

Poster

Gait Variability and Assessment of Cognitive Impairment

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Abstract

Background: Walking has long been considered to be an autonomic process involving little or no higher cognitive input. In healthy adults, stride-to-stride fluctuation of many gait parameters (eg, gait speed, stride time) is on the order of just a few percent, testimony to the accuracy and reliability of the fine-tuned systems that regulate locomotion. When the systems regulating walking are disturbed as a result of neurological disease or abnormal aging, movement control may be impaired leading to increased variability of several gait parameters. Gait assessment while the patient performs a cognitively challenging secondary task (“dual-tasking”) has been widely used to assess interaction between cognition, gait, and the risk of falling. Dual-task testing is clinically relevant, as most activities of daily living require the simultaneous performance of two or more cognitive and motor tasks. Traditionally, gait variability has been difficult to quantify and has been carried out in specialized laboratory settings. Current motion analysis systems are expensive, require trained personnel to operate, and limit evaluation to a few strides. Advances in consumer electronics allow for the development of a system that is cheap, unobtrusive, and easy-to-use in unconstrained ambulation. In addition, the use of a portable electronic device facilitates the development of a gamified Go/NoGo response inhibition task, which enables an automated approach to measuring relative trade-off in dual-task conditions.

Objective: Our primary objectives were as follows: (1) to develop a simple mobile-based tool to enable collection, aggregation, and visualization of gait variability data through a co-design process with clinicians; (2) to examine the feasibility of integrating a gamified dual-task assessment; and (3) to answer the question “If we build it, will they come?” Our secondary objective was to explore the factors that influence rehabilitation therapists’ willingness to use mobile/wearable technology in clinical practice.

Methods: We took an iterative design approach to incorporate user feedback during the development of the mobile application. To validate the gait assessment data, we utilized a convenience sample of 12 healthy adults and evaluated 30 seconds of walking data using the mobile application against a Vicon Motion Capture System. In parallel, we developed a questionnaire to gain insight into the barriers and motivating factors that affect use of consumer technology in clinical practice by physiotherapists. The questionnaire was pilot tested for content validity and internal consistency at a rehabilitation center and was distributed online.

Results: Preliminary validation demonstrates good agreement between the mobile application and the Vicon system for mean stride time ($r=0.89$, $P<.001$) and stride time variability ($r=0.79$, $P<.01$), $n=12$. However, further testing is required among cognitively impaired older adults.

Conclusions: Assessment of gait in single and dual-task conditions is suitable using a mobile device and allows for simple development of a game to assess cognitive challenge during ambulation. Barriers to clinical use exist, but physical therapy is a promising area to assess ideas and implementation strategies in mHealth. Consequently, more research is needed to understand the attitudes of physical therapists toward emerging consumer-grade technology in practice.

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KEYWORDS

gait; cognitive impairments; falls; neurorehabilitation; mHealth; Technology Acceptance Model (TAM); user-centred design

This poster was presented at the Connected Health Symposium 2016, October 20-21, Boston, MA, United States. The poster is displayed as an image in [Figure 1](#) and as a PDF in [Multimedia Appendix 1](#).

Figure 1. Poster.

UNIVERSITY OF TORONTO / MECHANICAL & INDUSTRIAL ENGINEERING

GAIT VARIABILITY AND ASSESSMENT OF COGNITIVE IMPAIRMENT

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INTRODUCTION

Cognitive status change is an important measure that is easily undetected in routine clinical assessments. With a growing population of older adults, indicators of cognitive dysfunction are indispensable for developing potentially effective intervention and management strategies.

Dual-Task Gait Analysis is a promising approach to identifying cognitive impairment. As we age, there is increased involvement of prefrontal cortical areas during motor tasks. Disturbances in gait (slower speed, increased stride-to-stride variability) while performing a secondary, attention-demanding task has been shown to be a feature distinct from healthy older adults¹.

Mobile and wearable systems enable gait assessment that is inexpensive, portable, and simple to implement. Previous work has demonstrated that an accelerometer (present in most smartphone devices) is sufficient for estimation of spatio-temporal gait parameters in healthy and clinical populations².

RESEARCH GOALS

1. Validate gait estimation approach against a gold-standard motion capture system
2. Examine predictive potential of dual-task gait analysis to infer cognitive function

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INTERFACE & FUNCTIONALITY

- The system allows for a clinician or researcher to collect and store data in individual assessments and profiles (Fig 1)
- As the user walks with the smartphone fixed to their torso, the accelerometer measures vertical movement to identify step events (Fig 2)
- Secondary task is an auditory implementation of the Go/No-Go task, in which the user responds to a positive stimuli by tapping the screen (80/20 ratio maintains bias to encourage response, even when the negative stimuli is heard)
- For each assessment, the user can choose whether to include the secondary task, and the inter-stimulus interval speed (Fig 4)
- Stop events are used to infer mean stride time (s), and standard deviation of stride time (σ). Stride time variability is expressed as the coefficient of variation:

$$CV = 100 \times \frac{\sigma}{\mu}$$




Fig. 1: Interface design of main patient menu. **Fig. 2:** Signal processing that Fourier transform & 4th order low pass filter (time of 60 Hz). **Fig. 3 (top), Fig. 4 (bottom):** Probability of stimulus presentation and weights for gait and secondary task.

METHODS

Part 1: Application performance was evaluated by comparing temporal gait parameters as measured by the smartphone compared to the Vicon Motion Capture System.

- 12 adults (18-30 yrs) were recruited
- 30 s of gait data recorded with both systems for each subject

Part 2: Predictive potential of cognitive function was evaluated by comparing dual-task gait parameters and dual-task cost (%) to a battery of cognitive assessments³

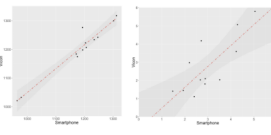
$$DT \text{ Cost } (\%) = \frac{\text{single task value} - \text{dual task value}}{\text{single task value}} \times 100$$

- 24 adults (40-60 yrs) were recruited
- Cognitive assessments:
 - I. Stroop task
 - II. Wisconsin card-sorting task
 - III. N-back task
- Gait assessments:
 - I. Single-task walking
 - II. Single-task Go/No-Go
 - III. Simultaneous execution (dual-task)

RESULTS

Part 1: Gait Parameter Validation Study

Acceptable correlation between the smartphone and Vicon system were found for mean stride time ($r = .91, p < .001$) and stride time CV ($r = .76, p < .01$).



Part 2: Gait Analysis vs. Cognitive Assessments

Dual-task cost showed moderate correlation to the Stroop task, but not to other cognitive measures.

	Stroop	Wisconsin	N-back
Age	.05	.47*	-.06
Gender	.28	.33	.46*
DT Condition			
Cadence	-.12	-.22	.11
Mean Stride Time	.19	.14	.04
Stride CV	.20	.31	.07
DT Cost (%)			
Cadence	.49*	.27	.33
Mean Stride Time	.55**	.29	.25
Stride CV	.45*	.08	-.05

Table 1: Correlation between data and cognitive assessments. Pearson's r is reported for all variables except gender (Cohen's effect size of 1 test). * p < .05, ** p < .01, *** p < .001.

DISCUSSION

Question: Is gait analysis using a smartphone device a feasible approach to cognitive assessment?


Findings: In a series of independent studies, we found that a smartphone device is a suitable tool for quantitative gait analysis, and that there is a moderate correlation between dual-task cost (%) and some previously used measures of cognitive function.

Meaning: There is good potential for dual-task gait assessment as an objective and unbiased indicator of cognitive function. Intra-subject comparison (i.e., performing assessments at regular intervals, and comparing historical data) may be more suitable than population-level metrics.

Limitations: Both studies included small, relatively healthy subjects whom were not diagnosed with any neurological disorder. Further work is needed to clarify the potential usefulness of this tool in a clinical population.

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Multimedia Appendix 1

Poster.

[\[PDF File \(Adobe PDF File\), 1MB-Multimedia Appendix 1\]](#)

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