Processing words in the real world: A protocol for investigating the dual-task costs of making lexicality judgements while walking in young and older adults

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***Abstract*— This novel study explores language processing in a real-world context, namely walking in a street. It combines performing lexicality judgments while walking on a self-paced treadmill in a virtual environment that simulates the real world to create a dual-task paradigm to evaluate cognitive-motor interference in older adults and healthy young individuals.**

Keywords—Lexical Decision, Gait, Virtual Reality, Dual Tasking, Aging

I. Introduction

Making lexicality judgements (i.e. the ability to differentiate a word from word-like stimuli) is considered a core cognitive component for language processing. The lexical decision task is one of the most frequently used paradigms in psycholinguistics, and is commonly employed to investigate word recognition [1]. The objective is to measure how quickly and accurately a person can discern if a stimulus is a word or not. For example, participants are presented with a mix of words and pseudowords (words that do not exist but respect the orthographic rules of a language, e.g. "fillow") or words and nonwords (words that do not exist and do not respect the orthographic rules of a language, e.g. "kjotd"). The complexity of the mental processes for making a lexicality judgement is reflected in response latency and accuracy [2]. Participants are faster to accept a word than to reject a pseudoword but slower to reject a pseudoword than a nonword [1]. Furthermore, older adults consistently take longer to make a lexicality judgement when compared to young adults [1, 3].

While walking is a common daily activity for most, it is a complex process that involves the ongoing integration of visual, proprioceptive, and vestibular sensory information [5]. Daily activities present numerous situations in which walking is done concurrently with another activity such as reading signs.

The dual-task paradigm requires an individual to perform two tasks simultaneously. Performance is then compared to that of each of the single-task conditions to investigate the "cost" of dual-task performance (measured by changes in the performance of one or both tasks when done concurrently). Dual-task walking studies involving varying cognitive loads have shown some age-related changes in gait outcomes during treadmill walking [6, 7]. Furthermore, when investigating language as a secondary task, wayfinding in a virtual city environment is affected when also performing a lexical decision task in young adults [8]. However, the authors did not report whether changes in making lexicality judgements were observed, nor did they include older adults. Yet with increasing age accompanied by cognitive changes, such a measurement is vitally important when considering pedestrian safety.

The research questions in this exploratory study are twofold: (1) Are the speed or accuracy of making lexicality judgements and/or gait variables affected in a dual-task condition compared to a single-task condition? (2) Is there an effect of aging on cognitive-motor interference and/or lexical processing in single and dual-task lexicality decision? To address these questions, an innovative virtual environment has been created using custom-made virtual reality (VR) technologies and a self-paced treadmill. This novel and innovative study combining VR, walking, and processing lexicality is a first step in understanding the combined dual-task effects of the lexical recognition and gait processes, and if whether aging can impact on these processes. Preliminary data from young and older adults will be presented.

II. Methodology and Analysis

A. Participants

A group of 20 young adults (18-30 y.o.) and one of 20 older adults (60-85 y.o.) will be recruited. Participants must be

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dominant English speaking, have normal or corrected to normal vision, be free of neurological or musculoskeletal deficits, and be able to walk independently and without discomfort for at least 5 minutes.

B. Virtual Scene Display and Self-Paced Treadmill

The custom built 0.6 x 1.5m self-paced treadmill was used for all walking. The treadmill is computerized-controlled and driven based on the participant's voluntary pace, including acceleration and deceleration phases. The treadmill motor is driven by signals from a micro-controller, which runs a proportional-integral-derivative (PID) servo-controlled algorithm, based on the velocity and real-time distance information obtained by a potentiometer via an extensible cord tethered to the participant's harness (see Fig. 1). The potentiometer detects changes in cord length, relative to the initial calibrated position, and instantly sends online distance and velocity signals via the micro-controller to synchronize speed changes between the treadmill and the VR display.

The virtual scene (see Fig. 1) was developed in the Unreal Engine 4 game engine (Epic Games). In the both single tasks, (i.e. walking task and lexical decision task) the urban setting will progress according to the participant's gait speed. The same controller powering the Unreal Engine controls a dual-projection display that is rear-projected onto a screen (2.34m x 1.83m) located approximately 1.5 m in front of the participant. This creates an immersive 3D virtual environment when the participant views it with polarized glasses.

C. Session 1 - Assessment and Single Lexical Decision Task

Participation begins with the Montreal Cognitive Assessment (MoCA) to assess general cognition. A visuospatial scanning task (VISSTA) is then administered to assess divided visual attention and speed of processing. This is followed by a Timed Up-and-Go (TUG) test to assess physical function. Finally, a Language Background Questionnaire will be administered to establish language dominance.

The participant will then perform the lexical decision task (Single Task Lexical Decision) portion of the experiment. This comprises 320 trials: 80 nouns, 80 verbs, 80 pseudowords, and 80 nonwords. Trials will be divided into 8 blocks. Participants will be asked to stand in front of the virtual display (See fig. 1) and will make lexicality judgements to stimuli presented on the screen. Responses will be made by a button press on a computer mouse. Speed and accuracy of responses will be collected as outcome variables.

D. Session 2 – Walking, Single and Dual-tasks

Session 2 begins with a 10m walk test to establish overground walking speed. Participants will then be given walking habituation time on the self-paced treadmill until a natural and comfortable pace is achieved. The experiment then resumes with 60 seconds of walking in VE (Single Task Walking) to record their comfortable baseline speed. The dual-task then begins as participants will perform lexicality judgements to each stimulus being presented on the screen while walking at a comfortable pace. Presentation of word stimuli will follow the same 8-block procedure as in the Single Lexical Decision Task. An additional 60 seconds of walking only will follow to control for fatigue effects. Gait speed, stride length, and coefficient of variation of gait speed will be collected as outcome variables. Participation will conclude with a 90 second verbal fluency task on the treadmill and, finally, participants will indicate on a visual analogue scale whether either walking or language was prioritized while performing the dual-task.

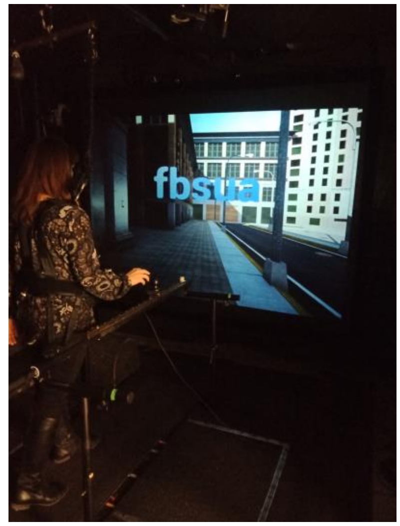

Fig. 1. VR and self-paced treadmill set-up. The virtual environment features and urban scene with a single word, nonword or pseudoword presented. While walking, the participant makes lexicality judgements.

E. Analysis

For the single lexical task, a parametric 3x2 mixed-model ANOVA design with post-hoc comparisons will be performed. For the walking tasks each gait variable will be analyzed in the same manner. A test for data normality (Kolomorov-Smirnov, Shapiro-Wilk, $p>0.05$) for both groups will be performed. Once normality is established, a parametric 4x2 mixed-model ANOVA design with post-hoc comparisons will be performed.

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