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Visual occlusion as tool to assess attentional demand and spare capacity

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ABSTRACT

Visual occlusion has been used in various ways to evaluate vision related aspects of driving [1]. Senders et al. [2] did pioneering work in real traffic to assess the visual demands of different traffic environments. Occlusion has also been used to simulate glances to traffic while parked to evaluate in-car technology [3], to simulate distraction while driving on a closed course [4], and to assess the influence of a secondary task in driving situations of varying complexity in a simulator [5]. Here, we compile and discuss findings from a series of four studies in which visual occlusion was used to assess situational demand for visual information and visual spare capacity, that is, the possibility to execute an additional visual task while driving. We also discuss the strengths and weaknesses of visual occlusion as a method in this field of research.

The concept of spare capacity has been forgotten in most popular definitions of driver distraction, which typically equate glances away from traffic with distraction. Harking back to Senders et al.'s [2] work, we used visual occlusion with the ultimate aim to achieve a better understanding about the relationship between situational demand, attention and self-regulation. The key features of the four studies are listed in **Table 1**.

	Study I	Study II	Study III	Study IV
aim	assess situation-based minimum required attention	assess situation-based minimum required attention	assess utility of occlusion distance as measure of event density	assess information decay rate under irrevocable occlusion
study platform	field study with instrumented vehicle	fixed-base simulator	motion-base simulator	linear motion-base simulator
road types	motorway	motorway, rural road, urban road	intersection, suburban, motorway	motorway
occlusion	occlusion goggles	blank-out of forward	unoccluding blanked-	blank-out of screen

apparatus	operated by micro-switch on finger, allowing rudimentary peripheral vision	screen (110°) with micro-switch on finger, allowing some peripheral vision	out scene with lever behind steering wheel, no peripheral vision	
occlusion type	self-paced occlusion onset and duration, default: not occluded	self-paced onset, fixed duration closed (1.0-2.6 s, increment 0.4), default: not occluded	self-paced onset, fixed duration open (0.5 s), default: occluded	system-paced, occlusion irrevocable until crash/ run-off-road
N (valid)	25	30	97	22
reference	Kircher, Kujala & Ahlström, 2019 [6]	Liu, Ahlström, Forsman & Kircher, 2019 [7]	Kujala, Mäkelä, Kotilainen & Tokkonen, 2016 [8]	Kircher, Ahlström, Nylin & Mengist, 2018 [9]

Table 1. Key features of the four occlusion studies.

A key finding emerging from all four studies and corroborating previous research is that drivers possess visual spare capacity to varying degrees, depending on several factors, which we will look into more closely in the following. This conclusion is based on the fact that drivers could occlude their vision without ensuing incidents or collisions.

Environmental circumstances predict the likelihood of visual occlusion (Studies II, III), with features like oncoming traffic or intersections, which are associated with higher prediction uncertainty [10], leading to less frequent and shorter occlusions. In more monotonous environments like motorways, the previous occlusion history is a predictor of future occlusions. Studies I, II and III indicated interindividual differences in occlusion strategies, but this was not associated with driving experience (Study III). The results suggest that drivers are sampling information in such a way that they predict and prepare for the near future. In Study II, the likelihood to occlude was lowest upon approaching an intersection and when still closing the gap to an oncoming vehicle but increased already in the first half of an intersection, or when the oncoming vehicle was still a few metres in front of the driver (Study II). In Study IV, drivers corrected their trajectory under occlusion, based on the information sampled before the occlusion occurred. It could be shown that visual occlusion can help differentiating necessary glances to and away from the forward roadway from unnecessary glances (Study I). Necessary glances away include glances to the mirrors and across the shoulder to check the blind spot, which are not neglected when attempting to maximise occlusion time. Comparing occlusion time with occlusion distance, which also incorporates speed, it was found that less information-dense environments allow longer occlusion distances, with occlusion duration being more constant across situations, reflecting higher speeds in less complicated environments (Study III).

We found the visual occlusion method to be a flexible and relatively objective tool to assess various aspects of self-assessed situational attentional demand and spare capacity. Depending on the research question, system-paced or self-paced occlusion with either fixed or variable duration can be used. Different areas of the visual field can be occluded, for example separating peripheral and foveal vision. Compared to executing an additional task, occlusion does not require a mental focus away from driving, except when an additional task is given during the occluded period [11]. A

drawback with the occlusion method is the lack of a given benchmark. There are no concrete criteria that allow a judgement of whether the frequency and duration of occlusions were below or just at capacity, or possibly over. An incident or collision would be a clear indication that the minimum required information was not sampled, but the absence of such occurrences does not guarantee that enough information was sampled for safe driving. With an unoccluded default state, many participants in Study I reported that they had occluded below their maximum capacity, keeping a safety margin. This self-reported assessment is supported by Study IV, where collisions/run-off-roads occurred on average first after twice the time or more as the typical self-paced occlusion duration. Usually the occlusion apparatus is operated by hand or foot, which may require more mental effort than the more natural closing of the eyes. Anecdotical evidence shows, however, that the latter quickly leads to mental fatigue and would not allow the flexibility offered by external occlusion devices.

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