypotheses. Last, children engaged in a second session within the virtual environment (VE) which included 12 simulated crossings, 6 while distracted by a cell phone conversation with a previously unfamiliar researcher and 6 undistracted. Distraction order was randomized across participants.

VE Protocol

The VE is detailed elsewhere.[7] Briefly, traffic moves bidirectionally on 3 monitors arranged in a semi-circle in front of the participant. Figure 1 displays an example simulated scene with traffic crossing the crosswalk in front of the child. Ambient and traffic noise is delivered through speakers. The environment is interactive and immersive, and validly measures real-world pedestrian behaviors.[7]

After 2 demonstration trials by a research assistant (1 successful crossing and 1 purposely demonstrating a pedestrian being "hit" to reduce participant curiosity), participants stepped onto the simulated curb. Children completed 10 familiarization trials; data from familiarization trials were discarded. After completing other tasks in a different room, children reentered the VE wearing an apron with a large pocket containing a cell phone and were taught how to answer and end calls. These tasks were eased by using a cell phone with all buttons covered except the 2 needed to answer and end calls (this manipulation also reflects the simplicity of cell phones currently marketed to children). Children were instructed that the cell phone would ring sometime during the session, and that they should answer the cell phone and converse, but also continue crossing the virtual street.

Other instructions and logistics were identical to previous protocols.[7] Participants watched traffic and stepped off the curb when they deemed it safe. Stepping down activated a pressure plate, switched the virtual world from first to third person perspective, and showed a gender-matched avatar crossing the virtual street at a speed identical to the child's actual walking speed (assessed separately before the test session). On reaching the other side of the street, the avatar stopped walking and an animated character offered feedback to the child. One of 2 brief positive responses was randomly selected for safe crossings and cautionary responses were delivered for "close calls" or collisions. After a collision, the screen froze briefly before the cartoon character appeared; after a successful crossing, including close calls, the avatar reached the opposite side of the street before the character delivered feedback. Replicating the actual environment shown in the simulation, traffic in the VE traveled at a constant speed of 30 miles per hour and appeared at an average density of 525 feet between vehicles.

The cell phone rang during either the first or seventh trial, depending on random assignment. Those in the "distracted first" condition received a cell phone call during the first of the 12 trials; those in the "distracted second" condition received a call on the seventh. In all cases, children answered the cell phone almost immediately, yielding 6 distracted and 6 undistracted trials for each participant.

Cell phone conversations were led by previously unfamiliar research assistants and were semi-structured to imitate a typical conversation between unfamiliar individuals. Example questions included "What's your favorite television show?" and "What do you like to do for fun?" Research assistants maintained a natural conversation flow during all distraction trials and observed carefully the time to terminate the cell phone conversation (after 6 road crossing trials, viewed through a 1-way mirror from a sound-proofed room).

Measures

Demographics

Parents reported basic demographics.

Pedestrian Safety

Four indicators of safe street crossing, adapted from previous research,[7–10] were computed: (1) average start delay (time in seconds after a car passes and before participants initiate crossing, which in previous research[11] has been found to be longer in young children and may represent cognitive processing time); (2) average safety time (latency in seconds between participants safely crossing the street and the next vehicle arriving in the crosswalk); (3) hits or close calls (instances when participants would have been struck by a vehicle in the real environment or when the gap between participants and the oncoming vehicle was <1 second); and (4) attention to traffic (the number of times participants looked left and right before beginning to cross the street, divided by average time in seconds waiting to cross).

For all analyses, pedestrian behaviors were averaged across tasks by condition. That is, start delays when the participant was not distracted were computed into an average start delay score for the no distraction condition for each child. The process was repeated for trials completed in the distraction condition. Thus, each child had 4 scores (start delay, safety time, hits or close calls, attention) by 2 conditions (not distracted, distracted).

Attentional Capacity

Children's attentional capacity was measured via standardizing and then aggregating 3 measures of attention into a composite. The first measure was the attention subscale of the Early Adolescent Temperament Questionnaire-Revised (EATQ-R),[12] a 6-item parent-report measure of the child's capacity to focus and shift attention. Interrater reliability is adequate ($\alpha = .65$).[12] Items were answered on a 5-point Likert scale, reversed, and averaged to yield a total score ranging from 1 (most attention) to 5 (least attention).

The second measure was the parent-report of child inattention on the Disruptive Behavior Rating Scale (DBRS),[13] a measure of clinically relevant disruptive behaviors. The Inattention subscale included 9 items answered on a 4-point Likert scale from 0 (child never/rarely engaged in behavior) to 3 (child very often did so). Item responses were summed to yield a total Inattention subscale score (possible range: 0–27); psychometrics are strong.[13–15]

The third measure of attention in the composite was a trailmaking test, a behavioral task assessing working memory, divided attention, and cognitive flexibility.[16] Past research indicates an association between the trailmaking test and both cognitive function and driving performance.[17] Part A of the trailmaking test requires sequentially connecting 25 encircled numbers as quickly as possible without making mistakes. Part B is more complex, requiring connecting alternating encircled numbers and letters in the correct order (1, A, 2, B). Children's errors were corrected as they occurred and subtests were scored by time (in seconds) required to complete the task. Following previous work,[18] a difference score was computed (part B–part A) for analysis.

Oppositionality

Oppositionality was measured by parent-report of children's oppositional behaviors on the DBRS. Eight items were scored identically to the DBRS Inattention subscale and yielded a total oppositionality subscale ranging from 0 to 24.[13]

TABLE 1 Continuous Independent Variables

Measure	Mean (SD)
Age, y	10.88 (1.53)
EATQ-R attention, 5-point scale	3.26 (0.75)
DBRS inattention, of 27 points	6.15 (5.60)
Trailmaking B-A, s	64.06 (47.03)
Attention aggregate, *z* score	−0.01 (0.77)
DBRS oppositionality, of 24 points	3.91 (3.41)
Cell phone use, min	11.82 (30.42)
Pedestrian experience, frequency × distance	5.36 (4.35)

Cell Phone Use

Parents completed a brief questionnaire concerning children's cell phone use. Of particular interest was an item addressing amount of time per day (in minutes) children spent using a cell phone.[19]

Pedestrian Behavior

Parents completed a brief measure regarding children's walking patterns over the past month. Items inquired about children's walking frequency and distance in various contexts (eg, to parks, school). Frequency and distance were multiplied and summed to yield a total pedestrian experience score.[20]

Interrater Reliability

Coding of both attention to traffic in the VE and results of the trailmaking test was conducted by 2 independent researchers. Attention to traffic coding was completed by videotape on 19% of the sample; coding of the trailmaking test was conducted live with the full sample. Reliability for both was high ($r > .95$).

RESULTS

Descriptive statistics were considered first (Table 1), followed by a series of independent-samples *t* tests to examine whether randomized order (distraction presented first versus second) influenced pedestrian behavior. Difference scores between distracted and nondistracted conditions on all 4 pedestrian variables (start delay, safety time, hits or close calls, attention to traffic) served as dependent variables. One significant result emerged, with children who were distracted first having larger safety time difference scores than children undistracted first ($t_{75} = 2.78$, $P < .01$). Conservatively, we included order in subsequent analyses. We next examined the effect of age and gender on pedestrian behavior. Independent samples *t* tests comparing boys and girls on difference scores for the 4 pedestrian variables yielded no differences. Pearson correlations between age and difference scores also yielded no significant differences.

The primary hypothesis was that children would behave in a riskier manner while distracted on the cell phone. This hypothesis was tested with a generalized linear model that included the 4 pedestrian variable difference scores (start delay, safety time, hits or close calls, and attention to traffic) as dependent variables; randomized order (distracted first or distracted second) as a between-subjects factor, and condition (distracted or not distracted) as a within-subjects factor. A main effect for condition emerged with 3 of the 4 outcome variables, suggesting children behaved in a riskier manner when distracted (start delay: $F_{1,74} = 6.68$, $P < .05$, partial $\eta^2 = .08$; hits or close calls: $F_{1,74} = 4.24$, $P < .05$; partial $\eta^2 = .05$; attention to traffic: $F_{1,74} = 8.52$, $P < .05$, partial $\eta^2 = .10$) (Figs 2, 3, and 4). An order-by-condition interaction also emerged for 2 dependent variables, indicating the dual effects of risky behavior while distracted and learning over trials (hits or close calls: $F_{1,74} = 7.52$, $P < .01$, partial $\eta^2 = .09$; safety time: $F_{1,74} = 12.14$, $P < .001$, partial $\eta^2 = .14$) (Figs 3 and 5).

The secondary aim was to explore what variables might predict reduced distraction in the pedestrian environment. Bivariate correlations were computed between the 4 outcome variables and age, gender, attention, oppositionality, cell phone use, and pedestrian experience (Table 2). Younger children and those rated as oppositional tended to be more likely to experience greater distraction and a postponed start delay in initiating crossing while talking on the cell phone. There was some indication that children who used a cell phone more frequently were not distracted on the cell phone. Higher rates of inattention and oppositionality were associated with greater influence of distraction on attention to traffic.

We pursued univariate results in multivariate linear regression models predicting difference scores for the 2 dependent variables that yielded univariate findings of interest (start delay, attention to traffic). Age, gender, the attention aggregate, oppositionality, cell phone use, and pedestrian experience served as independent variables. The model predicting attention to traffic was not

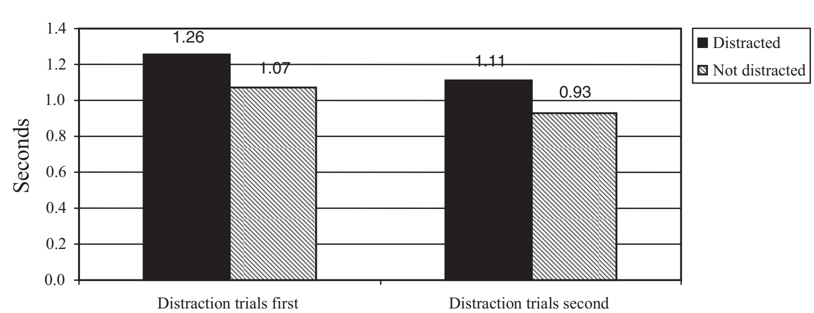

FIGURE 2
Start delay.

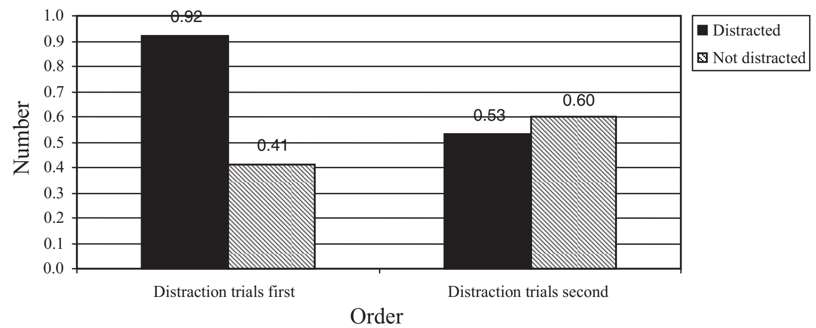

FIGURE 3
Hits or close calls.

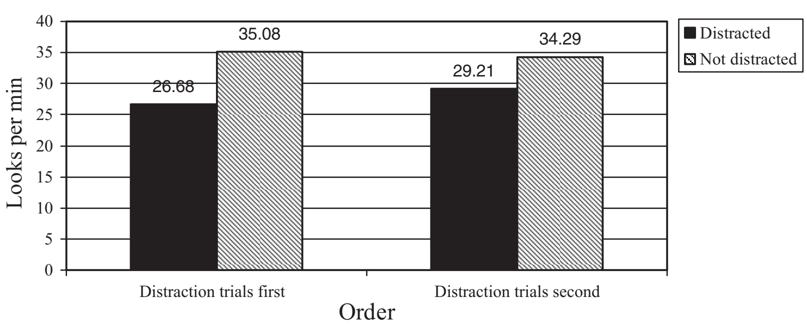

FIGURE 4
Attention to traffic (looks by waiting time).

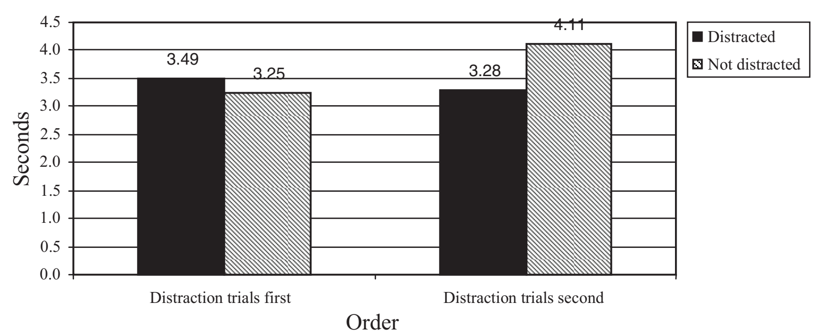

FIGURE 5
Safety time.

significant. The model predicting start delay was significant, with oppositionality emerging as the only significant predictor (Table 3).

TABLE 2 Bivariate Correlations Between Predictors and Pedestrian Behavior Difference Scores

	Start Delay	Safety Time	Hits or Close Calls	Attention to Traffic
Age, y	−.35[a]	−.05	−.07	.06
Gender, 1-male, 2-female	−.09	.02	.12	−.04
Trailmaking B-A, s	.10	−.07	−.20	−.31[b]
EATQ-R attention, 5-point scale	−.02	.07	.01	.15
DBRS inattention, of 27 points	.21	−.06	−.10	−.24[b]
Attention aggregate, *z* score	.14	−.09	−.13	−.29
DBRS oppositionality, of 24 points	.36[a]	−.02	−.01	−.27[b]
Cell phone use, min	−.29[b]	.02	−.14	.11
Pedestrian experience, frequency × distance	−.08	.04	−.30[b]	.01

[a] $P < .01$.
[b] $P < .05$.

DISCUSSION

Results suggest cell phones distract preadolescent children while crossing streets. On all 4 measures of risky pedestrian behavior, children tended to behave in a riskier manner while talking on the cell phone than when not talking on the cell phone. There was some indication

TABLE 3 Linear Regressions Predicting Pedestrian Behavior

Predictors	Start Delay[a]			Attention to Traffic[b]		
	B	SE	*β*	*B*	SE	*β*
Age, y	−0.10	0.09	−.14	0.10	0.06	.25
Gender, 1-male, 2-female	0.04	0.15	.04	−0.06	0.09	−.10
Attention aggregate, *z* score	−0.08	0.10	−.12	−0.04	0.06	−.09
Oppositionality, of 24 points	0.06	0.02	.39[c]	−0.02	0.01	−.19
Cell phone use, min	0.15	0.10	.20	0.06	0.06	.14
Pedestrian experience, frequency × distance	−0.00	0.02	−.00	−0.01	0.01	−.14

[a] Start delay: $R^2 = 0.22$, $P < .05$.
[b] Attention to traffic: $R^2 = 0.12$, $P = .36$.
[c] $P < .01$.

that younger children and those children rated high on oppositionality and inattention had somewhat higher rates of distraction than older children and those rated lower on oppositionality and inattention.

Several results are especially noteworthy. First, it seems that all children were influenced by the distraction. Even those children who used a cell phone often, who crossed streets often, or who were rated as highly attentive seemed to experience reduced safety while distracted and crossing the virtual street, although there was some evidence that greater experience using a cell phone reduced distraction effects on children's delay in starting to cross while distracted. Bivariate results offer some evidence of increased risk among inattentive, young, or oppositional children, but these results were largely lost in multivariate analyses and do not seem to be strong influences.

Second, it is important to recognize that pedestrian behavior is multifaceted. A safe pedestrian must juggle many cognitive, perceptual, and motor tasks. We tapped several of these tasks with our dependent variables and discovered, not surprisingly, that distraction and learning influenced different pedestrian risks in different ways. Attention to traffic, for example, was altered greatly by distraction on the cell phone, and did not show a significant learning effect. Start delays, which are considered by some to be the best measure of development of pedestrian safety skills,[21] showed a similar pattern.

Other outcome measures showed a different pattern. Children were much more likely to be hit or have a close call in the VE when distracted and in their first set of trials. In other words, the rate of hits or close calls was greatest for children who experienced distraction first, and was much lower when children were undistracted or had 6 undistracted trials immediately before becoming distracted (recall, however, that all children completed 10 familiarization trials before reported data were collected).

A third and final noteworthy result is the fact that we targeted children aged 10 to 11 years old, who in most cases are reasonably safe pedestrians.[10] One might suppose that more novice pedestrians— those younger than 10 years old— would experience an even greater level of risk when distracted by a cell phone call, but this is an empirical question in need of future investigation. As to older and more experienced pedestrians, 2 observational studies suggest even adults take greater risk when talking on the cell phone and crossing streets,[3–4] but additional research is needed to confirm those observational findings with greater experimental control and in other age groups (eg, adolescents).

This study had several strengths. It used a within-subjects experimental design to test the effect of distraction while talking on the cell phone in a validated, realistic virtual pedestrian environment. It also suffered from limitations. The sample was fairly small, narrow in age range, and recruited from just 1 geographic location. The distracting cell phone call was friendly, but with an unfamiliar adult; most children talk on the cell phone with familiar individuals (parents or friends) rather than strangers when crossing streets. Distraction was only by cell phone conversation, and not by other commonly used distracting devices such as text-messaging, hand-held computer games, or portable audio players. Finally, there is the question of whether our controlled experimental virtual setting represents real-world behavior. Although the VE has been validated to represent real-world behavior,[7] the environment was semi-controlled, traffic appeared at a density representative of suburbia but not rural or urban settings, and only 1 street environment was used. Future work should address these limitations.

CONCLUSIONS

Cell phones are not necessarily bad for children to carry and use. In fact, they probably preserve safety more than they increase risk of injury. However, our results suggest that just as drivers should limit cell phone use while driving, pedestrians— and especially child pedestrians— should limit cell phone use while crossing streets. It remains to be tested empirically, but one might suppose that other distractions (eg, listening to music, text messaging, and even perhaps talking to peers) also increase the odds of risky pedestrian behavior.

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