Real world blink-related potentials reveal the positive impact of landmark-based navigation instructions on incidental spatial knowledge acquisition

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Introduction

The use of navigation assistance systems reduces the attentional demand for wayfinding to assure safe locomotion. This, however, reduces the processing of the surroundings leading to diminished spatial memory of the travelled environment (Münzer et a., 2006). Instead, introducing a landmark reference in auditory navigation instructions enhances landmark and route knowledge acquisition during assisted navigation (Gramann et al. 2017, Wunderlich and Gramann, 2018). Whether this way underlying brain regions could be incidentally trained needs still to be investigated.

In order to investigate the impact of landmark-based navigation instructions on incidental spatial learning and the underlying brain activity in an ecologically valid setup, we used mobile electroencephalography (EEG) allowing for free active ambulation in an uncontrolled city environment. Within such a setting, standard events like transient displays of landmarks as known from controlled laboratory experiments are no longer available. To overcome this limitation and to find sufficient numbers of events for event-related analyses of brain activity during navigation, we extracted blinks from the ongoing EEG. Blinks are natural events that represent the onset of visual information intake and thus enable the investigation of the subsequent visual information processing (Wascher et al., 2014).

Methods

Twenty-two participants navigated a predefined route through Berlin using either standard navigation instructions as used in commercial navigation assistant systems (e.g. "Now, turn left"), or landmark-based auditory navigation instructions referencing a landmark at the respective intersection and adding further landmark-related information (e.g. "Turn left at the zoo. This one also contains an aquarium.") Solely auditory navigation instructions were provided. Afterward, in a cued-recall task testing the incidentally acquired landmark and route knowledge, participants responded to presented landmark pictures according to the landmark's presence and associated route direction in the previously navigated route.

Brain activity was collected during the entire experiment using 65 electrodes (eego sports, ANT Neuro, Netherlands). The EEG was decomposed using independent component analysis (ICA, Makeig et al., 1996). Independent components (ICs) representing vertical eye movement were used to identify blinks and a combination of vertical and horizontal eye movement ICs were jointly used for saccade detection. Gait related ICs were selected to create events for every step. EEG data was further cleaned using IClabel (Pion-Tonachini et al., 2019) and only components classified at least 30% as brain source were kept for back projecting to the channel level. Using the unfold toolbox (Ehinger & Dimigen, 2019), blink-, saccade-, and gait-related EEG activity were deconvolved. The impact of auditory navigation instructions was then investigated in blink-related brain activity (bERPs) at the central midline electrodes.

Results

Replicating previous studies, performance in the spatial tasks indicated that participants using landmark-based instructions incidentally learned more environmental features compared to participants using standard instructions (Figure 1).

Deconvolved bERPs revealed significantly increased fronto-central activity during the presentation of landmark-based compared to standard navigation instructions (Figure 2).

Discussion

Landmark-based, auditory navigation instructions lead to increased spatial knowledge acquisition for augmented landmarks. Mobile EEG during real-world navigation allowed for dissociating eye movement-, and gait- from brain-related EEG activity. Clear blink-related potentials can be extracted from the EEG recorded from pedestrians who are actively navigating in an uncontrolled real environment without additional eye movement recordings.

bERPs at FCz support increased involvement of higher cognitive processes in alignment with more acquired spatial knowledge when using landmark-based navigation instructions. Increased activity in the superior frontal gyrus was previously linked to spatial working memory processing (Boisgueheneuc et al.,2006).

Conclusions

Landmark information in auditory navigation instructions is a promising approach to incidentally engage users with the environment and to foster spatial information processing. Unfolded bERPs support this and allow for investigating visual information processing during unrestricted movement in real-world.

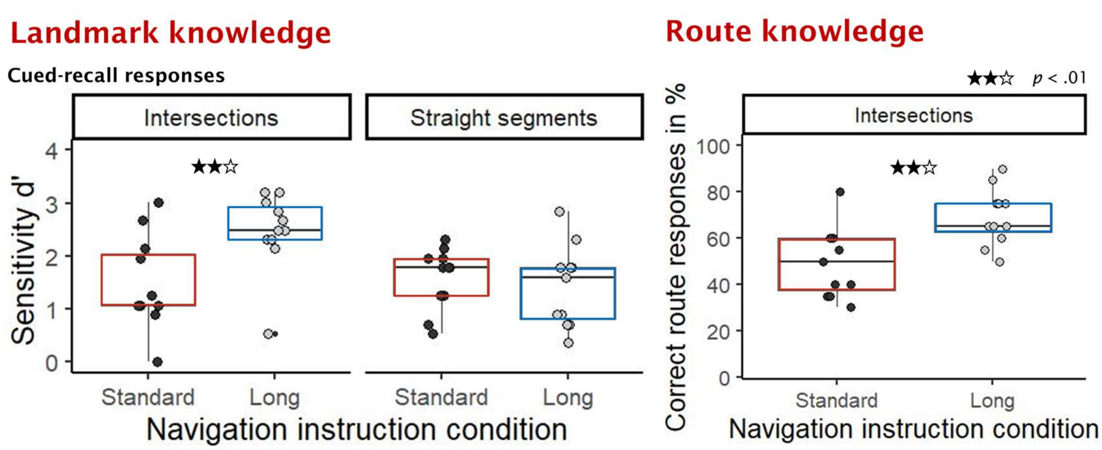

Figure 1. Incidentally acquired landmark and route knowledge tested in a cued-recall task and comparing navigation instruction conditions.

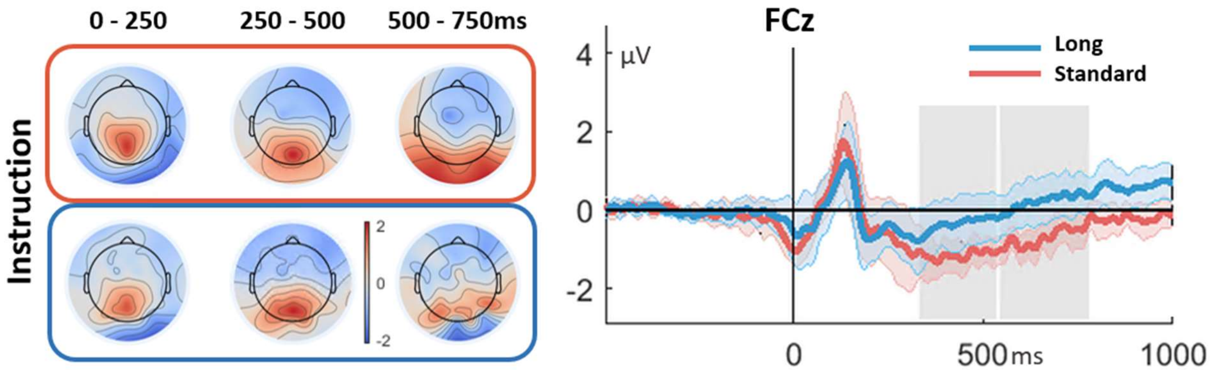

Figure 2. Blink-related potentials during the presentation of navigation instructions using the activity distribution over the scalp in three time windows following the blink (left) and the time-course of the bERP with grey areas representing significant differences between navigation instruction conditions (right).

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