Summary

I selected three short abstracts from my research group on recent research. We rely extensively on eye tracking and EEG in our research and are interested in information processing, particularly during closed-loop steering tasks such as driving.

Christiane Glatz investigates how an auditory notification causes the brain to respond to an upcoming visual target, earlier than if there was no notification, as well as how some sounds result in larger brain responses.

Menja Scheer researches how perceived task-irrelevance in the auditory modality could give rise to inattentional deafness. She isolates this to the late P3a component that is implicated in working memory updating.

Nina Flad works on simultaneous EEG and eye tracking, the motivation being to evaluate: (a) the visual information that was fixated, and (b) the brain response that this fixated information elicits. In her abstract, she describes how this is non-trivial because the brain can respond to visual information even before it is fixated. A better understanding of peripheral information processing is necessary to achieve meaningful simultaneous eye tracking and EEG.

These work represents my interest in understanding how we manage overt and covert attention, especially in environments that require us to monitor more than one source of information. The goal with respect to HCI is to design notification environments that are sensitive to our limitations in information monitoring across multiple channels, such as:

(a) the lower limit of information sampling in terms of number of sources
(b) when is an information channel perceived as being task-irrelevant (when it is not)
(c) what are the factors that induce active and passive fatigue in information monitoring

WHY DO AUDITORY WARNINGS DURING STEERING ALLOW FOR FASTER VISUAL TARGET RECOGNITION?

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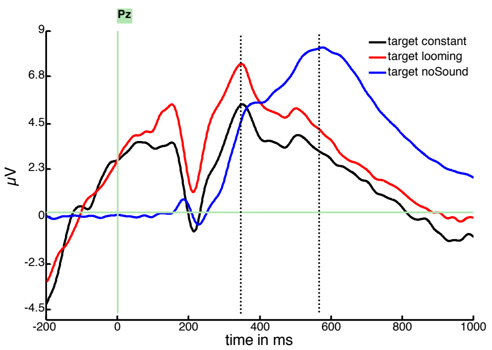
Introduction & Aim: Auditory cues are often used to capture and direct attention, away from an ongoing task to a critical situation. In the context of driving, previous research have shown that looming sounds, which convey time-to-contact information in their rising intensity profiles, promote faster braking times to potential front collisions[1]. The current experiment investigates the role of auditory warnings in facilitating the identification of visual objects in the visual periphery during steering. This approximates the use of auditory warnings for cueing possible candidates for side-collisions. We expected faster response times for visual targets cued by a looming sound compared to a constant sound. Electroencephalography (EEG) was recorded to determine whether faster response times were due to either earlier or stronger neural responses to the visual target. We hypothesize: 1) earlier event-related-potentials (ERPs) for cued compared to not-cued visual targets, and 2) larger amplitudes for visual targets that were cued by looming versus constant sounds.

Methods: While performing a primary steering task, participants (N=20) had to identify visual stimuli (i.e., Gabors patches) presented in the periphery and to discriminate them for their tilt-orientation. In 50% of the trials, visual stimuli were preceded by a 400Hz sound with either constant or looming profiles. The looming sounds' intensity profile increased exponentially over time, while the intensity profile for the constant sound did not change across the 500ms.



Results: Our results show that participants responded faster to cued targets than to trials without a warning [t(19) = -9.054, p<.000]. The maximum peaks in the ERPs to visual targets were earlier for those that were cued with an auditory warning (black and red curve) compared to those without warning cues (blue curve). Next, looming warnings resulted in faster visual discrimination than constant sounds [F(1,19) = 6.934, p = .016]. The maximum peaks of ERPs to cued visual targets were larger for those that were cued by looming sounds compared to those that were cued by constant sounds. Looming sounds result in a larger ERP at 350ms than constant sounds.

Discussion & Conclusion: The maximal ERP peak that we report is likely to be the P3 component that is related to visual object recognition performance. This response occurs later in the absence of a warning cue. Looming auditory warnings might have induced a larger P3 component to visual targets, relative to constant warnings, by being more effective attentional cues. Our EEG data corresponds to behavioral benefit of looming auditory cues observed in faster reaction times. Interestingly, warning signals can prepare the brain to respond earlier to visual events, even with a predictability of only 50%. These findings can directly be applied to the design of auditory warnings where fast but also accurate reaction times are preferable.

References

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ATTENDING TO THE AUDITORY SCENE IMPROVES SITUATIONAL AWARENESS

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Aim: Early studies suggest that auditory stimuli are only (cognitively) processed if they are relevant for the task at hand [1]. However, more recent studies show that this is not necessarily true. Rather it depends on the nature of the auditory stimuli. Environmental sounds are processed even when they are irrelevant for the task and even when participants are engaged in demanding visual tasks [2]. These latter results can be interpreted within the framework of situational awareness. In order to maintain situational awareness it is essential to continuously scan the environment for unexpected sounds that might not be of immediate task relevance but could inform us about important changes in the environment. In the current study, we investigate whether and how the scanning for, and processing of, environmental sounds—in other words, situational awareness of the auditory scene—is influenced by auditory attention manipulations. Here, auditory attention was manipulated by requiring participants to perform an auditory oddball-detection task or not, while task-irrelevant environmental sounds were occasionally presented in the background. The current study answers the following questions: 1) Is the processing of environmental sounds influenced by manipulations of auditory attention or is it an automatic process? 2) Is the processing of irrelevant environmental sounds attenuated or enhanced by auditory attention? On the one hand, the processing of the irrelevant environmental sounds could be attenuated, because the additional task increases the demand for auditory attentional resources [2]. On the other hand, the processing of the environmental sounds could be enhanced because more attention is directed towards the auditory channel, in order to optimize performance in the auditory oddball-detection task.

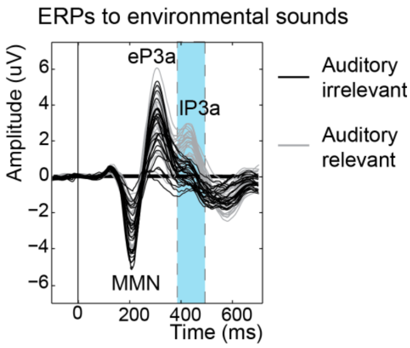

Figure 1: Grand average waveform of the ERPs to the environmental sound for the condition when auditory attention was directed towards sounds (grey) or not (black). Each line represents the electrical potential at one electrode.

Methods: Two groups of participants (N=48) were involved in a manual steering task, while being probed with environmental sounds as well as beep-tones. The first group of participants was instructed to only perform a steering task ('auditory irrelevant'). The second group was instructed to additionally perform an oddball-detection task by detecting the oddball beep-tones ('auditory relevant). The environmental sounds were task-irrelevant for both groups of participants. The event-related potentials (ERPs) to the environmental sounds are illustrated in Figure 1.

Results: We found that the ERPs to the irrelevant environmental sounds were selectively enhanced when the auditory channel was task relevant. This was, however, specific to one component of the ERP, the IP3a (blue in Fig. 1). No influence of our manipulation on the other measured ERP components, MMN and eP3a, was observed.

Conclusion: We found that task relevance in the auditory channel, influences the processing of environmental sounds. Therefore we conclude that this process is not fully automatic but depends whether or not the auditory channel is task relevant. Directing attention towards the auditory scene let to an enhanced processing of the environmental sounds. Thus, situational awareness towards environmental sounds can be improved by adding an additional task in the auditory domain to direct the attention towards the auditory scene. Surprisingly, this improvement does not concern early processes, like the detection of the unexpected event (reflected in MMN). Thus, our results show that directing the attention towards the auditory scene does not improve the detection and orienting to irrelevant environmental sounds per se, but specifically improves the later processing step of extracting the meaning of the environmental sound, that is reflected by the IP3a [3].

References:

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3. **Escera C, Corral M.** The distraction potential (DP), an electrophysiological tracer of involuntary attention control and its dysfunction. *The Cognitive Neuroscience of Individual Differences.* 2003; 63-76.

WHEN DOES THE BRAIN RESPOND TO INFORMATION DURING VISUAL SCANNING?

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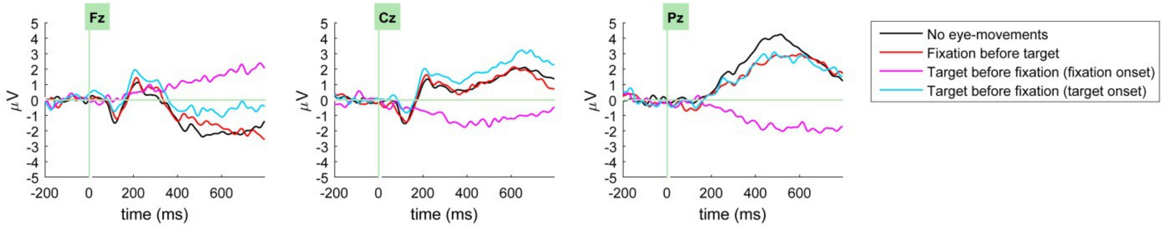
Aims: High stress work environments such as a flight deck (or surveillance systems) present operators with multiple instruments that have to be constantly monitored with eye-movements. Eye-tracking allows us to infer when an operator's overt attention has been assigned to an instrument, namely when fixation begins. However, the brain could already be processing information prior to its fixation. When does the brain respond to information when the operator is free to scan the environment freely? Is it the emergence of a target stimulus? Or rather the fixation on a target stimulus?

Methods: In our study, participants were required to continuously monitor four regions-of-interest (ROIs) that presented 3-letter-strings and to respond with a key-press to the appearance of a target string. This is comparable to tasks such as instrument monitoring. Allowing for self-paced visual scanning gave rise to two different conditions in our study. These two conditions differ with respect to the sequence of target appearance and target fixation: 1) There was a fixation on the target position before the target appeared. 2) The target appeared before there was a fixation on the target. In the latter condition, the event evoking a change in the EEG signal could either be the target onset or the fixation onset (i.e., start of target fixation). All ERPs from the naturalistic visual scanning scenario were compared to the ERP of a baseline condition that only had one ROI and prohibited eye-movements.

Results: Our results show that ERPs that were epoched to the target onset were similar, regardless of eye-movements (black, red, blue lines). In contrast, the ERP that was epoched to the fixation onset was atypical (pink line).



Conclusion: It is commonly assumed that a visual stimulus is processed when it is fixated. However, we demonstrate that visual perception can take place even prior to fixation. Experimental studies have shown how far peripheral vision is sufficient for recognizing animals in complex scenes[1]. Here, we show that target onsets gave rise to brain responses even before the targets were fixated. This poses a challenge for the use of EEG/ERP in visual scanning environments. If fixation onset is not necessarily the onset of perception, they cannot always be used for epoching ERP data as has been the assumption of previous research[2,3] in natural scene viewing and reading. Future studies that seek to employ EEG/ERP measures in visual scanning work environments should take into account that the brain can respond to to-be-fixated information prior to fixation and to exercise caution in determining when this is.

References

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