# The Gait Real-Time Analysis Interactive Lab is a safe and feasible test setting to investigate the automaticity of gait

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**ABSTRACT**

*Purpose:* The purpose of this study was to determine a safe and feasible test setting to evaluate the automaticity of gait in healthy elderly. *Methods:* Seven healthy elderly participated and three different randomly ordered gait modes, with and without the performance of an auditory Stroop test, were assessed. *Conclusion:* This study revealed that the Gait Real-Time Analysis Interactive Lab is a safe and feasible test setting to determine the automaticity of gait. In addition, the present research has implications with regard to a feasible test setting to evaluate the automaticity of gait in people with a compromised mobility function.

**Keywords**

Rehabilitation, Stroke, GRAIL, Functional electrical stimulation, Automaticity of gait.

**INTRODUCTION**

In the Netherlands, yearly, 18.000 people who have had a stroke suffer from a contralesional ‘drop foot’ [1]. In general, the term ‘drop foot’ has come to be used to refer to the inability to dorsiflex the ankle, due to dorsiflexion weakness/ paresis, spasticity of the ankle plantarflexors, and/ or contraction of the muscles. These problems provides an insufficient toe clearance during walking, which places them at a higher risk of falling or tripping [2,3].

The consequences of a ‘drop foot’, are generally treated with an ankle- foot orthosis (AFO). The AFO puts the ankle in a 90 degrees angle to avoid tripping or falling. However, depending upon their stiffness, most AFOs cause limitations during other activities than walking. The AFO may therefore be experienced as practically and cosmetically unappealing, which sometimes leads to rejection by patients [4]. For that reason, implanted functional electrical stimulation (FES) of the common peroneal nerve has been introduced as an alternative treatment [5]. Throughout this thesis, FES is used to refer to a system that activates the paretic muscles and therefore leads to dorsiflexion of the ankle. Although FES appears to have mechanical advantages, these mechanical benefits are not associated with an improved participation and satisfaction. Thus, there still seems to be a mismatch between objective and subjective effects of FES in patients.

The mismatch between objective and subjective findings might, firstly, arise from the test setting in which gait was assessed. In previous research, quality of gait was tested in simple, single task environments. During daily life stroke patients encounter more difficult situations as they walk on more uneven terrain, face balance perturbations and interact with their environment. Secondly, previous studies did not investigate if cognitive effort is a possible measure that represents the functional improvements of FES. In more detail, stroke patients have to compensate for the loss of automaticity and, therefore, illustrate a heightened prefrontal cortex activity while walking. This heightened activity reflect an increased cognitive demand, which leads to the inability to perform cognitive and motor functions simultaneously [2,6,7]. For that reason, it is important to investigate if FES is an intervention that make patients walk more easily and, therefore, reduce the cognitive demand while walking.

This study, therefore, assessed the automaticity of gait in a complex walking environment, by using a Gait Real- Time Analysis Interactive Lab (GRAIL). The GRAIL seems to be a feasible test setting to simulate complex situations from daily life, because it consists of a (1) virtual reality, projected on a 180° semi-cylindrical screen, (2) a self- paced treadmill which enables the participants to walk on their comfort walking speed and (3) the self- paced treadmill can simulate mechanical perturbations as a consequence of lateral translations.

However, before patients with stroke are tested extensively in such a setting it is of upmost importance to test whether the automaticity of gait is safe and feasible. To test this, first a group of healthy age matched controls need to be evaluated. If these healthy elderly can perform the task safely, it is suggested that stroke patients can be tested as well. Also, the scores of the healthy controls can be used as reference values for the people with stroke, to interpret meaningfulness of functional improvements. Therefore, this paper will focus on whether the test setting is safe and feasible to evaluate the automaticity of gait in healthy elderly. In addition, the study will assess how the automaticity of gait is characterized in healthy elderly. To answer this



*SRC 2016*, November 30, 2016, The Netherlands.

question, the study will investigate (1) the performance of healthy elderly on a cognitive dual- task during various gait tasks, (2) the performance of healthy elderly in gait assessments, (3) how healthy elderly perceive automaticity, and (4) if there is a correlation between objective and subjective automaticity. A hallmark of the mobility function of healthy people is automaticity, which is the ability to successfully coordinate movements with minimal use of attention-demanding executive control resources [6]. It is, therefore, reasonable to expect that healthy elderly are able to perform cognitive and motor tasks simultaneously. Moreover, it is hypothesized that the performance under complex environmental conditions will be reduced in comparison to normal walking tasks, because it requires a higher amount of executive resources.

## METHODS

### Participants

Seven healthy adults between the ages of 45 and 70 year participated in the experiment. The project was conformed with the standards of the Declaration of Helsinki and with local ethical guidelines. To be included in this study, participants had to be able to (1) walk independently for 10 minutes without walking aids and (2) to walk on a treadmill without handrail support. Participants provided a written informed consent.

### Study design

The participants performed three different gait modes on the GRAIL: (1) a normal walking task, (2) a mechanical perturbation task, and (3) a visual manipulation task. These gait modes were performed under two conditions: (I) with a cognitive dual- task and (II) without a cognitive dual- task. Thus, all the participants performed a total of 6, randomized, trials on the GRAIL, three with and three without the performance of a cognitive task. In addition, the participants were asked to perform the cognitive task while seated to measure the baseline performance. Furthermore, after the performance of a dual- task the participants were asked to complete a questionnaire about the walking task, about the auditory task and about task preference.

### Normal walking task

During the normal walking task participants walked on the self-paced treadmill, while at least 150 strides were recorded after a familiarization period of 1 minute.

### Mechanical Perturbation task

Participants performed a mechanical perturbation task on the self- paced treadmill to determine their gait stability. During the test, at least 20 mechanically perturbations in the medial and lateral direction were recorded after a familiarization period of 1 minute. Each perturbation appeared during randomly selected stance phases and was followed by at least 7 steps of unperturbed walking.

### Visual manipulation task

During the visual manipulation task visual stepping stones were projected on the self- paced treadmill while participants were walking. In this task, the participant performed continuous adaptations in step width and step length, due to anteroposterior as well as mediolateral manipulations of the distances between the consecutive stepping stones. These manipulations, were proportional to the participant’s own step width and step length. During the task, at least 150 strides were recorded after a familiarization period of 1 minute and, therefore, data of 300 step adjustments were collected.

### Cognitive task: Auditory Stroop task

The cognitive task consists of an auditory Stroop task, in which the participants had to listen to the words “low” or “high” spoken at a low or high frequency, presented through headphones (Sennheiser, Wedemark, Germany) with an inter stimulus- interval of 1.5 seconds. Participants were instructed to report the pitch of the stimulus out loud as fast as possible. For instance, the word “low” was presented at a low (congruent, correct response is ‘low’) or a high pitch (incongruent, correct response is ‘high’). Responses of the subjects (recorded by the microphone attached to the headphone) and the Stroop stimulus were recorded with an official voice recorder at a sample frequency of 44100 Hz. Moreover, accuracy of the verbal responses were registered during the experiment by an online observer and recorded by the voice recorder for offline assessment. Before the start of the measurement participants were allowed to practice the Stroop test. This was followed by a series of Stroop stimuli while seated to measure the single- Stroop task performance. In addition, all the participants accomplish the Auditory Stroop test, while performing the three different gait modes.

### Statistical analysis

The effect of the addition of a cognitive task on the gait mode performances were analysed using a 3x2 (gait modes x single/dual) repeated measures (RM-) ANOVA. Similarly, the different Stroop task performances between the tasks were tested in a 4x3 (modes x auditory Stroop task) RM- ANOVA. To evaluate the effect of the gait modes on the subjective automaticity a 1x3 (questionnaires x gait modes) Friedman’s ANOVA by ranks was conducted for the questionnaire about walking and about the auditory task. However, to evaluate the effect of gait mode on the questionnaire about task preference a 1x3 (questionnaire x gait modes) RM- ANOVA was performed. Moreover, the associations between the subjective outcomes of the questionnaires and the objective cognitive performance in response time and accuracy, either for the objective motor performance were calculated with Pearson (in case of scale variables) and Spearman (in case of ordinal variables) correlation coefficients.

## RESULTS

A total of seven people (4 female, 3 male; M = 55, SD = 8.7) were recruited in the study. The subjects (n = 7), participated in all the assessments and were able to complete the tasks. The data of one person was not eligible for analysis, due to problems with the Auditory Stroop task recordings. Therefore, six subjects were used for statistical analyses and five sets of analyses were conducted.

### Gait performance

The average time spent walking on the self-paced treadmill during a single walking task (M = 148 seconds, SD = 8.65) was lower, than during the mechanical perturbation single task (M = 155 seconds, SD = 13.2) and visual manipulation single task (M = 152, SD = 11.5). The time to complete the trial during a dual- walking task (M = 148, SD = 9.16) was also lower, than during the mechanical perturbation dual-task (M = 160, SD = 10.2) and visual manipulation dual- task (M = 161, SD = 18.2). The results revealed no significant effect for gait mode and single- dual-task performance, neither an interaction effect between gait mode and single- dual- task performance ($F(1, 2) = 3.22$, $p > 0.05$; $F(2, 1) = 1.73$, $p > 0.05$; $F(2) = .74$, $p > 0.05$, respectively).

### Stroop task performance in reaction time and accuracy

Although, no main effect was found regarding Stroop test performance in reaction time ($F(3, 15) = 2.75$, $p > 0.05$, $\eta p^2 = .36$), results revealed a significant main effect regarding Stroop test performance in accuracy ($F(3, 15) = 6.51$, $p < 0.05$, $\eta p^2 = .57$). Post- hoc analyses using pairwise comparisons for the main effect revealed that accuracy was significantly better during the seated, normal walking and mechanical perturbation task as compared with the accuracy during the visual- manipulation task (mean difference = 8.1, $p < 0.05$; mean difference = 8.4, $p < 0.05$; mean difference = 8.2, $p < 0.05$, respectively). The mean differences in accuracy between the seated, normal walking and mechanical perturbation task were quite small (*all* mean differences < .003) and statistically not significant.

### Subjective automaticity: Walking and auditory task

The answers on the questionnaire about the automaticity of walking did not significantly change over the different gait modes $X^2(3) = 4.67$, $p > 0.05$. In contrast, results for the answers on the questionnaire about the auditory task revealed a significant change over the three gait modes $X^2(3) = 7.91$, $p < 0.05$. A Wilcoxon Signed- ranks test was used to follow up this finding. It appeared that the answers on the auditory questionnaire did significantly change from the normal walking task (Mdn = 4.50) in comparison to the visual manipulation task (Mdn = 2.25), $Z = -2.23$, $p < 0.05$.

### Questionnaire about task preference

Participants focused more on the auditory task during the normal walking task (M = 83.6, SD = 21.4) than during the visual manipulation task (M = 55.0, SD = 28.9), but less than during the mechanical perturbation task (M = 90.0, SD = 19.1). Mauchly's test indicated that the assumption of sphericity had been violated ($X^2(2) = 8.59$, $p < 0.05$), therefore degrees of freedom were corrected using Greenhouse- Geisser estimates of sphericity ($\varepsilon = .55$). Main effects of subjective task preference during the different gait modes, $F(1.10, 6.59) = 6.31$, $p < 0.05$, $\eta p^2 = .51$ were found. Post hoc analysis using pairwise comparisons indicated that participants focused more on the auditory task during the mechanical perturbation task in comparison to the visual manipulation task (mean difference = 35.0, $p < 0.05$), but task preference did not significantly differ between the visual manipulation and normal walking task (mean difference = 28.6, $p > 0.05$).

### Correlations

A correlation analysis showed that the time to complete the trial for the normal walking task, the mechanical perturbation task and visual manipulation task were not significantly correlated with the Stroop test performance in reaction time and accuracy (*all*, $p > 0.05$).

Besides, the subjective automaticity of walking and the auditory task were not significantly correlated with the Stroop test performance in reaction time and accuracy (*all*, $p > 0.05$).

## DISCUSSION AND CONCLUSIONS

The study had two different main aims: (1) To determine a safe and feasible test setting to evaluate the automaticity of gait, and (2) to assess how the automaticity of gait is characterized in healthy elderly. The results of the study showed that all the participants were able to complete the trails without tripping or falling. The main finding was that, the simultaneous performance of a visual manipulation and cognitive task was most difficult with respect to Stroop test performance in accuracy. Although, similar results were found subjectively, no significant correlation was found between subjective dual-task automaticity and objective dual- task performance. In addition, no significant interaction between objective dual-task performance and objective walking automaticity was found, because the motor performance did not significantly change over the different gait modes.

### Safety and feasibility of the test setting

Although previous studies already investigated the safety and feasibility of using visual stepping stones and mechanical perturbations, no study ever determined it in one protocol [8,9]. This study revealed that it is safe and feasible to use both, visual manipulation and mechanical perturbation tasks, in one protocol. This is because all subjects were able to complete the trials and no trips or falls occurred. The protocol is, therefore, an appropriate test setting to evaluate the automaticity of gait in healthy elderly.

**The automaticity of gait in healthy elderly**

The second goal of this study was to determine how the automaticity of gait is characterized in healthy elderly. To answer this question, sub-questions were formulated. First of all, the cognitive and motor performances of healthy elderly were measured during a normal walking, mechanical perturbation and visual manipulation dual- task. Our results confirm the hypothesis that healthy elderly are able to perform motor and cognitive tasks simultaneously. Interestingly, results revealed that healthy elderly performed better on the auditory Stroop test in response time and accuracy during a normal walking task in comparison to a complex gait task, such as the visual manipulation task. This finding agrees with that in previous studies indicating that the control of walking is a balance between, automatic and executive control processes, that depends upon the complexity of the walking task being performed [6,10]. Because demands increase with the complexity of the task, the visual manipulation task requires substantial effort and interfere with the other controlled processing task: The auditory Stroop task. This results in a competition for executive resources and may result in performance decrements for walking and concurrent tasks. However, the results in this study only revealed performance decrements for the cognitive task and no performance decrements for the walking task with the addition of a cognitive task. Therefore, no significant correlation between the objective gait and cognitive performances is observed. This can be explained by the findings revealed from our third sub- question: How healthy elderly perceive automaticity. In that, during the visual manipulation task participants explained that they focused more on the motor task (i.e. 50%) with regard to the normal walking task (i.e. 15%). The attentional shift from cognitive to motor, prevents performance decrements on the walking task, but exceeds the available supply for executive control resources, which results in performance decrements on the cognitive task. Similarly, healthy elderly answered the questions about the automaticity of the cognitive task significantly lower during the visual manipulation task. Although, subjective results are the same regarding objective results, no statistically significant correlation was found between subjective dual- task automaticity and objective dual- task performance. A possible explanation for this finding is its small sample size, which have probably resulted in false negative findings. Remarkably, there was also no statistically significant performance difference between the sitting Stroop and the visual manipulation task, although mean difference was quite high. Possibly, no significant effect was found, due to the large variance in cognitive performance during the seated Stroop task. In conclusion, the GRAIL set- up is besides safe and feasible also challenging enough, to test automaticity in complex gait. The combination of complex gait tasks and cognitive performance suggests that this method is suitable for future evaluation of interventions, in for instance stroke.

## ROLE OF THE STUDENT

Elise Verhoog was an undergraduate student in Psychobiology, working under the supervision of Frank Berenpas when the research in this report was performed. The topic was proposed by the supervisor. The design of the questionnaires, the data collection, the processing of the results, as well as the formulation of the discussion and conclusions and the writings, were done by the student.

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