AUDITORY SPATIAL ATTENTION IN A COMPLEX ACOUSTIC ENVIRONMENT WHILE WALKING: INVESTIGATION OF DUAL-TASK PERFORMANCE

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1. INTRODUCTION

In many everyday situations, listeners must attend to one sound while dividing attention to also listen to other sound sources or while trying to ignore irrelevant competing sound sources. Furthermore, they may need to listen while dividing their attention between the task of listening and non-auditory tasks (e.g., driving a car while talking on a cell phone). In an earlier study, we measured the effect of spatial attention on word recognition in younger and older adults using Coordinate Response Measure (CRM; Bolia, Nelson, Ericson, & Simpson, 2000) stimuli presented in a display of three spatially separated "talkers" (Singh, Pichora-Fuller & Schneider, 2008). One important finding was that all participants performed better when they had prior knowledge of callsign identity (Singh et al., 2008).

1.1 Psychoacoustic studies

Psychoacoustic and speech experiments, including the study by Singh et al., are usually conducted in soundbooths. In daily life, however, we encounter more complex, less controlled listening situations. In a pilot study, the testing paradigm employed by Singh et al. was adapted and examined in a new, state-of-the-art Virtual Reality (VR) laboratory facility, called StreetLab. In StreetLab it was possible to incorporate visual and 3D auditory cues in the display (see Maracle, Lau, Coletta, Singh, Pichora-Fuller, & Campos, 2012). Maracle et al. (2012) found that three healthy, young adults had similar performance when tested in a sound-attenuating booth as when tested in StreetLab. The replication in StreetLab of the results obtained earlier in typical soundbooth conditions established a baseline against which we could compare the effects of increasing task demands during listening in even more realistic scenarios.

1.2. Current experiments

Another level of complexity that exists in the real world involves executing and coordinating multiple tasks and competing priorities at the same time. Therefore, the current experiment expands upon the findings of Maracle et al. (2012) by introducing a concurrent walking task. The purpose of this study was to compare word identification and the effects of spatial attention when listening was either the sole task or when listening and walking were concurrent dual tasks. These two tasks are arguably the most ubiquitous of dual tasks performed in everyday life. In particular, the scenario selected for the study was intended to represent the real life situation of waiting to cross or walking across a major city road intersection, while listening to one talker with two competing talkers nearby.

2. METHOD

2.1 Participants

Three undergraduate students, ages 19 to 26 years, with normal pure-tone air-conducted hearing thresholds (≤ 25 dB HL) for frequencies from 0.25 to 8 kHz, performed a word identification task in two experimental conditions. All participants were fluent speakers of English who began learning English prior to the age of 5 (participants A and B were bilingual, while participant C was monolingual).

2.2 Apparatus

Testing was conducted in StreetLab in the Challenging Environment Assessment Laboratory (CEAL) at the Toronto Rehabilitation Institute. A 240^0 horizontal curved projection screen surrounded participants. A high-resolution virtual representation of a major city road intersection was displayed on the screen. No vehicle traffic or pedestrians were simulated. Sound was presented from seven loudspeakers embedded behind the projection screen in the horizontal plane at head height. The distance from the loudspeakers to the participant was 2.14 m. As seen in Figure 1, a treadmill is located in the floor of StreetLab. The display is stationary when the participant is standing still and the treadmill is not activated. When the treadmill is activated, the visual and auditory displays are updated so as to simulate changes in the scene as would occur during walking.

Figure 1: Interior of StreetLab

2.3 Stimuli

The stimuli for the listening task were all sentences recorded by four male talkers for the Coordinated Response Measure (CRM; Bolia et al., 2000). The sentences took the format "Ready [callsign], go to [colour][number] now" (Bolia et al., 2000). There were eight different callsigns and numbers, and four different colours. Each sentence was presented at 60 dB A. Three sentences were presented simultaneously in each trial; one sentence was the target and the other two were competing sentences. Each sentence was displayed at a different simulated location, with the target sentence at 0° azimuth (in front) and the two competing sentences at ±90° (right/left).

2.4 Design and Procedures

All participants completed 8 sessions in each of two conditions; standing and walking. The standing and walking conditions differed in terms of whether or not there was a secondary task (walking) during listening. Testing in the standing condition was completed before testing in the walking condition (two participants had also been tested in the study of Maracle et al., 2012).

Standing condition. In the standing condition, the treadmill was not activated and the visual and auditory displays were spatially static. Participants remained positioned at the southwest corner of the simulated intersection for all trials. On the first test day, participants completed a set of 30 practice trials in the 1.0 location certainty condition, followed by 30 practice trials in the 0.6 condition. On subsequent test days, participants completed 15 practice trials in the 0.6 location certainty condition.

Walking condition. At the start of each testing block in the walking (dual task) condition, participants were positioned at the southwest corner of the simulated intersection and used a joystick to activate the treadmill to begin the simulation of walking across the road. Once they reached the southeast corner of the intersection, the display was repositioned back to the starting point. The treadmill was set at a maximum speed of 1 metre per second (m/s). Prior to testing in the walking condition, participants practiced walking on the treadmill and maneuvering the joystick for 5 minutes. Following this, participants completed 15 practice trials in the 0.6 location certainty condition in the walking condition.

In each session there were four blocks of 30 test trials. On each trial, one of eight possible callsigns was displayed visually on the center of the screen in StreetLab for 3 sec followed by a 2 sec pause, followed by the presentation of a target and two competing sentences. Listeners were told to listen for the sentence containing the callsign which had been visually displayed and to report the colour and number from that sentence. Once they verbally responded, their response was typed into a tablet by the experimenter and the next trial was initiated.

Four location certainties were tested (1.0, 0.8, 0.6, 0.33) corresponding to the likelihood that the target stimulus would originate from each of the three simulated spatial locations. In the 1.0 location certainty condition, the target was presented from the "front" location 100% of the time; whereas in the 0.8 location certainty condition, there was an 80%, 10%, and 10% probability that the target would originate from the front, left, and right locations, respectively. At the start of each block of trials, participants were informed verbally of the certainty condition to be tested. Within a session, each of the four location certainty conditions was tested in a random order, with one block used to test each certainty condition.

The tester entered participant's responses on a tablet computer and the participant was informed of the accuracy of their response by a "correct" or "incorrect" that was displayed on the screen after each trial.

3. RESULTS

In all conditions, word identification accuracy decreased as certainty about the location of the target decreased. The pattern of results was virtually identical in the standing and walking conditions. Furthermore, the results of the participants tested in the current study all fall within one standard deviation of the group means found previously (Singh et al., 2008) for 24 young adults tested in a typical soundbooth environment (see Figure 1).

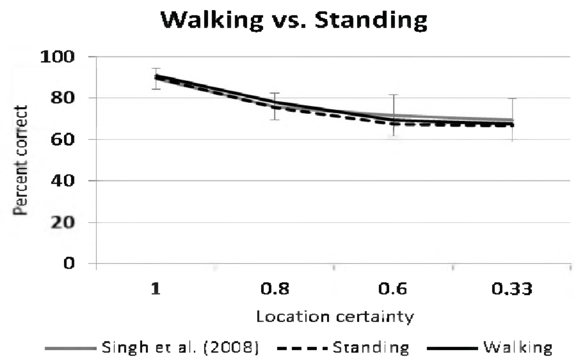

Figure 2. Percent correct as a function of location certainty.

4. DISCUSSION

The high degree of similarity in listening task performance between the standing and walking conditions suggest that the listening abilities in multi-talker environments of these participants were not affected by the inclusion of a walking component. The dependent measure in this study was target identification accuracy in the listening task. It would be of interest to include measures of gait in future studies to investigate whether maintaining a similar level of listening performance in the walking condition was associated with deviations in gait. Parameters of interest related to gait include measures of walking stability such as cadence, speed, step length, step width and head sway. In addition, it would be interesting to examine the performance of healthy older adults and younger and older adults with hearing on this dual task.

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