Neuroscience Letters 674 (2018) 101–105

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Research article

Effect of auditory stimulus on executive function and execution time during cognitively demanding stepping task in patients with Parkinson's disease

Tatsunori Watanabe[a,b], Kotaro Saito[a], Kazuto Ishida[a], Shigeo Tanabe[c], Mitsuya Horiba[d,e], Shogo Itamoto[e], Yoshino Ueki[d,e], Ikuo Wada[d,e], Ippei Nojima[a,*]

[a] Department of Physical Therapy, Nagoya University Graduate School of Medicine, Nagoya, Aichi, 461-8673, Japan
[b] Japan Society for the Promotion of Science, Tokyo, Japan
[c] Faculty of Rehabilitation, Fujita Health University School of Health Sciences, Toyoake, Aichi, 470-1192 Japan
[d] Department of Rehabilitation Medicine, Nagoya City University Graduate School of Medical Sciences, Nagoya, Aichi, 467-8601, Japan
[e] Division of Rehabilitation Medicine, Nagoya City University Hospital, Nagoya, Aichi, 467-8601, Japan

ARTICLE INFO

Keywords:
Step initiation
Executive function
Parkinson's disease
Start hesitation
Auditory stimulus
Anticipatory postural adjustment

ABSTRACT

Start hesitation in patients with Parkinson's disease (PD) occurs predominantly during distractive and conflictual situations. The aim of this study was to investigate how differently an auditory stimulus (AS) influences execution function and execution time during a cognitively demanding stepping task in PD patients as compared to healthy controls. PD patients and healthy controls stepped forward in response to a visual imperative stimulus of an arrow. We applied a Simon task that comprised congruent and incongruent conditions. Direction and location of the arrow matched in the congruent condition, while they didn't in the incongruent condition. AS were randomly and simultaneously presented with the visual stimulus. An error in the direction of an anticipatory postural adjustment (APA), termed an APA error, and temporal parameters (reaction onset of APA and APA duration) were analyzed. As a result, the AS increased the APA error rate in the control group regardless of the condition, but they did not influence it in the PD group. The AS also speeded the reaction onset in both groups regardless of the condition. The APA duration was prolonged by the AS for the control group, while it was unaffected by the AS for the PD group in both conditions. These findings indicate that AS could facilitate a step initiation, conceivably by facilitating a stimulus identification process and increasing attentional control of stepping behavior, without influencing a decision-making process even in a cognitively demanding condition in patients with PD.

1. Introduction

Postural instability is a commonly observed problem in patients with Parkinson's disease (PD). It could increase incidences of falls and reduce the quality of life [19]. Step initiation that entails the transition from a quiet standing posture with bipedal support to stepping is one of everyday-life movements that remarkably increases postural instability, and has been reported to be impaired by PD [2]. When voluntarily initiating the first step to start walking, patients often encounter a sudden, short-term inability to move forward. This, so called "start hesitation," is shown to be associated with several clinical factors, including lack of automaticity and reduced executive function [20].

During step initiation, an anticipatory postural adjustment (APA) precedes lift-off of the swing foot. APAs involve a series of muscle activities that create ground reaction forces to move the center of pressure (COP) underneath the feet initially backward and toward the swing foot. These COP movements subsequently generate the force required to move the center of mass forward and toward the stance foot [13,14]. In patients with PD, the APAs are reported to be smaller in amplitude and longer in duration as compared with healthy individuals [2,11]. Furthermore, they can be absent or repeated, creating multiple APAs, especially in those with PD who display start hesitation [2,15].

One of the methods utilized and studied for facilitating step initiation in PD is an external stimulus. Effects of cutaneous, auditory, and visual stimuli have been consistently investigated to develop the effective and practical rehabilitation programs [2,5,6,16]. When a cutaneous stimulus was used as an imperative stimulus to initiate a stepping movement, APA characteristics were improved in terms of latency, force, and velocity [2]. Also, auditory and visual stimuli were reported to be effective in ameliorating the impaired APAs of patients with PD [5,6,16].

Environmental factors that frequently trigger start hesitation

* Corresponding author at: Department of Physical Therapy, Nagoya University Graduate School of Medicine, 1-1-20 Daiko-Minami, Higashi-ku, Nagoya-shi, Aichi, 461-8673 Japan.
E-mail address: nojima@met.nagoya-u.ac.jp (I. Nojima).

https://doi.org/10.1016/j.neulet.2018.03.032
Received 25 October 2017; Received in revised form 5 March 2018; Accepted 16 March 2018
Available online 17 March 2018
0304-3940/

include constraint and distraction [9]. It has been reported that an impaired ability in inhibiting unwanted responses is associated with start hesitation [25]. Neurophysiological evidence also suggests decreased responses within the brain areas that are related to executive function in patients displaying start hesitation [22]. To our knowledge, however, no studies have investigated the effects of sensory stimuli on a step initiation or APA during such conflictual conditions necessitating a response inhibition. Previous studies have shown that when it is necessary to inhibit an unrequired stepping response during a choice stepping task, incorrect weight shift, defined as an APA error, occasionally occurs [3,27,28]. During a trial with the APA error the COP initially moves toward the stance foot, generating multiple APAs that are often observed in patients with PD when start hesitation occurs [15]. Moreover, the incidence rate of APA errors becomes higher as cognitive demand increases, and auditory stimuli (AS) were further reported to impact the executive function and increase the APA error rate while reducing reaction onsets of APAs [27,28]. It is, hence, possible that AS, when used as a rehabilitation strategy for patients with PD, deteriorate the ability to inhibit inappropriate APAs, worsening the start hesitation. Accordingly, the purpose of the present study was to examine how differently an AS influences executive function and execution times of APAs when making a step response to visual stimuli that require inhibitory control in patients with PD as compared with healthy controls. In this study, we applied a Simon task, consisting of spatially congruent (arrow direction and location match) and incongruent (arrow direction and location do not match) conditions, that evaluates interference inhibition [23]. Based on a previous study showing insignificant difference in the APA error rate between patients with PD and healthy controls [3], we expected that there would not be group difference in the APA error rate in the absence of AS, although the APA error rate would be larger in the incongruent than congruent condition in both groups. More importantly, we hypothesized that AS would increase the rate of APA errors in both groups, and that the effects by AS on APA error rate would be greater for the patients with PD than the healthy controls especially in the incongruent condition requiring a strong inhibition, due to potential executive dysfunction in PD [12]. It was further hypothesized that AS would reduce the APA onset in both groups regardless of the task condition, and that an increase in the rate of APA errors that result in multiple APAs would prolong the duration of APA.

2. Materials and methods

2.1. Subjects

A total of twenty-one subjects living in the local community participated in this study: ten patients with PD (mean age ± SD = 69.9 ± 4.5; seven females; mean Hoehn and Yahr scale ± SD = 2.7 ± 0.5; mean Unified Parkinson's Disease Rating Scale (UPDRS) part III ± SD = 17.2 ± 5.9, the other clinical information is presented as Supplementary material) and eleven healthy controls (mean age ± SD = 68.8 ± 3.5; six females). Mean ages were not different between the groups ($p > 0.50$). We recruited patients with PD who were able to ambulate independently without significant tremor from Nagoya City University hospital while they were staying at the hospital for drug adjustment. Experiments were conducted after overnight withdrawal of antiparkinsonian medications to avoid the confounding effect of medication on the performance. Exclusion criteria for two groups included a history of hearing, orthopedic, musculoskeletal, cardiopulmonary, or other neurological problems that affect a stepping movement. All subjects also had normal or corrected-to-normal vision. This study was approved by Nagoya University and Nagoya City University hospital's trust ethics committee, and all subjects gave informed consent before their participation.

2.2. Protocol

The subjects stood on a force plate (Tec Gihan, Kyoto, Japan) in a balanced position with their bare feet and stepped forward in response to a visual imperative stimulus of an arrow that was displayed 1.0 m in front of them. Feet were separated 10 cm apart, which was kept consistent from trial to trial by marking each foot with tape. We also instructed the subjects not to move their weight significantly on one side before initiating a step. This was confirmed by checking the COP online. The subjects were asked to step forward as quickly and accurately as possible with the foot that corresponded to the direction of an arrow and moved back to the initial starting position after each trial to prepare for the next trial.

2.3. Visual and auditory stimuli

Each subject performed four blocks of a Simon task [23], which consisted of congruent and incongruent conditions. Direction and location of an arrow displayed on a screen matched in the congruent condition (e.g., a right-pointing arrow on the right side of a screen), while they did not in the incongruent condition (e.g., a right-pointing arrow on the left side of a screen). AS (80 dB, 1000 Hz, 300-ms long) were also presented randomly and simultaneously with the visual imperative stimulus from two speakers placed next to the screen. The stimulus intensity was chosen to be consistent with previous studies [27,28]. Each block composed of 20 trials, and the visual imperative stimuli were displayed in a pseudo-random order. A short break was placed between the blocks as necessary.

2.4. Data recording and analysis

Data of ground reaction forces from the force plate were collected at a sampling rate of 1000 Hz. The signal acquisition along with the visual stimulus and AS presentations was performed using a customized LabVIEW program (National Instruments, Austin, TX, USA).

The obtained mediolateral COP data were initially low-pass filtered at 50 Hz with a fourth-order zero phase lag Butterworth filter, and several temporal parameters were identified (Fig. 1). Reaction onset of APA was defined as the time at which the COP movement speed exceeds

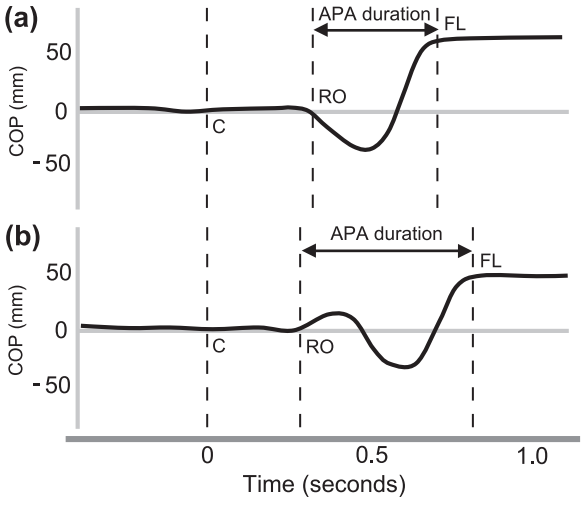

Fig. 1. Example force plate data for step execution with the right foot.
(a), a trial with a correct anticipatory postural adjustment (APA). (b), a trial with an APA error. The vertical line indicates the mediolateral center of pressure (COP) and the following temporal events were shown: C, the timing of the imperative stimulus; RO, reaction onset of an APA; FL, foot-lift time. APA duration was the time between RO and FL. The APA error was defined as the mediolateral deviation of the COP toward the stance foot that resulted in multiple APAs. This figure was modified from our previous study [28].