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To blink, or not to blink, that is the question: Eye blinking as an indicator of general dynamic attention allocation

Stefan E. Huber, Markus Martini & Pierre Sachse

Department of Psychology, University of Innsbruck, Austria

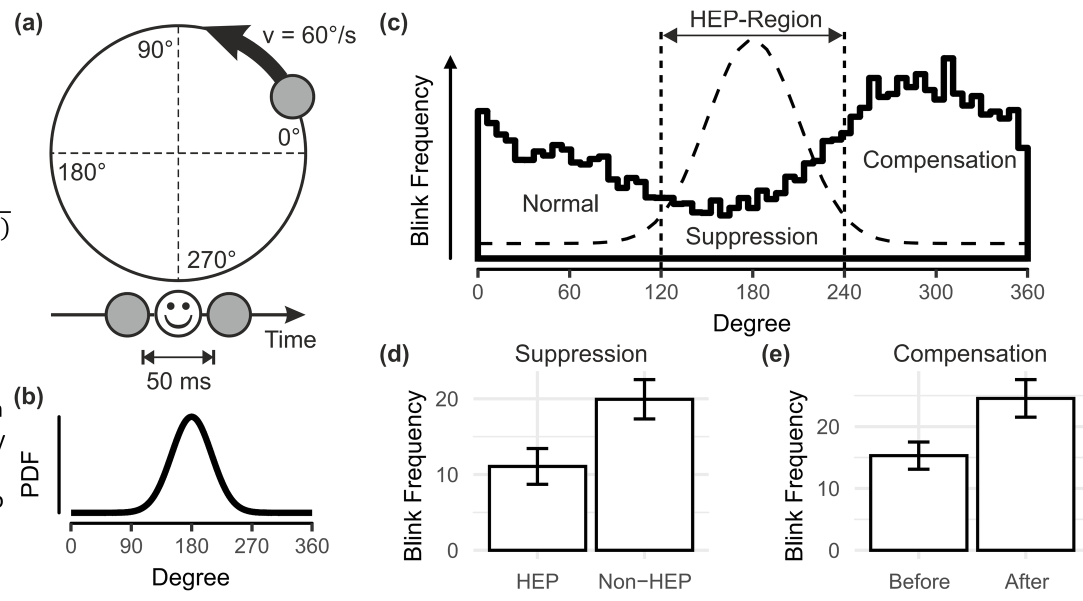
Background

We blink about 15 times per minute and many thousand times each day while being hardly ever aware of it. That this is not different in people blind from birth has been one of the longest standing arguments for the primary role of attention for eye blink regulation instead of physiological needs such as lubricating the surface of the eye (Ponder & Kennedy, 1927). In fact, to maintain a stable tear film and hence good and healthy vision, about a fifth of the number of blinks would suffice (Sweeney et al., 2013). The surplus blinks, however, do not occur at random points in time, but are strategically executed in regard of the temporal course of an activity like Hoppe et al. (2018) could demonstrate for a visual attention task (note that the image has been reconstructed from data given in Figs. 1 and 2 of the given reference and adapted for illustrative purposes):

Hoppe et al. (2018) could further show that eye blinking could be described with the following mathematical model:

$$P(\text{blink at } \theta \mid \alpha, \psi) \propto \frac{1}{(1-\alpha)c_s + \alpha c_e(\theta, \psi)}$$

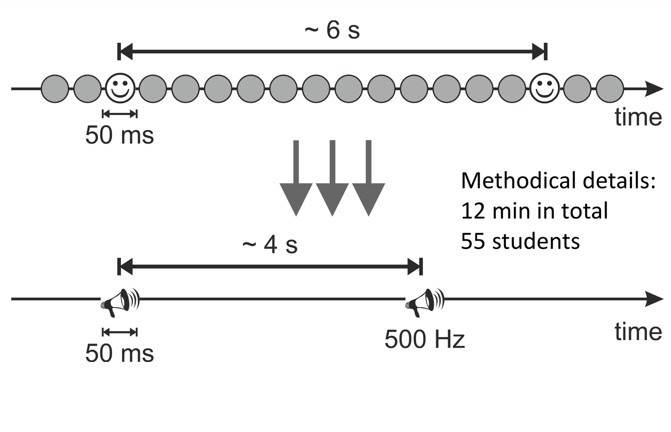
θ…time
α…weight, „importance“ of the task
ψ…parameters describing subject‘s belief about the experiment given previous observations
c_s…associated with cost for blink suppression due to physiological need to maintain healthy vision
c_e…cost for blink execution, i.e. probability to miss an event

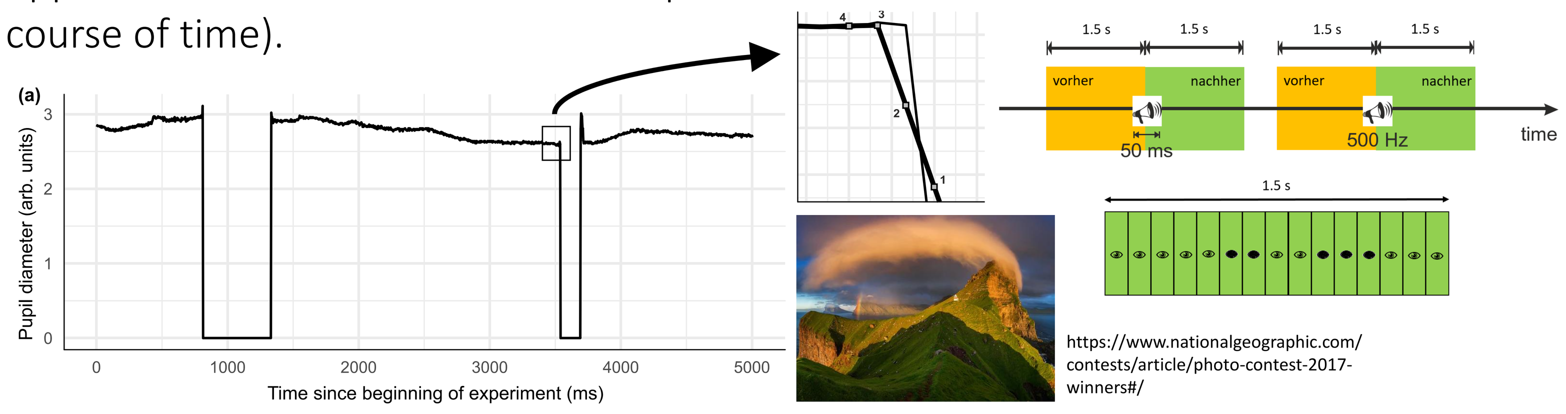


Hoppe et al. (2018) concluded that eye blinking is dynamically regulated to minimize visual information loss. Yet both from an evolutionary and a action-regulation-theoretical perspective it could argued that an association between the timing of eye blinks and temporal task structure can be expected in non-visual domains either. For instance, also acoustic stimuli can announce important visual information. Already 2012, Oh et al. had thus suggested that eye blinking is dynamically modulated by attention in a general sense on the basis of a purely auditory attention task.

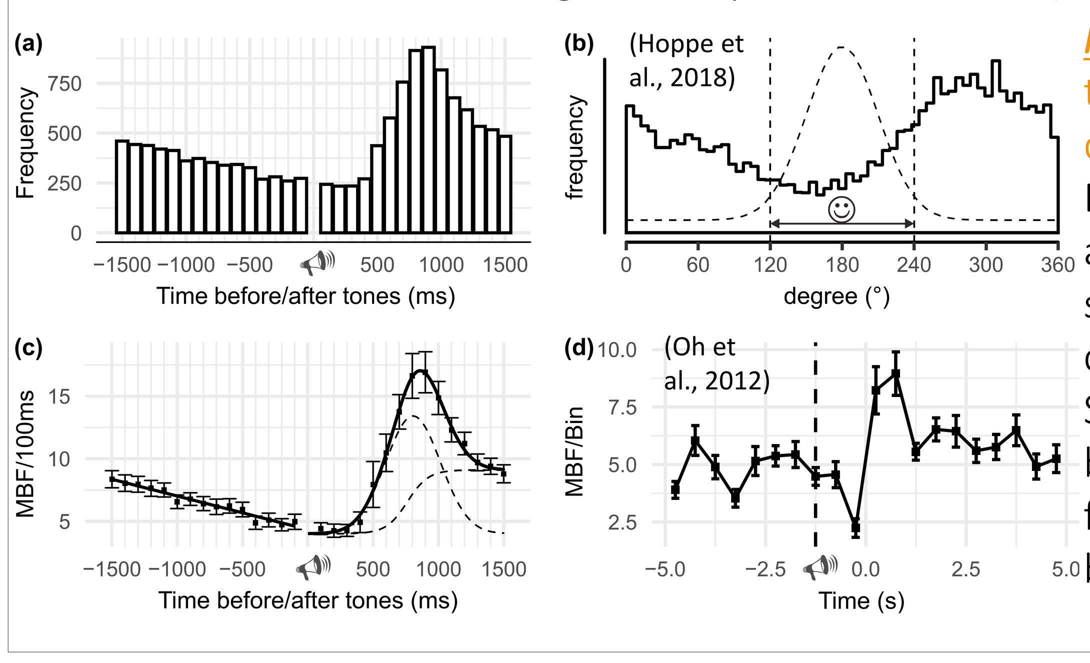
Study 1

In a first study (Huber et al., 2022; Huber, 2021), we thus attempted to replicate this result of the study of Hoppe et al. (2018) for the case of an auditory attention task. In order to do so, we transferred stimuli from the visual to the auditory domain and the representation of the task from a spatial to a temporal one (i.e. the opposite of what the clock does to represent the course of time).





For blink detection, we used the pupillometric data recorded via eye tracking and the noise-based blink detection algorithm by Hershman et al. (2018).



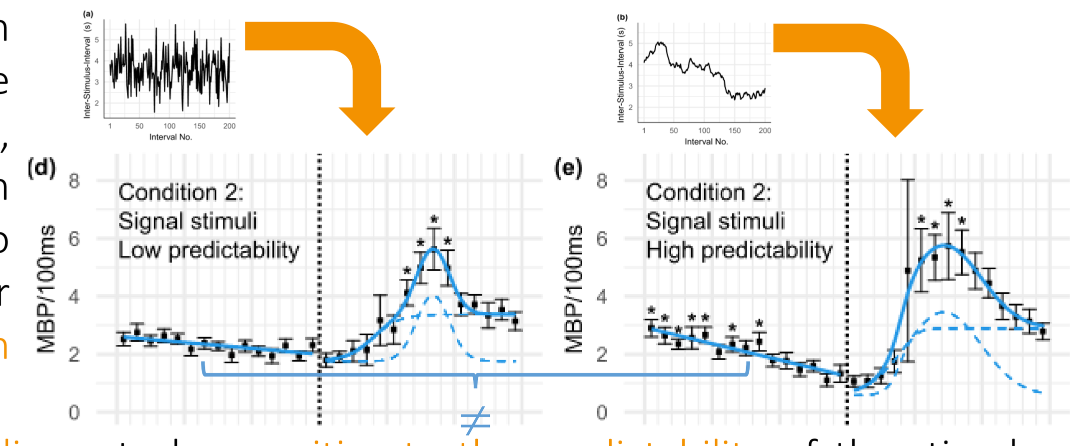
Main result: Form of strategic blinking does not require visual stimulation. Blink likeliness is reduced around the time when stimuli occur and is overcompensated afterwards. Similar result as obtained by Oh et al. (2012) but with finer resolution as provided by Hoppe et al. (2018).

Contact

Stefan E. Huber (s.huber@uibk.ac.at)

An unexpected result and a discrepancy?

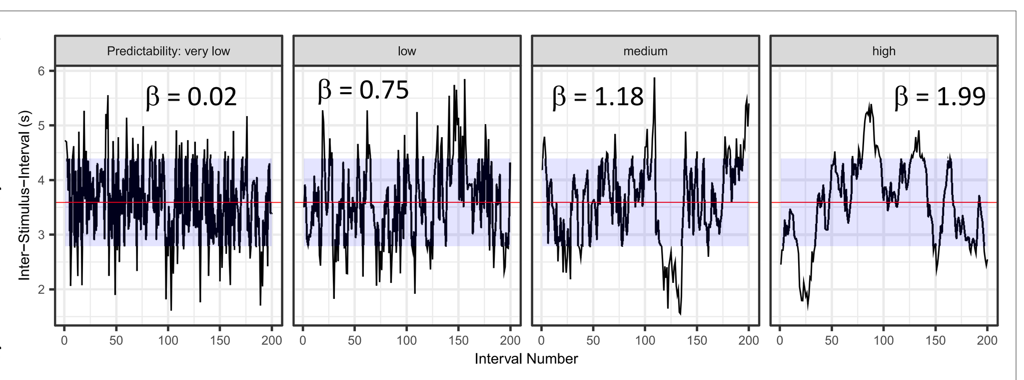
We also explored how the predictability of when acoustic stimuli would occur in time affected the temporal eye blink distributions (Huber et al., 2022). In one case the time intervals between consecutive pairs of stimuli corresponded to Gaussian noise (low predictability), in the other case they corresponded to Brownian motion (high predictability).



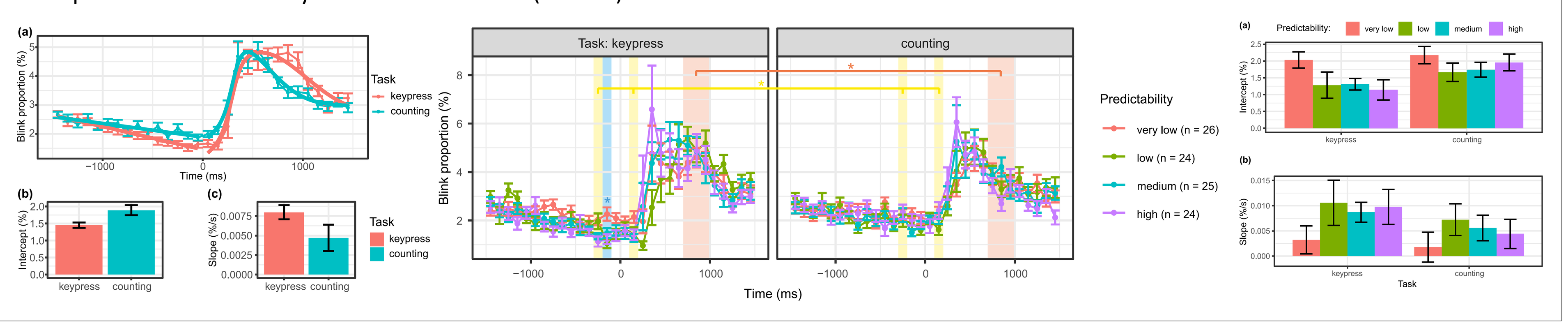
We found especially the pre-stimulus blink likeliness to be sensitive to the predictability of the stimulus series. For low predictability the likeliness decreased at a significantly lower rate towards a significantly higher value at stimulus occurrence than for high predictability. In both cases, however, slopes were significantly different from zero. This suggests that a top-down, prediction process remains involved in eye blink regulation in both cases in a purely auditory attention task. This appears to be somewhat in disagreement with a result by Brych and Händel (2020) who investigated particularly top-down and bottom-up influences on dynamic eye blink regulation in both the visual and auditory domain. In their experiments, however, only visual input induced a significant decrease in pre-stimulus blink likeliness.

Study 2

Hence, we aimed to clarify these issues in another study (Huber et al., 202?) in which we increased the signals of different predictability from 2 to 4 to get a finer resolved image of the dependence of the eye blink modulation by temporal task structure on this parameter. We also contrasted the keypress task of study 1 – like in the study of Hoppe et al. (2018) – with a second task in which participants had to silently count stimuli – like in the experiments of Brych and Händel (2022).



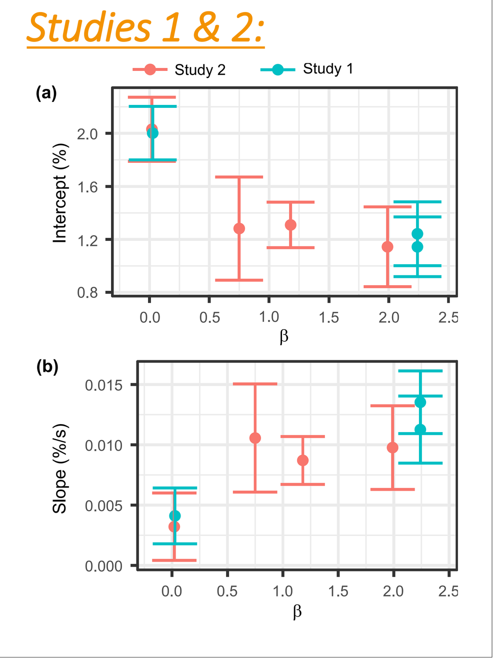
Methodical details:
99 students, randomly assigned to one of 8 groups (predictability x order)
counter-balancing of task order (keypress, then counting, or counting, then keypress)
otherwise, the same as in study 1



Conclusion

We conclude that eye blinking is affected by top-down, cognitive processing associated with prediction also in purely auditory attention tasks, but to a lesser extent than in visual attention tasks. The synchronization of eye blinking with temporal task characteristics is further modulated by the involvement of active motor responses, i.e. it is more pronounced if participants e.g. need to press a key to indicate stimulus detection than if processing of stimuli is done purely cognitively by e.g. silent counting of stimuli. Task predictability turns out to be a further, but weaker modulating factor of eye blink synchronization. Especially under highly unpredictable conditions, e.g. when inter-stimulus-intervals are distributed according to Gaussian noise, the modulation of eye blink dynamics can become so weak that it could hardly be noticed. Nevertheless, also in that case, general attentional processes and particularly prediction seem to remain underlying the dynamical regulation of eye blinking.

Studies 1 & 2:



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