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# Walking and Talking: Dual-Task Effects on Street Crossing Behavior in Older Adults

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The ability to perform multiple tasks simultaneously has become increasingly important as technologies such as cell phones and portable music players have become more common. In the current study, we examined dual-task costs in older and younger adults using a simulated street crossing task constructed in an immersive virtual environment with an integrated treadmill so that participants could walk as they would in the real world. Participants were asked to cross simulated streets of varying difficulty while either undistracted, listening to music, or conversing on a cell phone. Older adults were more vulnerable to dual-task impairments than younger adults when the crossing task was difficult; dual-task costs were largely absent in the younger adult group. Performance costs in older adults were primarily reflected in timeout rates. When conversing on a cell phone, older adults were less likely to complete their crossing compared with when listening to music or undistracted. Analysis of time spent next to the street prior to each crossing, where participants were presumably analyzing traffic patterns and making decisions regarding when to cross, revealed that older adults took longer than younger adults to initiate their crossing, and that this difference was exacerbated during cell phone conversation, suggesting impairments in cognitive planning processes. Our data suggest that multitasking costs may be particularly dangerous for older adults even during everyday activities such as crossing the street.

*Keywords:* dual-task, attentional control, aging, cell phones, locomotion

The ability to manage two tasks concurrently, or dual-task, has grown increasingly important as attention-demanding technologies such as cell phones, personal music players, and navigation systems have come to pervade everyday behavior. Although younger adults suffer significant performance losses when dual-tasking (e.g., Kahneman, 1973; Pashler, 1984), older adults experience even larger costs (e.g., Kramer, Larish, & Strayer, 1995; Kray & Lindenberger, 2000; Salthouse, Hambrick, Lukas, & Dell, 1996; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003; see Kramer & Madden, 2008, for a review). Dual-task impairments in older adults are especially pronounced when the concurrent tasks reside within overlapping stimulus modalities (e.g., Kray & Lindenberger, 2000; Tsang & Shaner, 1998) or place high demands on attentional control processes such as behavioral planning (e.g., Salthouse et al., 1996). These effects have often been explained in the context of a resource-based attentional framework (e.g., Craik & Byrd, 1982; see Kramer & Madden, 2008, for a review), which argues that attentional resources diminish with age, leaving fewer total resources to be distributed across competing tasks and causing older adults to experience disproportionate dual-task costs.

Although much of the previous work examining dual-task performance in older adults has used conventional laboratory tasks, some efforts have been made to understand older adults' multitasking in more naturalistic contexts. For example, Lindenberger, Marsiske, and Baltes (2000) investigated the dual-task declines associated with aging by having participants perform a memory task while walking on tracks of varying complexity (also see Chen et al., 1996; Mulder, Berndt, Pauwels, & Nienhuis, 1993). Young, middle-aged, and older adults all showed dual-task costs in memory encoding and walking speed, but these effects were larger for the older adults and middle-aged adults than for young adults. Thus, although walking is generally thought of as automatic, it in fact consumes attention and imposes increasing attentional demands with age (Blake et al., 1988; see Woollacot & Shumway-Cook, 2002, for a review).

The finding that walking requires attention, notably, may imply that the performance consequences of everyday distractions such as cell phones are greater than has been believed. A wealth of research has already demonstrated that drivers are significantly impaired when conversing on a cell phone (e.g., Becic et al., 2010; Kubose et al., 2006; Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001), with this impairment possibly being attributable to systemic limitations on attentional capacity (e.g., Duncan, 1980; Kahneman, 1973; see, Pashler, 1998, for a review). Similarly, both experimental (Neider, McCarley, Crowell, Kaczmarski, & Kramer,

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2010) and observational (e.g., Hatfield & Murphy, 2007; Nasar, Hecht, & Wener, 2008) studies have found that pedestrians are less likely to make successful street crossings in simulated environments and are more likely to attempt unsafe crossings in real-world environments when conversing on a cell phone. Such data have been useful in shaping public policy, as several municipalities in the United States (e.g., Chicago and New York) have considered enacting legislation to limit the use of cell phones by pedestrians in an effort to stem the 61,000 pedestrian–motor vehicle accidents that occur annually (National Highway Traffic Safety Administration, 2006). To date, however, no studies have examined how the cognitive declines associated with normal aging affect a pedestrian's ability to successfully cross an intersection while engaged in a cell phone conversation.

The current study was intended to build on previous work examining dual-task performance in older adults in naturalistic tasks. Specifically, we examined dual-task performance in older and younger adults in a simulated street crossing task. The street crossing task was performed in an immersive virtual reality environment (see http://isl.beckman.illinois.edu/Labs/CAVE/CAVE.html). To move in the simulated environment, participants walked on a manual treadmill, allowing for a close emulation of real-world behavior within a relatively well-controlled environment. For all participants, a single-task condition (crossing the street) served as the baseline for two dual-task conditions. In one dual-task condition, participants crossed the street while listening to music through headphones; in the other, they crossed while participating in a simulated cell phone conversation with a research assistant. Previous work has shown that older adults become particularly susceptible to dual-task impairments as task difficulty increases. To examine this possibility, we also varied crossing difficulty by manipulating the gap distance (either 75 m or 90 m) between vehicles in each crossing; a smaller gap size creates a more challenging crossing.

## Method

### Participants

Eighteen undergraduate students (ages 18–26 years, $M = 22$ years, $SD = 2.50$; nine women and nine men) from the University of Illinois at Urbana–Champaign and eighteen high-functioning older adults (ages 59–81 years, $M = 73$ years, $SD = 5.33$; seven women and 11 men) recruited from the local community participated in the study. Older adults lived independently and were required to achieve a score of 27 or better on the Mini-Mental State Exam (Folstein, Folstein, & McHugh, 1975) to participate in the study. All participants had normal or corrected-to-normal vision as measured by a Snellen chart for visual acuity and Ishihara plates for color vision, and all had no prior experience in the street crossing simulation. Participants received $8 for a 1-hr session.

### Apparatus, Stimuli, and Design

The study was conducted in the Beckman Institute's virtual reality CAVE, and the paradigm was similar to that used in recent work by Neider and colleagues (2010) with college students. On each trial, the participant's task was to safely cross a busy street at an unsigned intersection (see Figure 1). The roadway comprised two lanes of traffic, each 4 m wide (total roadway width was 8 m). Cars in the lane nearer to the participant moved from left to right as the participant faced the roadway, and cars in the farther lane travelled from right to left. All cars moved at a speed of 33 mph. Intervehicle distance (IVD; the bumper-to-bumper distance between vehicles moving along the roadway) was varied on each trial, but it never changed within a given trial. In half of the experimental trials, IVD was 75 m; in the other half of trials, IVD was 90 m.

To navigate the virtual environment, participants walked on a LifeGear Walkease manual treadmill that was modified to link with the virtual environment. Synchronization with the virtual environment was accomplished by placing eight magnets around a flywheel on the treadmill. Each magnet closed a switch on the treadmill's frame as it passed by. The switch was buffered by a networked PC through a dedicated USB external microcontroller, allowing the experimental program to advance the virtual environment by 2 cm each time a switch-closing event occurred. The treadmill was equipped with a handrail system that participants were instructed to hold on to throughout the experiment.

The virtual reality CAVE environment comprised three viewing screens and a floor. Each viewing screen measured 303 cm wide by 273 cm high (~10 ft × 9 ft). Screen resolution was 1,024 × 768 pixels. When walking on the treadmill, participants were approximately 149 cm (~4.9 ft) from each of the viewing screens, with visual angle of each screen subtending 91° × 85°. All aspects of the experiment were controlled via custom designed software using a combination of C++ and Python. A PC running on 64-bit Windows Server 2003 SP2 and containing an Intel Xeon Core 2 Quad CPU, 8GB of RAM, and an nVidia Quadro Plex 1000 Model 2 with G-Sync graphics card controlled all images projected to the screens. An Ascension Flock of Birds 6DOF electromagnetic tracker was used to measure head position and orientation. Movements of the head were counted as head movements if they traversed from at least 10° in one direction to at least 10° in the other direction. Throughout the experiment participants wore a pair of CrystalEyes liquid crystal shutter goggles. By rapidly alternating the display to each eye, these goggles create the illusion of depth associated with virtual reality.

The primary manipulation of interest was level of distraction. All participants performed the street crossing task while undistracted, listening to music on an iPod Nano, or engaging in a hands-free cell phone conversation. The no-distraction condition served as a single-task scenario (the participant needed only to cross the street), and the music listening and cell phone conditions served as dual-task scenarios. In the music listening conditions, participants were allowed to choose from among playlists of a variety of genres. Each participant set the volume of the iPod to a level that was comfortable to him or her, and an experimenter then checked to assure that the music was in fact audible. In the cell phone condition, participants conversed with a trained confederate. Conversations were guided by a set of age-specific questions (see Table 1) that the confederate used to identify areas of interest for each participant that would produce a high level of engagement. The confederate was then free to ask whatever questions seemed appropriate to keep the conversation flowing or to respond to comments made by the participant in a manner consistent with a normal conversation. The three distraction conditions were blocked and counterbalanced across 60 total experimental trials

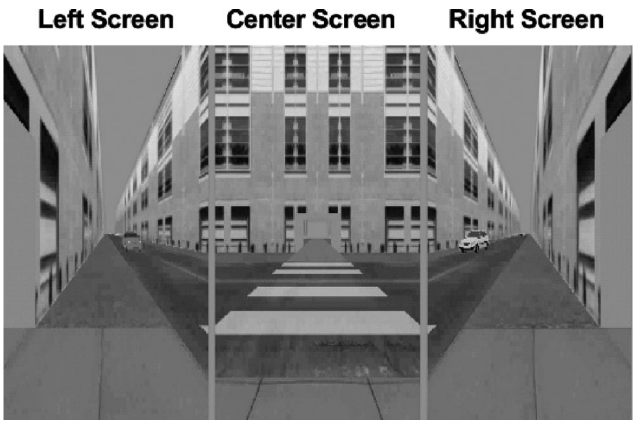


*Figure 1.* A sample still capture of the virtual reality street crossing task. Each image is representative of the wall in the CAVE on which it was presented. Although the street appears to be U shaped in the still image captures, when presented in the virtual viewing environment, the street appeared to run straight and seamlessly.

(two blocks of 10 trials per distraction condition; six total trial blocks). Each block contained an equal number of 75-m and 90-m IVD trials, with the IVD conditions randomly interleaved within each block. The order of the distraction blocks was counterbalanced across all participants so that every possible order was administered an equal number of times. Prior to the experiment, each participant received 10 practice trials to acclimate to the treadmill and become familiar with the task.

## Procedure

Each trial began with the participant located between two buildings in the simulated environment. The participant was told to walk forward past the edges of the buildings and approach the street, and then to cross the street as he or she saw fit (participants were simply asked to cross the road as they would normally). Participants were instructed that they could walk at whatever speed they liked but were not permitted to run, and they were monitored by an experimenter to ensure that they complied with these instructions. After crossing the street, the participant walked through another alleyway and through a gate, after which a new trial began. The participant was given visual and auditory feedback (i.e., the screen faded to red while screeching tires were heard) if they were struck by a car during their crossing and auditory feedback if the crossing was a success. There was no safe zone between the two lanes of traffic where the participant could linger and avoid being hit by a car. If the participant did not complete a crossing within 30 s, the trial terminated and was counted as an error.

# Results

Unless otherwise noted, all analyses were conducted as repeated measure analyses of variance (ANOVAs), with age as a between-participants factor and IVD and distraction type (no distraction, cell phone, music listening) as within-participant factors. In cases where significant omnibus effects of IVD and significant Age × Distraction interactions were observed, we independently conducted additional analyses on each level (75 m and 90 m) of the IVD factor. In such cases, an ANOVA was conducted with age included as a between-participants factor and distraction type was included as a within-participant factor.

## Success Rates

The percentage of trials in which participants successfully completed a street crossing is shown in Table 2. Overall, the main effect of age approached, but did not reach, significance, $F(1, 34) = 3.36$, $p = .08$. However, success rate did vary as a function of IVD, $F(1, 34) = 12.36$, $p < .005$, with IVD having a more pronounced effect on older adults as reflected by a significant Age × IVD interaction, $F(1, 34) = 9.18$, $p < .01$. Success rates also differed as a function of distraction type, $F(2, 68) = 4.25$, $p < .05$. No other omnibus effects approached significance.

## Collision Rate and Timeout Rate

Older adults were less likely to successfully cross the road than younger adults in the more difficult 75-m IVD condition. However, it may not necessarily be the case that a lower success rate implies more accidents. This stems from the fact that there were two possible ways to make an error in our street crossing simulation. The first was to be hit by a car. The other was to fail to complete a crossing before the 30-s timeout deadline. In the latter case, no pedestrian–vehicle collision occurred. To assess the man-

Table 1
*Sample Topics and Questions Used for the Cell Phone Distraction Condition for Younger and Older Adults*

| Younger adults | Older adults |
|---|---|
| Classes | Restaurants |
| What were you favorite classes? | What are your favorite restaurants? |
| Which classes have you liked least? | Can you suggest some good places around town? |
| What classes are you taking next semester? | Movies |
| Major | Have you seen any movies recently? |
| Did you come to college knowing your major? | What are your favorite moves? |
| What are you future career plans? | Who was in it? |
| Job | Books |
| What kinds of jobs have you had? | Have you read any books recently? |
| What has been your favorite job? | What are your favorite books? |
| | What was the book about? |

Table 2
*Mean Crossing Success Rates, Collision Rates, Rate of Errors From Timeouts, and Time to Contact (s) in the 75- and 90-m Intervehicle Distance (IVD) Condition*

| Variable | Success rate | Collision rate | Timeout rate | Time to contact |
|---|---|---|---|---|
| | | 75-m IVD | | |
| Younger adults | | | | |
| No distraction | 91.67 (1.85) | 8.33 (1.85) | 0.00 (0.00) | 4.16 (0.05) |
| Cell phone | 91.38 (2.17) | 8.61 (2.17) | 0.00 (0.00) | 4.18 (0.07) |
| iPOD | 95.56 (0.98) | 4.77 (1.01) | 0.27 (0.27) | 4.24 (0.06) |
| Older adults | | | | |
| No distraction | 88.33 (2.49) | 8.61 (2.32) | 3.06 (1.57) | 3.93 (0.07) |
| Cell phone | 81.67 (3.28) | 6.94 (1.41) | 11.39 (3.30) | 3.99 (0.07) |
| iPOD | 86.94 (2.69) | 8.61 (1.84) | 4.44 (2.06) | 3.96 (0.07) |
| | | 90-m IVD | | |
| Younger adults | | | | |
| No distraction | 92.22 (1.91) | 7.77 (1.91) | 0.00 (0.00) | 4.26 (0.06) |
| Cell phone | 91.39 (2.17) | 8.61 (2.16) | 0.00 (0.00) | 4.22 (0.06) |
| iPOD | 96.11 (0.95) | 3.61 (0.97) | 0.27 (0.27) | 4.66 (0.06) |
| Older adults | | | | |
| No distraction | 92.22 (1.77) | 5.28 (1.24) | 2.50 (1.52) | 4.44 (0.08) |
| Cell phone | 88.89 (3.35) | 5.83 (1.47) | 5.27 (3.16) | 4.43 (0.07) |
| iPOD | 90.83 (3.06) | 5.27 (1.87) | 3.88 (2.19) | 4.45 (0.07) |

*Note.* IVD = intervehicle distance. Values in parentheses indicate standard error of the mean.

ner of errors in the task, we analyzed both the collision rate and timeout rate (i.e., trials in which the crossing was not completed in the allotted 30 s).

**Collision rate.** An omnibus ANOVA of collision rates (see Table 2) indicated that the likelihood of a collision varied as a function of IVD, $F(1, 34) = 7.83$, $p < .01$, with collisions being more frequent in the 75-m IVD trials. Furthermore, older adults were differentially affected by IVD, as reflected by a significant Age × IVD interaction, $F(1, 34) = 4.40$, $p < .05$. No other omnibus effects approached significance. Although older adults were more likely to be involved in a collision in more challenging trials, their likelihood of a collision did not increase when conversing on a cell phone or listening to music.

**Timeout rate.** Analysis of timeout rates (see Table 2) produced a different story. Overall, older adults were more likely to not complete a trial within the allotted time than younger adults, $F(1, 34) = 5.74$, $p < .05$. Timeouts were more likely in the more difficult 75-m IVD condition than in the easier 90-m IVD condition, $F(1, 34) = 9.06$, $p < .01$, with a decrease in IVD particularly impairing older adults, as reflected by a significant Age × IVD interaction, $F(1, 34) = 9.07$, $p < .01$. Similarly, timeout rate varied as a function of distraction type, $F(2, 68) = 4.98$, $p < .05$, with distraction type having a larger impact on the performance of older adults, $F(2, 68) = 5.30$, $p < .01$. A significant Distraction × IVD interaction indicated that dual-task costs varied with the difficulty of the street crossing task, $F(2, 68) = 7.60$, $p < .005$, with larger costs in 75-m IVD trials. This effect was larger for older adults, as indicated by a significant three-way Age × Distraction × IVD interaction, $F(2, 68) = 7.59$, $p < .005$.

To better understand age-related differences in timeout rates, we analyzed levels of the IVD factor independently. In the more difficult 75-m IVD condition, older adults (~6.0%) displayed higher timeout rates than younger adults (~0.1%), $F(1, 34) = 8.98$, $p < .01$; younger adults had nearly zero errors attributed to exceeding the trial's time limit. Timeout rate varied as a function of distraction type, $F(2, 68) = 8.03$, $p < .005$; however, this variation was driven almost entirely by the older adult group, as evidenced by a significant Age × Distraction interaction, $F(2, 68) = 8.46$, $p < .005$. Older adults were more likely to timeout when conversing on the cell phone (~11%) than when listening to music (~4%), $t(17) = 3.26$, $p < .01$, or when undistracted (~3%), $t(17) = 3.30$, $p < .01$. They were equally likely to timeout when listening to music as when undistracted, $t(17) = 0.86$, $p = .40$. In contrast, timeout rates did not differ as a function of distraction for younger adults in any cases ($ps > .33$).

Analysis of behavior in the easier 90-m IVD condition revealed no statistically significant effects ($ps > .09$). Taken as a whole, timeout rates suggest that the performance cost of conversing on a cell phone while crossing a street is related to the difficulty of the crossing task for older adults. When the task was relatively easy, older adults were able to cross the road within the allotted time period on almost all trials; when the task was more difficult, conversing on a cell phone impaired the ability of older participants to complete their crossing in a timely manner.

## Initiation Duration and Crossing Duration

Older adults were less likely to successfully complete a crossing in difficult traffic conditions due to timeouts, with timeouts particularly likely during cell phone conversation. The fact that success rate differences across IVD in older adults were driven by timeouts rather than collisions raises questions about how older adults used their time during each crossing. To determine how participants spent their time during each trial, we analyzed the amount of time that participants spent standing on the sidewalk next to the road before beginning their crossing (presumably they were preparing during this time) and the amount of time they required to cross the road once their crossing had begun.

**Initiation duration.** Initiation time was defined as the amount of time that participants spent on the sidewalk adjacent to the roadway, as measured via a bounding region, prior to beginning their crossing (see Table 3). Overall, older adults spent more time than younger adults standing adjacent to the road prior to initiating their crossing, $F(1, 34) = 44.23$, $p < .001$. Initiation times were longer in the 75-m IVD trials than the 90-m IVD trials, $F(1, 34) = 15.74$, $p < .001$, and varied as a function of distraction type, $F(2, 68) = 14.81$, $p < .001$. A significant Age × IVD interaction, $F(1, 34) = 6.84$, $p < .05$, reflects the fact that older adults displayed longer initiation times as the crossing task became more difficult; younger adults were not as affected by crossing difficulty. Similarly, the significant Age × Distraction interaction, $F(2, 68) = 3.88$, $p < .05$, reflects the longer initiation time required by older adults to successfully cross the road when conversing on the cell phone; younger adults were less severely affected by distraction type.

Examination of the 75-m IVD trials revealed main effects of age, $F(1, 34) = 55.22$, $p < .001$, and distraction type, $F(2, 68) = 14.64$, $p < .001$; older adults took more time to initiate their crossing than younger adults, and both age groups were affected by the form of distraction. The effect of distraction was largely driven, however, by older adults, as supported by a significant Age × Distraction interaction, $F(2, 68) = 3.46$ $p < .05$. Older adults took more time to initiate their crossing when conversing on a cell phone compared with when listening to music, $t(17) = 3.68$, $p < .005$, or undistracted, $t(17) = 3.96$, $p < .005$. Initiation times for older adults did not differ in the music listening and undistracted conditions, $t(17) = 0.35$, $p = .72$. Younger adults displayed a similar, but nonsignificant, trend ($p$s $\geq .06$).

The pattern of data in the easier 90-m IVD trials was similar to that in the 75-m IVD trials. Older adults generally took more time to initiate their crossing than younger adults, $F(1, 34) = 31.71$, $p < .001$, and initiation time varied as a function distraction type, $F(2, 68) = 5.47$, $p < .01$. The latter effect was largely driven by longer initiation times for older adults when conversing on a cell phone compared with when undistracted, $t(17) = 2.47$, $p < .05$. The cell phone versus no-distraction comparison for younger adult participants approached but did not reach significance, $t(17) = 2.03$, $p = .06$. All other comparisons for both the older and younger adult groups failed to reach significance as well ($p$s $\geq .07$). Furthermore, under easier crossing conditions, older adults were not affected by distraction any more than were young adults, as indicated by an insignificant Age × Distraction interaction, $F(2, 68) = 1.64$, $p = .20$.

**Crossing duration.** Crossing duration was the amount of time required for a participant to successfully traverse from one side of the road to the other (i.e., curb-to-curb; see Table 4); lower times indicate faster walking during the crossing. Somewhat surprisingly, older adults were generally faster to cross the road than younger adults, $F(1, 34) = 13.25$, $p < .005$, perhaps due to a greater sense of urgency. Crossing times also varied as a function of distraction type, $F(1, 34) = 6.13$, $p < .01$, indicating that subjects were generally slower to traverse the road when conversing on the cell phone. No other omnibus effects reached significance.

## Time to Contact

In general, older adults were less likely to successfully complete the crossing task than younger adults, largely as the result of an increased timeout rate in the older adult group. What is more, older adults were more likely than younger adults to have a trial end in a timeout when the crossing conditions were more difficult (i.e., 75-m IVD condition) and while engaged in a cell phone conversation. This increased timeout rate appears to be related to longer initiation times. When conversing on a cell phone, older adults required more time to initiate their crossing than younger adults, particularly under difficult crossing conditions. One possible explanation for this increase in initiation time might be a conservative shift in older adults' criterion for entering the roadway. Specifically, if older adults became more cautious about their crossing when conversing on a cell phone in the 75-m IVD condition, they might have taken more time looking for a safer opportunity to initiate their crossing than when undistracted. To examine this possibility, we analyzed time to contact (TTC) at the onset of crossing (see Hecht & Savelsbergh, 2004, for a review). TTC was calculated by dividing the nearest vehicle's distance from the participant at crossing onset by the speed at which that vehicle was traveling. Lower TTC values at the start of a crossing indicate a closer vehicle at crossing onset and a less safe crossing compared with those in which the TTC is larger. If older adults were exercising more conservative crossing criteria when on a cell phone, then we might expect larger TTC values under those conditions, reflecting the selection of safer crossing opportunities.

Table 3
*Mean Initiation Duration (s) and Mean Head Turns During Initiation*

| Variable | 75-m IVD | | 90-m IVD | |
|---|---|---|---|---|
| | Initiation duration | Head turns | Initiation duration | Head turns |
| Younger adults | | | | |
| No distraction | 4.69 (0.46) | 2.02 (0.25) | 4.51 (0.42) | 2.00 (0.25) |
| Cell phone | 5.29 (0.51) | 1.86 (0.24) | 4.86 (0.42) | 1.90 (0.23) |
| iPOD | 4.67 (0.37) | 2.02 (0.23) | 4.71 (0.39) | 1.96 (0.25) |
| Older adults | | | | |
| No distraction | 8.61 (0.42) | 0.82 (0.18) | 7.90 (0.55) | 0.76 (0.12) |
| Cell phone | 10.42 (0.58) | 0.92 (0.18) | 8.97 (0.59) | 0.62 (0.13) |
| iPOD | 8.72 (0.41) | 0.68 (0.16) | 8.14 (0.54) | 0.48 (0.08) |

*Note.* IVD = intervehicle distance. Values in parentheses indicate standard error of the mean.

Table 4
*Mean Crossing Duration (s) and Mean Head Turns During Crossing*

| | 75-m IVD | | 90-m IVD | |
|---|---|---|---|---|
| Variable | Crossing duration | Head turns | Crossing duration | Head turns |
| Younger adults | | | | |
| No distraction | 3.82 (0.11) | 0.62 (0.15) | 3.82 (0.11) | 0.60 (0.15) |
| Cell phone | 4.12 (0.17) | 0.75 (0.16) | 4.13 (0.16) | 0.76 (0.17) |
| iPOD | 3.91 (0.14) | 0.59 (0.16) | 3.96 (0.14) | 0.63 (0.16) |
| Older adults | | | | |
| No distraction | 3.30 (0.11) | 0.60 (0.09) | 3.30 (0.14) | 0.63 (0.09) |
| Cell phone | 3.36 (0.11) | 0.67 (0.10) | 3.43 (0.12) | 0.67 (0.10) |
| iPOD | 3.33 (0.16) | 0.63 (0.11) | 3.33 (0.13) | 0.64 (0.06) |

*Note.* IVD = intervehicle distance. Values in parentheses indicate standard error of the mean.

TTC values are shown in Table 2. Omnibus ANOVA revealed a main effect of IVD, $F(1, 34) = 28.31$, $p < .001$, indicating that TTC was generally shorter in harder trials, and a significant Age × IVD interaction, confirming that older adults were more affected by crossing difficulty than younger adults, $F(1, 34) = 15.16$, $p < .001$. No other omnibus effects were significant, and in particular, no interactions involving age by distraction reached statistical significance ($p$s $> .37$). These data thus suggest that older adults did not adopt a more conservative criterion for initiating a crossing when conversing on a cell phone than when undistracted.

## Initiation Head Turns and Crossing Head Turns

Crossing difficulty and dual-task load played a role in how successful older adults were at crossing the street safely in our task. An important part of deciding whether it is safe to cross a street is gathering information about the environment. Head movements might provide some indication of how information was sampled in our task. To examine this possibility, we analyzed the average number of head turns made by each participant when standing on the sidewalk adjacent to the road, the time when participants were presumably gathering information in preparation to cross, along with the average number of head turns made by each participant while actually crossing the road.

The average number of head turns during initiation (i.e., prior to starting a crossing) is shown in Table 3. Older adults made fewer head turns than younger adults, $F(1, 34) = 23.97$, $p < .001$, but no other effects reached significance. Analysis of head turns during crossing (see Table 4) produced no significant differences; older adults and younger adults made a similar number of head turns during crossing regardless of crossing difficulty and distraction.

## Discussion

Older adults often suffer disproportional performance costs when engaged in two tasks concurrently (e.g., Kramer et al., 1995; Kray & Lindenberger, 2000; Salthouse et al., 1996; Verhaeghen et al., 2003; see Kramer & Madden, 2008, for a review), costs that are evident even in naturalistic task combinations such as walking while encoding material into memory (Lindenberger et al., 2000). The current study extends this work to the domain of pedestrian distraction. Here, older and younger adults attempted simulated street crossings in traffic conditions of varied difficulty while undistracted, conversing on a cell phone, or listening to music. The data suggest that both task difficulty and task load are important factors in governing dual-task performance in older adults. Older adults were less likely to successfully complete a crossing than younger adults when crossing conditions were difficult (i.e., 75-m IVD trials). These success rate differences were driven not by an increased likelihood of collision, but rather by an increase in errors due to exceeding the 30-s timeout limit allowed in the task. Differences in timeout rate resulted from older adults' tendency to require more time initiating their crossings than younger adults when the crossing task was difficult, an age-related difference that was exacerbated by cell phone conversation. Initiation times for younger adults did not vary as a function of distraction. It is interesting that recent work by Lövdén, Schellenbach, Grossman-Hutter, Kruger, and Lindenberger (2005) found that handrail support attenuates age-related differences in tasks requiring postural control, suggesting that the age-related differences we observed in our study may have been even more pronounced had participants not been required to maintain their grip on the treadmill's handrail throughout the study.

What are the mechanisms underlying these effects? If increases in timeout rate differences had coincided with an increased likelihood of collision, then we might have inferred that differences in motor function made older adults slower to move across the street than younger adults. However, that was not the case. Although older adults were a bit more likely than younger adults to be involved in a collision in difficult trials, collision rates did not vary as a function of task load for any participants. It is also interesting to note that older adults actually traversed the street more quickly after initiation than younger adults, and their crossing speed did not vary as a function of task load. In contrast, younger adults were slower to traverse the road when conversing on a cell phone than when undistracted or listening to music. These effects imply that although postural control and movement are compromised with age and distraction (e.g., Blake et al., 1988; see Woollacot & Shumway-Cook, 2002, for a review), these motor-related losses were not the proximate cause of age-related performance differences in our findings. The conclusion that task load did not affect walking speed in older adults is somewhat inconsistent with findings by Lindenberger et al. (2000), who observed that older adults walked more slowly when engaged in a secondary task. However, our task differed quite significantly from that used by Lindenberger and colleagues in that it simulated a time-critical real-world activity. Furthermore, although their walking speed did not differ across levels of distraction, older adults still might have experienced motor-related task difficulties. Older adults might have maintained walking speed under distraction, for example, by temporarily sacrificing secondary-task performance. Alternatively, they might have undergone a surge in mental workload (Wickens & Hollands, 2000) under dual-task conditions that young adults did not experience. What the data show, then, is not that older adult participants sustained no motor-related difficulties performing the current task, but that they were able to effectively manage these difficulties in order to maintain street crossing performance.

Given that success rate differences were driven by trial timeouts rather than collisions, it seems likely that cognitive mechanisms played the more prominent role in producing the performance costs experienced by older adults when talking on a cell phone. For instance, timeouts would have been increasingly likely if dual-task load impaired the ability of older adults to make crossing judgments. This assertion is consistent with previous work showing that dual-task costs in older adults are exacerbated when either or both of the individual tasks being performed require substantial cognitive control processes, such as planning, updating, and encoding (e.g., Paxton, Barch, Racine, & Braver, 2008; Salthouse et al., 1996). Our analysis of initiation times provided some evidence for this account. Presumably, initiation time reflects some preparatory cognitive processing, with participants analyzing the traffic pattern for safe crossing opportunities. In difficult trials, older adults spent nearly twice as much time as younger adults standing on the sidewalk prior to initiating a crossing. Furthermore, high dual-task load resulting from cell phone conversation induced an additional and disproportionate time cost relative to that suffered by younger adults. Evidence consistent with the encoding difficulty hypothesis comes from the finding that, on more difficult trials, older adults initiated their crossing when the nearest vehicle was closer (lower TTC) than did young adults, suggesting that older adults' delays in initiating crossing did not provide them with more safety or a lower margin for error than those enjoyed by the young adults.

An alternative explanation for the older adults' increased initiation times under dual-task conditions might be that distraction caused a conservative shift of the older adults' response criterion. That is, when older adults were forced to make difficult crossings under high-load conditions, they might simply have exercised more caution before stepping into the roadway. Such behavior has indeed been observed in studies examining cell phone usage during driving. When conversing on a cell phone, for example, young adult drivers tend to increase the gap distance between their vehicle and the vehicle in front of them (e.g., Horrey & Simons, 2007). Similarly, research by Li, Lindenberger, Freund, and Baltes (2001) has shown that when under dual-task load, older adults tend to prioritize the task domain for which the most negative consequences are expected to occur should that domain be neglected. However, TTC data in the current study seem to argue against such an account. If older adults were in fact exercising increased caution when crossing while using a cell phone, the result should have been an increase in the TTC during those crossings, indicating safer behavior. No such effect was seen. TTC values were similar for older adults in difficult conditions regardless of task load and distraction type, suggesting minimal differences in crossing criteria across distraction conditions. Still, given the previous findings showing conservative behavior shifts by older adults when under dual-task load (Li et al., 2001), future research will be necessary to more thoroughly explore the possibility of a conservative shift in behavior by older adults when conversing on a cell phone and crossing a street.

Another factor that likely contributed to the difficulty that older adults had in successfully crossing the street while conversing on a cell phone in our task was age-related decline in attentional control processes. Evidence that attentional control diminishes with age has come largely from experiments using the task-switching paradigm (e.g., Allport, Styles, & Hsieh, 1994; Rogers & Monsell, 1995; see Kramer & Madden, 2008, for a review), which measures a participant's ability to rapidly alternate between two tasks. In homogeneous blocks, the same task is performed on every trial; in heterogeneous blocks, two different tasks are intermixed. Specific switch costs, which represent the reaction time difference between switch and no-switch trials in heterogeneous blocks, are thought to measure the efficiency of control processes underlying the activation and deactivation of relevant and irrelevant task sets. General switch costs, which measure the reaction time difference between heterogeneous and homogeneous blocks, are thought to reflect the participant's ability to maintain multiple task sets in working memory. A number of studies have found that both specific and general switch costs are larger for older adults than for younger adults (Kramer, Hahn, & Gopher, 1999; Kramer, Larish, Weber, & Bardell, 1999; Kray, Li, & Lindenberger, 2002; Mayr, 2001), suggesting age-related declines in attentional control and working memory.

Although our task was more naturalistic and less controlled than traditional task-switching studies, similarities between the two do exist. Here, participants performed a street crossing task in isolation or while using a cell phone or listening to music. In the latter conditions, participants would have needed to divide attention between competing task demands (the street crossing and conversation tasks) while maintaining accurate representations of those tasks in memory (e.g., the spatial representation of vehicles in the roadway or a certain question asked over the cell phone by the confederate). To the extent that advancing age impairs attentional control processes, performance under load should decline under these conditions, consistent with our finding of increased initiation times for older adults when conversing on a cell phone. In addition, Kramer, Hahn, and Gopher (1999) have shown that older adults are more likely to experience switch costs under high memory load. Our finding that older adults showed greater dual-task costs when the crossing task was particularly difficult (75-m IVD condition) is consistent with this finding (also see Lindenberger et al., 2000) and with other work showing that dual-task costs in older adults become larger as demand on attentional control processes increases (e.g., Salthouse et al., 1996).

Although age-related declines in attentional control processes likely played some role in our findings, given the initiation time differences we observed between the older and younger adults, other processing impairments might have also played a role in producing the dual-task costs displayed by older adults in the street crossing task. For this speculation, we borrow from the recent literature exploring the effects of conversing on a cell phone while driving. Specifically, research has suggested that the costs associated with conversing on a cell phone while driving might be due in part to dual-task interference in visual encoding processes (McCarley et al., 2004; Strayer & Drews, 2007; Strayer et al., 2003). Such encoding interference might be reflected in a slower accumulation of visual information in a manner consistent with the pattern of increased initiation times observed in the older adult group in more challenging crossing conditions. A recent study by Bock (2009) found that dual-task costs for older adults during walking tend to arise when tasks are visually demanding. This finding would seemingly be supportive of the impaired visual encoding hypothesis; however, additional research will be required to further investigate this possibility.

A further question that arises when considering our results is, Why did listening to music not produce dual-task costs similar to those observed when older adults conversed on a cell phone? It can be hypothesized that, to the extent that a listener is attending to the music he or she is listening to, there should be some costs to other concurrent tasks (e.g., Dell'acqua & Jolicoeur, 2000; Jolicoeur, 1999). However, conversation and music listening are two distinctly different types of tasks. Whereas the former requires an individual to constantly monitor what the partner is saying and to produce a rational response, the latter might be effectively "tuned out" at times with no observable penalty. Along these lines, previous work by Neider et al. (2010) failed to find any dual-task costs associated with listening to music while crossing the street in younger adults. Similarly, studies of passive listening (e.g., listening to a radio) while driving have also found no evidence of dual-task costs (e.g., Kubose et al., 2006; Strayer & Johnston, 2001). Nonetheless, the absence of dual-task costs during music listening in the current study should be interpreted with caution.

Although our task represented a reasonably realistic approximation of what a street crossing in the real world is like, one vital component of real-life street crossing was absent: auditory information. Outside the lab, auditory cues may provide information about the level of traffic density generally and about the distance, direction of movement, and speed of individual vehicles more specifically. Sound therefore might be highly valuable in judgments of street crossing safety, and music that obscured environmental sounds might well compromise crossing performance. Unfortunately, the technical difficulties of simulating environmental noise in a 360° environment precluded the presentation of auditory cues or ambient environmental noise in the current study. The absence of this ambient noise should be taken into account when considering the lack of any dual-task cost in the music listening condition. It is certainly conceivable that, in the real world, listening to music on a portable listening device might affect the ability of a pedestrian to extract auditory cues that might aid in the crossing process. We hope to address this possibility in future studies where simulated ambient noise is included in our street crossing simulation.

The current study has practical implications as well. Previous studies have found that younger adults suffer performance impairments when attempting to cross a street while conversing on a cell phone (Hatfield & Murphy; 2007; Nasar et al., 2008; Neider et al., 2010). We extend those findings to older adults, but with an important caveat. Although younger and older adults are both susceptible to impairment when conversing on a cell phone and attempting a street crossing, older adults become susceptible under much less challenging conditions than younger adults. In our simulated street crossing task, older adults showed impairment in the more difficult 75-m IVD condition, but dual-task impairments were largely absent for younger adults in that condition. The cell phone-related impairments observed by Neider et al. (2010) in younger adults were found under different and more difficult crossing conditions, where cars moved at variable speeds and gap distances were dynamic. Given the current data, older adults would likely suffer even larger costs under similar conditions. Despite the fact that conversing on a cell phone did not increase the likelihood of a collision in our simulated task, evidence of cognitive impairment was observed. In the real world, any impairment in performance must be taken seriously.

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