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The effects of aging on the attentional demands of walking toward and stepping up onto a curb

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ABSTRACT

Community ambulation requires the capacity to alter gait in response to obstacles within the path of travel that appear at a known location. Acquiring information from the environment to safely negotiate a curb may increase the cognitive demands of walking. The purpose of this study was to examine the attentional demands of walking toward and stepping up onto a curb in young, middle-age and older adults. Single and dual-task voice reaction time (VRT) was measured in community-dwelling young ($n = 24$), middle-age ($n = 24$), and older adults ($n = 24$) across 5 conditions: sitting in a chair, standing, level walking, and walking toward and while stepping up onto a curb. A 3 (group) by 5 (task condition) ANOVA was used to examine VRT. The interaction of group with task revealed statistically significant within group increases in VRT when comparing either sitting and/or standing to walking on a level surface and walking toward the curb and stepping up onto the curb. When compared to the other groups, older adults had significantly longer VRT for all walking tasks. Stepping onto the curb significantly increased the attentional requirements of walking for all of the groups when compared to level walking. The pattern of statistically significant between group and within group differences during the walking tasks indicate the effects of a curb located at a predictable place in the environment on attentional allocation.

1. Introduction

Navigating safely within the community requires the capacity to acquire information from the surrounding environment to guide ongoing and emergent motor actions [1,2]. Proactively altering gait in response to obstacles within the path of travel is essential to prevent tripping, which has been identified as a common cause of falls for older adults [3–5]. When walking in the community, a number of environmental features, which include uneven sidewalks and curbs, have been reported by older adults as causing a fall due to tripping [5].

The failure to perceive an environmental feature as a potential balance hazard is a risk factor for falls in older adults [6]. Such perceptual errors may arise due to limitations in the capacity to appropriately allocate attention to acquiring information from the surrounding environment. Dual-task paradigms have shown that older adults with and without balance impairments allocate greater attention to stepping over an obstacle appearing in the path of travel [7,8]. When accessing the community, a curb is a commonly encountered feature or obstacle. Visual information is used to adaptively modify foot placement in advance of curb contact and to guide foot placement in preparation for stepping up onto the curb [9]. Reported changes in gait and visual scanning preferences occurring prior to curb contact suggests a role for cognition related to planning foot placement [9,10] that has the potential to further increase the associated attentional requirements of walking. Unfortunately, little is known about the attentional demands of managing a curb, which may differ from the requirements to step over an obstacle appearing in the path of travel.

The purpose of this study was to examine the attentional requirements of walking toward and stepping up onto a curb in young, middle-age and older adults using a dual-task, voice reaction

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time (VRT) paradigm. We hypothesized that the attentional demands of walking, as measured by VRT, would increase when approaching and ascending a curb and that there would be differences in attention between the groups that reflect aging.

2. Methods

2.1. Participants

Utilizing convenience sampling, 3 cohorts were recruited: young adults (YA, $n = 24$) – age 20–30 years; middle-age adults (MA, $n = 24$) – age 40–50 years; and, older adults (OA, $n = 24$) – age 65 or older (Table 1). The study inclusion criteria required participants to be independent in both community ambulation and curb management without using any type of assistive device. Participant exclusion criteria included: (1) reported active musculoskeletal pain localized to the trunk or lower extremities on the day of testing; (2) self-reported history of central nervous system impairment or medical instability; (3) requiring physical assistance to restore balance during testing; or (4) requesting more than 2 min of rest between any ambulation trials. Widener University and Temple University provided Institutional Review Board review and approval for the study; all participants provided informed consent prior to study enrollment.

2.2. Instrumentation

2.2.1. VRT measurement

Attentional allocation was examined by measuring the time required to respond verbally to a 75 dB, 4200 Hz piezo-electric tone (Model 273-054, RadioShack, USA). A wireless headset microphone (Model 32-1221, RadioShack, USA) transmitted the verbal response to a voice activated relay switch (Model 63040A, Lafayette Instruments, USA) which triggered a digital stop clock (Model 54035A, Lafayette Instruments, USA). The tone generator and stop clock were activated either manually by a researcher or automatically by the participant breaking the beam of an infrared photocell switch (Model 63501IR, Lafayette Instruments, USA) placed along the path of travel. One infrared switch, located 1.9 m from the front of the curb, examined the effects on planning for foot placement prior to contact with the curb. The other was positioned in line with the front edge curb so that the leading limb, while passing over the front edge of the curb, triggered the auditory stimulus during the process of placing the foot onto the curb [10,11]. Manual activation of the tone generator, located centrally in the room, occurred during the sitting, standing and level walking tasks. Stimulus anticipation was controlled by hiding the triggering and switch activation mechanisms.

2.2.2. GAITRite Gait Mat®

The validity of the dual-task reaction time paradigm requires the subject to maintain primary task performance (walking) when presented with the secondary task (responding verbally to the auditory stimulus) [12]. Walking velocity and cadence were examined using the GAITRite Gait Mat® (CIR Systems Inc., USA). A continuous 7.6 m walkway was created by joining 3 mats together with carpet tape. Data were collected from the middle 4.57 m portion of the walkway during level walking. During the curb approach and ascent task, the GAITRite Gait Mat® was positioned to allow speed and cadence to be examined prior to participant contact with the curb. Single and dual-task walking velocity and cadence were compared to determine if walking was altered to improve VRT.

Table 1
Participant demographics for age, gender and measures of balance and balance confidence.

	Young adults $n = 24$		Middle-age adults $n = 24$		Older adults $n = 24$	
	Mean	SD	Mean	SD	Mean	SD
Age (years)						
Females $n = 12$	23.73	1.44	45.64	3.43	71.86	2.83
Males $n = 12$	25.38	2.08	45.77	3.16	73.62	4.74
Total	24.55	1.94	45.70	3.22	72.74	3.92
Body mass index	24.90	4.90	26.50	6.60	26.90	4.10
Timed Up and Go (s)	7.35	0.91	8.35	1.47	9.98	1.66
ABC Scale (%)	95.30	5.00	93.80	5.90	81.50	16.50

ABC – Activity-specific Balance Confidence Scale.

2.3. Procedure

Data collection required approximately 1 h and occurred in a room free from noise and distractions. The participants completed 2 measures of balance and provided information about history of falling. Developed as a performance-based measure of functional mobility and balance, the Timed Up and Go Test (TUG) requires the subject to rise from a chair, walk 3.0 m at a comfortable pace to a mark placed on the floor and turn around, walk back to the starting point, and return to sitting [13]. The test completion time determines the functional mobility score. The Activities-specific Balance Confidence Scale (ABC) examined self-perceptions of mobility confidence for functional walking and standing activities [14].

The attentional demands of curb management were determined by measuring VRT under 5 task conditions: (1) sitting in a chair with back support; (2) standing without upper extremity support; (3) walking on a level surface; and (4a) walking toward (curb approach), and (4b) while placing a foot onto a 15 cm curb (curb ascent). Baseline single-task VRT was established in sitting which was always the first task condition completed. Transmitter and receiver sensitivity was set based on the participant's voice output. The participants were instructed to vocalize the letter "B", as quickly as possible, whenever the auditory tone was presented. Of the 15 trials performed, sitting VRT was determined by averaging trials 6–13.

After establishing baseline, single-task VRT, the remaining task conditions were performed randomly; each group performed the same combination of task conditions. When measuring standing VRT, participants assumed their preferred posture and the auditory stimulus was presented 13 times. Standing VRT was determined by averaging the responses from trials 4 to 11. Prior to starting each of the remaining task conditions, a scripted reminder to respond as quickly as possible to the auditory tone was provided.

Prior to measuring level walking VRT, participants were instructed to ambulate at their usual pace and were informed that the auditory stimulus would not be presented during the first 4 trials; gait data collected were used to determine single-task walking performance. Upon completing the single-task walking trials, participants were informed that the auditory stimulus would be presented during some of the remaining 11 walking trials and reminded to respond quickly to the VRT stimulus. No specific instructions were given regarding the prioritization of performance on the primary and secondary tasks. The participants were instructed to (1) walk at their usual pace and (2) respond as quickly as possible when first hearing the auditory stimulus. Five catch trials, or trials where the VRT stimulus was not presented, were randomly incorporated to prevent stimulus anticipation that could potentially enhance secondary task performance [15]. Responses from the 6 dual-task trials were averaged to determine VRT.

The curb, located at one end of the walkway, provided space for continued walking and deceleration after ascent [10]. The distance from the start of the walkway to curb contact was 6.18 m. Infrared photocell switches, placed at 2 locations along the pathway leading up to the curb, automatically activated the VRT stimulus and