A COMPARISON OF TWO SIMULTANEOUS TASK PROTOCOLS FOR THE ASSESSMENT OF PARKINSON'S DISEASE

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INTRODUCTION

The application of current sensing and robotic technology to the assessment of Parkinson's disease (PD) has the potential to provide an automated way to quantify the motor differences associated with this disease. Research groups have considered a number of alternatives, including automated assessment of tremor [1], tracking [2], and drawing [3]. The goal of such systems is to objectively evaluate the effects of new medications or other neuroprotective interventions on the progress of PD in order to speed the development of new, more effective therapies.

The goal of our research is to combine automated assessment with the use of simultaneous tasks to magnify the fine motor signs of PD, thus making them easier to quantify reliably. Brown and Marsden [4] and Dalrymple-Alford *et al.* [5] theorize that decrements in performance associated with a simultaneous task for individuals with PD may be due to reduced attentional resources or deficits in the "central executive" function responsible for allocating those resources. Tasks that are performed automatically in individuals without PD may also require more attention as a result of the disease, reducing the attention available to devote to other tasks and creating deficits in performance with multiple simultaneous tasks.

Our previous work demonstrated that force tracking combined with a simultaneous cognitive task could be used to quantify the fine motor signs of Parkinson's disease [6]. This quantitative information was successfully used to predict an individual's score on the Unified Parkinson Disease Rating Scale, a common clinical measure of Parkinson's disease [7]. In this paper, the previous experimental protocol consisting of force tracking with an unrelated cognitive task is compared to a more functionally relevant simultaneous task protocol. In the new simultaneous task protocol, the individual being tested must try to follow a particular path with the hand while maintaining his or grip force force within certain bounds. This protocol simulates the functional task of moving a fragile object with the goal of creating a functionally relevant quantitative assessment for PD. Variables measured with both protocols have been shown to be reliable upon retest [8]. This paper will compare the effects of simultaneous tasks on fine motor performance for these two protocols in individuals with Parkinson's disease.

METHODS

Eleven subjects with PD participated in this experiment. Data from one subject was omitted from the analysis because data for this subject was incomplete. All subjects abstained from PD medication for 12 hours before testing.

The experimental environment included two PHANTOM^{TM} 1.5 Premium HF robots (SensAble Technologies, Inc.) and two NANO-17 force/torque sensors (ATI Industrial Automation)

Figure 1: The robotic system used in this study.

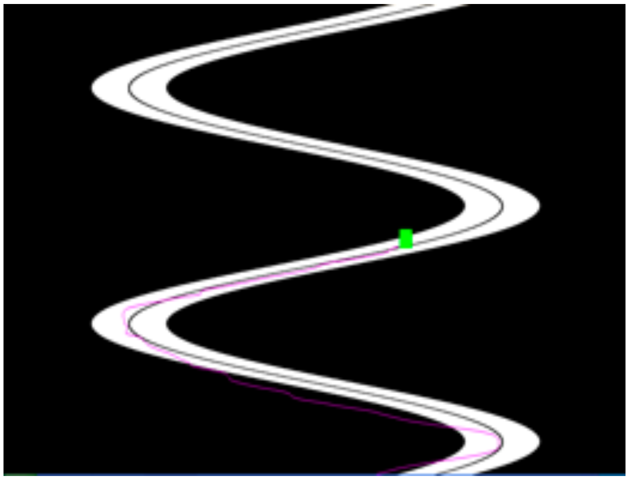

Figure 2: An example of the visual feedback given to each subject on the computer screen during the study.

(Figure 1). The experimental environment measured the position of the index finger and thumb in three dimensions as well as the force and torque exerted by these digits. Measurements were made at 100 Hz. The PHANTOM robots were also capable of exerting force feedback up to 37.5 N on the index finger and thumb of the subject.

On each trial, the subject completed first a force tracking protocol and then a position tracking protocol. During the force tracking protocol, the subject sat with the arm stationary and grasped a virtual object created using the haptic PHANTOM robots. The subject used the force exerted by the thumb and index finger on the virtual object to track a target wave shown on the computer screen. The subject performed only the tracking task for 60 s and then continued to perform the force tracking task while simultaneously counting down from 100 by 3 (simultaneous cognitive task). Force tracking with a simultaneous task continued for 30 s, and the the subject rested before beginning the position tracking protocol (described below). The force tracking protocol combines a nontypical motor task (force tracking) with an unrelated cognitive task (counting down by 3).

During the position tracking protocol, a small box on the computer screen indicated the position of the virtual object created by the haptic robots (Figure 2). The individual moved the hand left and right along the surface of the table in order to move the virtual object along a target path shown on the computer screen. The subject performed only the position tracking task for 60 s. Then the subject continued to perform the position tracking task while simultaneously maintaining the grip force on the virtual object within a specified range (simultaneous motor task). The color of the virtual object on the computer screen indicated whether or not the grip force was within the specified range. The subject performed this simultaneous task for 60 s, 30 s with a specified force range of 3 - 5 N, then 30 s with a specified force range of 3.5 - 4.5 N. The position tracking protocol combines two related and functionally relevant motor tasks, moving an object along a trajectory while maintaining an appropriate grip force.

The subject performed the protocols described above for two target waves, a sine wave and a pseudorandom wave. The subject completed trials for both target waves using both the right and left hands, resulting in a total of four trials for each individual. Before performing the trials for the right and left hands, the subject completed a practice trial to ensure that he or she understood the protocols.

The root-mean-square error (RMSE) relative to the target wave was computed for each combination of tracking task and simultaneous task condition. For the force-tracking task, a three-way repeated-measures ANOVA was conducted for the independent variables of simultaneous task condition (none or counting down from 100 by 3), hand (right or left), and wave type (sine or pseudorandom). For the position-tracking task, an analogous repeated-measures ANOVA was conducted, but the simultaneous task conditions were no grip requirement, 3-5 N force range, and 3.5-4.5 N force range.

RESULTS

For the force-tracking task, there was significant main effect of simultaneous task condition ($F(1,9) = 14.3$, $p = 0.004$). The RMSE was higher when individuals were counting down from 100 by 3 than in the absence of a simultaneous task (Figure 3). There were no other significant main effects or interactions.

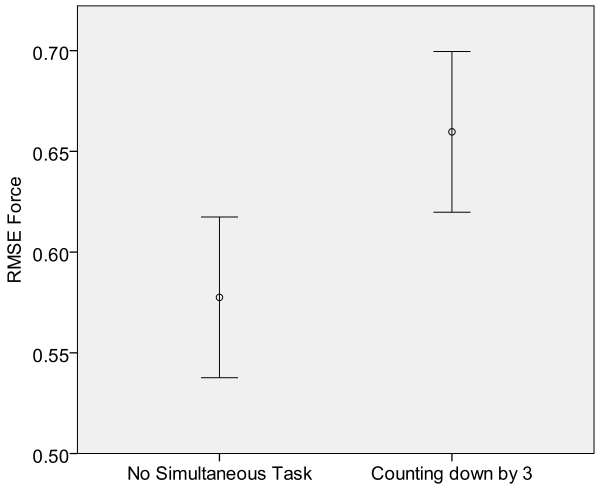

Figure 3: Results for the force tracking protocol. The RMSE was significantly larger when tracking while counting down by 3 (simultaneous cognitive task) than when tracking with no simultaneous task.

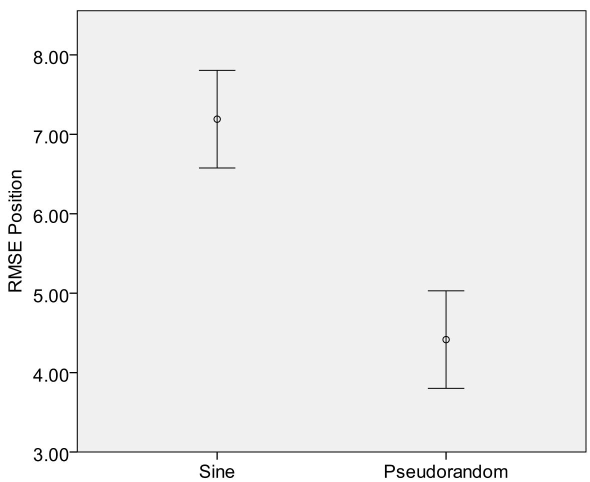

Figure 4: The results of the position tracking protocol. The RMSE for the sine target wave was significantly higher than for the pseudorandom target, but there was no significant main effect of simultaneous task condition.

For the position-tracking task, there was a significant main effect of the type of target wave ($F(1,9) = 7.97$, $p = 0.02$). There were no other significant main effects or interactions. In particular, there was no significant main effect of simultaneous task condition (Figure 4).

DISCUSSION

In this study, the force tracking protocol consists of a motor task that is not typical of daily tasks (force tracking) combined with an unrelated, cognitive task (counting down from 100 by 3). The position tracking protocol, on the other hand, incorporates two motor tasks that are more related to daily functional tasks: moving an object along a path and maintaining an appropriate grip force. The paths in this experiment were contrived, artificial targets, rather than the freely chosen paths typical of daily life. This modification of the task was made in order to objectively quantify the subject's performance. Similarly, the grip force ranges in this experiment are arbitrary, though the required grip forces used are within the range used to manipulate daily objects. Despite these constraints, the dual motor tasks required by the position tracking protocol are similar to skills used in functional tasks. In a task such as moving an egg, a grip force that holds the object without breaking it must be maintained as the object is moved along a trajectory.

This study found that performance of a simultaneous, unrelated cognitive task was associated with a deterioration in force tracking performance in individuals with PD. This result is consistent with our previous results for a group of 30 individuals with PD [6]. Our previous work compared individuals with PD to a group of age-matched control subjects. That study found that the deterioration in force tracking performance with a simultaneous cognitive task was greater for individuals with PD than for the control group. These results are congruent with those of Dalrymple-Alford *et al*. [5], whose studied individuals performing a tracking task while attempting to recall sequences of digits. For individuals with PD, performance of the simultaneous task was associated with a deterioration in tracking performance; this relationship was not observed for an age-matched control group. Brown and Marsden [4] also observed a similar effect for two cognitive tasks.

Performance of a second motor task during position tracking did not result in a deterioration in tracking performance. The only significant result for the position tracking protocol was a higher RMSE for the sine target relative to the pseudorandom target; this is likely because the sine target wave changed more quickly. Brown and Marsden [4] state that two tasks must be demanding in order to observe a decrement in performance when they are performed simultaneously. Observation of subjects in this experiment indicated that many considered the position tracking protocol to be less difficult that the force tracking protocol. Force tracking is not a task performed in daily life, while elements of the position tracking protocol are more functionally relevant. Increased familiarity with the skills required for the position tracking protocol may have made those tasks less demanding, which may be why the simultaneous tasks did not result in a deterioration in performance.

Brown and Marsden [4] also observed smaller decrements in performance with simultaneous tasks that were externally cued relative to simultaneous tasks in which the user was responsible for generating internal cues for the tasks. In this study, the force tracking task was externally cued while simultaneous counting task was internally cued. In the position tracking protocol, on the other hand, both the position tracking task and the grip force task were externally cued. This could also partially explain why no decrement in performance was observed with the simultaneous tasks in the position tracking protocol.

A final reason for the difference between the force tracking protocol and the position tracking protocol may be that the force tracking protocol utilized two unrelated tasks, one motor and one cognitive, while the position tracking protocol used two related motor tasks. The relationship between the two motor tasks may have made it easier for individuals with PD to manage both tasks simultaneously.

Future research in this area will include a further exploration of how simultaneous functional motor tasks are affected by PD. In addition, some of the task constraints used in this study could be removed in future work to enable more naturalistic, self-determined movements within the context of a similar environment. This would require the user to do more of the motor planning and cueing. This modified protocol may result in an objective, quantitative assessment with which to assess the functional effects of new therapies for PD.

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