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STIMULUS-DRIVEN ATTENTION MODULATES THE RELEASE OF ANTICIPATORY POSTURAL ADJUSTMENTS DURING STEP INITIATION

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Abstract—*Objective:* Step initiation can be modified by environmental stimulations, suggesting the involvement of stimulus-driven attention. Therefore, we assessed the influence of attentional status during step preparation.
***Methods:* Fourteen healthy, young subjects were presented with an auditory oddball paradigm in which an infrequent "target" stimulus was presented among frequent "standard" stimuli. An imperative visual "Go" signal for step initiation was presented 1.4 s after the auditory stimulus. Both the P300 event-related potential (associated with the auditory attention task) and the trajectory of the centre of pressure (associated with step initiation) were recorded.**
***Results:* When presented before the visual "Go" signal, the auditory stimuli prompted the early release of low-amplitude anticipatory postural adjustments, not followed by step execution. They occurred twice as frequently in the "target" condition as they did in the "standard" condition. P300 component was greater after presentation of the target stimulus than after presentation of the standard stimulus.**
***Conclusion:* Stimulus-driven attention can modify the release of anticipatory postural adjustments.**
***Significance:* The cortical integration of an auditory stimulus (as evidenced by the P300 component) in a subject conditioned to initiate gait appears to release postural adjustments via two different attentional mechanisms: an "alerting effect" and an "orienting effect".**

Key words: attention, gait initiation, posture, dual-task, cueing, oddball paradigm.

INTRODUCTION

Anticipatory postural adjustment (APA): a marker of step initiation

The anticipatory postural adjustments (APAs) that occur before step initiation have a variety of roles, they notably minimize the balance disturbances associated with execution of the first step and improve execution itself: the greater the amplitude of the APA, the higher the speed at the end of the first step. The latter observation suggests that the kinematic characteristics of the first step depend on APAs, which are thought to be (at least in part) under subcortical control (Brénière and Do, 1991). The postural preparation for foot-off can be assessed by monitoring the trajectory of the centre of pressure (COP), which shows a backward shift toward the swing leg and then a lateral shift toward the stance leg (Winter et al., 1990; Delval et al., 2005). According to Takakusaki et al. (2008), step initiation is characterized by a volitional process and an emotional process. Voluntary processes are involved in willful initiation of gait, whereas locomotor behaviors associated with fight-or-flight reactions are considered to be emotional. These authors also considered on the basis of animal studies that locomotion can be an automatic process involving the brainstem structures, basal ganglia and spinal cord. However, neurophysiological studies in humans have generated strong evidence of the involvement of the cerebral cortex in motor behavior during gait initiation. For instance, it is known that the premotor cortex participates in motor preparation during a step initiation task under self-triggered conditions; a movement-related potential called Bereitschafts potential occurs prior to foot movement in healthy subjects (Vidailhet et al., 1993). It preceded the activation of the tibialis anterior muscles, which defines the start of the APAs. Indeed, the Bereitschaftspotential is thought to arise partly from the supplementary motor area (Yazawa et al., 1997). It's role was also emphasized by the results of a study in which repetitive transcranial stimulation was used to disrupt neuronal function in this brain area and thus modify the release of APAs (Jacobs et al., 2009).

Modulation of step initiation: an effect of stimulus or stimulus-driven attention?

Step initiation can be either self-triggered or modulated by the cortical integration of environmental stimuli. In a study of the influence of sensory cueing on the gait initiation process in Parkinson's disease, Burleigh-Jacobs et al.

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Abbreviations: APA, anticipatory postural adjustment; COP, centre of pressure; ERP, event-related potential; MBS, maximum backward shift; MLS, maximum lateral shift; RT, reaction time; T_0, beginning of the COP's backward displacement.

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(1997) concluded that the modification of attention by a sensory stimulus might be responsible for changes in step preparation and execution. In the latter case, an attentional mechanism has to select the sensory information that is relevant to the specific goal (step initiation, in this case). This type of adaptive behavior appears to involve a complex interaction between cortical systems that specialize in the selection of sensory information (Corbetta et al., 2008). However, it is not known whether the release of postural adjustments depends on the attention allocated to the stimulus or on the characteristics of the stimulus itself (in terms of intensity, for example). Indeed, high-intensity stimuli are associated with higher rates of APAs release via a variety of mechanisms, e.g. the startle-like response, the blink response (Kohfeld, 1969; Valls-Solé et al., 2005) or other mechanisms described in a precedent study in which an auditory pre-cue stimulus could provoke shorter and less ample APAs not followed by a step called pre-APAs (Delval et al., 2012). We assumed that attentional load could act on the release of an engaged motor program, indirectly assessable by the APAs of this motor program.

The oddball paradigm to capture attention

In the literature, a single stimulus or a pair of two-stimuli close in time was used to trigger step initiation (MacKinnon et al., 2007; Rogers et al., 2011a,b). We hypothesized that a task combining an alerting stimulus (to capture attention) and an imperative ‘‘go’’ stimulus (to trigger the motor program), clearly separated one from another clearly time separated, would enable us to specifically explore the role of attentional mechanisms in motor preparation. Here, we chose to evaluate the influence of focused attention on the release of APAs with two different stimuli for which the treatment by the subject could be consciously different. Furthermore, we monitored cortical integration of the stimulus by recording the P300 component of the event-related potential (ERP) during an oddball paradigm. The traditional, two-stimulus, oddball paradigm consists in presenting an infrequent ‘‘target’’ stimulus among a sequence of frequent ‘‘standard’’ stimuli. In oddball tasks, participants direct their attention chiefly to the designated targets, whereas standard non-targets are selectively rejected. The P300 component serves as a marker of the attention allocated to each of these stimulus categories. It occurs about 300 ms after stimulus presentation and is thought to mirror the revision of mental representations by incoming stimuli (Donchin et al., 1984). After initial sensory processing, an attention-driven comparison process evaluates the representation of the previous event in working memory. If no change in the stimulus' attribute is detected, the current mental model (or ‘‘schema’’) of the stimulus context is maintained and only sensory-evoked potentials are recorded (N1, P2 and N2). If a new stimulus is detected, attentional processes govern an updating of the stimulus representation that is concomitant with P300. The distracter- and target-elicited P300 are generated by the dorsal frontoparietal network whereas the target processing recruits a specific ventral network, both involving cortical processes (Bocquillon et al., 2011). The objective of the present study was to establish how an attention-capturing auditory stimulus might modify APA release.

We hypothesized that stimulus-driven attention could facilitate release of the step initiation motor program by means of cortical integration. A pure cortical attentional process, by modifying the perception of a stimulus (Corbetta and Shulman, 2002), could be able to trigger the release of APAs. Moreover, focusing attention (that leads to a specific cortical integration) could cause an increase in this rate of release. To this end, we primarily studied APA release and the consequences on step preparation and execution. To better control for the role of attention, the ERPs associated with auditory stimuli were recorded.

EXPERIMENTAL PROCEDURES

Subjects

Fourteen right-handed, healthy, young adult volunteers (6 males, 8 females) with a median age of 23 (1st quartile: 22; 3rd quartile: 27) participated in the study after providing their informed, written consent. None had a history of any medication use, drug abuse or disease that could have interfered with gait. The study was approved by the local independent ethics committee (reference: 2009-5656-A00821).

Experimental setting

The four tasks described below were administered in successive blocks, in the same order for all the subjects. Between each block, a break of 1 min was proposed.

Task 1: the ‘‘oddball’’ condition. In this condition, only an auditory warning cue was presented. The participant listened to a series of 100 auditory stimuli (duration: 40 ms; intensity: 80 dB) presented through headphones with a constant inter-stimulus interval (5 s). In this auditory oddball task, the participant was instructed to detect rare (probability: 0.15), high-pitched (2000 Hz) target tones that were randomly inserted into a series of frequent (probability: 0.85), low-pitched (500 Hz) standard tones by pressing a button with his/her right hand as rapidly and as accurately as possible. This oddball paradigm allowed registering the P300 component. These trials were performed to test specifically the attentional load.

Task 2: the ‘‘push’’ condition. The subjects were told to stand on a force platform in the most natural posture possible (with their feet always in the same position) and press a button held in the right hand. These 15 trials per subject were performed in order to check the effect of pressing a button on the subject's posture during quiet stance.

Task 3: the ‘‘go’’ condition. In this condition, only a visual ‘‘go’’ cue was presented. The subjects were told