IMPAIRMENT TO PERIPHERAL DETECTION WHEN DRIVING. EXPERIMENTS INVESTIGATING THE EFFECT OF FOG AND THE TRANSITION BETWEEN LIT AND UNLIT SECTIONS OF ROAD

ADDENDUM: VISUAL PERFORMANCE IN THE 3-SECOND PERIOD IMMEDIATELY FOLLOWING THE TRANSITION FROM LIT TO UNLIT

Authors: **Uttley J, Fox S, Fotios S, Cheal C.**

Version 1.1

15th May 2017

1 Introduction

An experiment was conducted to investigate the change in detection performance following the transition from lit to unlit sections of road [Cheal et al 2017]. The detection target events were timed to occur semi-randomly, to reduce the risk of apparent correct responses due to chance. This meant that the interval before initiation of the first event, following the switch-off, could be anything from approximately 2 to 20 seconds. The data were then analysed in 4-minute bins.

During presentation of this work to Highways England (23/02/2017), Highways England identified a particular interest in understanding the change in detection performance in the first few seconds following a transition from a lit to an unlit section of road. We therefore carried out two further investigations to isolate detection in the immediate post-switch period:

1) A post-hoc analysis of the original data, considering only those detection events initiated within the first 3 seconds.
2) A few further trials were carried out but with the system reprogrammed to schedule the initiation of a target event within the first 3 seconds.

2 Post-Hoc Analysis Of The Original Data

In the original experiment, detection targets were initiated at semi-randomised intervals within one-minute bins and was not designed to investigate specifically any detection targets initiated within the initial few seconds post-switching On or Off (i.e. near-immediately following the transition between lit and unlit sections of road). Further analysis was carried out of those events initiated within the first 3 seconds but due to the programming used there were no initiations in the first two seconds and analysed here are those detection targets initiated at a period of 2.0 to 3.0 seconds after the switch off. 31 targets were initiated in this this period. The way the program worked and the criteria for the minimum and maximum intervals between targets meant that all of these events were vehicle lane-changes and did not include any road surface obstacle detection events.

All 31 lane changes were detected. What is examined here is reaction time to detection, compared against mean reaction time for the later lane changes within that same one minute bin. This has been used for comparison as using the whole of the rest of the recovery period could introduce the influence of fatigue. The results (Table 1) do not suggest a significant difference. In other words, with these data we cannot show any difference between responses to a target that occurs near-immediately after the light switch, compared with responses to a later-occurring target. This is however a very small sample size from which to draw robust conclusions, and is only based on the lane change detection task.

Table 1. Comparison of reaction times to detection of lane change initiated within the first 3 seconds following a light switch transition (early target) with detection of the same event occurring later in the same 60 second period (subsequent target).

Transition sequence	**Sample**	**Mean reaction time (std dev)**		**Difference**
		Early target	**Subsequent target**	(paired samples t-test)
On-Off	13	2954 ms (1205 ms)	3264 ms (1242 ms)	p=0.16
Off-On	18	1943 ms (494 ms)	1960 ms (747 ms)	p=0.93

3 Additional Experiment

3.1 Method

This experiment followed the same procedure as was used in the original trials. Specifically, following a 20-minute period for dark adaptation, test participants were instructed to indicate detection of either the road surface obstacle (by pressing the foot switch) or the vehicle lane change (by pressing the steering wheel button) whilst tracking the dynamic fixation marker and reading aloud the randomly occurring digits.

The aim of this experiment was to investigate the change in detection in the moments following switch off and only one light setting was used: the high S/P ratio and a luminance of 1.0 cd/m^2.

The schedule of light switching followed a repeated cycle of 60 seconds with lighting switched on and 30 seconds with lighting off. Altogether, there were six target events in each 90s cycle, to maintain the same rate of occurrence as in the original experiment. Following the switch-off, one target was scheduled to commence within the first 3 seconds, and a second target scheduled to commence later within the same 30-second Off period. Four targets were associated with the 60-second On period, although due to the randomised scheduling the first of these may have been initiated towards the end of the Off period.

Given that one event was forced to occur quite soon after the switch off, this could be noticed by test participants, with false correct detection (false alarms) occurring by anticipation rather than by visual detection of the stimulus. Hence a third of the detection events were actually 'null' trials, in which no target was present, and this included one third of the events that were initiated in the immediate 3 seconds after lights were switched from On to Off. For the participant, the occurrence of null condition trials was indistinguishable from the background/baseline condition.

Each trial lasted for two hours and included 60 On-Off cycles with a total of 240 real detection events and 120 null detection events. Five test participants completed the task (all were drawn from the younger age group) and had not participated in the previous experiments.

3.2 Results

False alarms were recorded as any response (i.e. a press of either the steering wheel button or foot switch) during a 'null' event. This was the period starting at the switch-off and ending at initiation of the next target occurring at a randomised interval after the first 3 seconds. Within the post-switch period there were 20 null events per participant and the mean rate of false responses to these was 4%. This was the result of one participant falsely responding to 4 of the 20 null events. The other four participants did not falsely respond to any null events within the 3-second period immediately after switch-off. This is considered low, and provides reassurance that participants were responding to real detection events rather than responding randomly or to the switching of the lighting. For comparison, a previous target detection study [Fotios and Cheal, 2009] found that false alarms were given to 13.7% of null conditions.

Detection rates and reaction times to detection were used as measures of performance in the test. Responses to the left and right cars were compared to check for position bias but no differences were found ($p = 0.53$ for detection rates, $p = 0.97$ for reaction times, Wilcoxon signed-rank test). Data for both cars have therefore been combined and not analysed separately. Linear models were used to compare detection rates and reaction times between the different periods of the On-Off cycle, for both car and obstacle detection events. This type of test was used as it avoids the need to exclude unmatched data – reaction time data for the obstacle were missing for two participants in the immediate post-switch period of the Off stage of the cycle as they failed to detect any obstacle targets during this period.

Mean detection rates during the first 3 seconds following a light switch from On to Off and after the first 3 seconds are shown in Figure 1, alongside detection rates when the overhead lights were on. Detection of both the car and obstacle appears better with the overhead lights on than off. Detection rates of the obstacle appear to be worse within the first 3 seconds after the overhead lights switch from on to off, compared with the Off period following the initial 3-second period. Detection rates for the car lane-change display a much smaller difference between the 0-3 seconds and 3+ seconds periods.

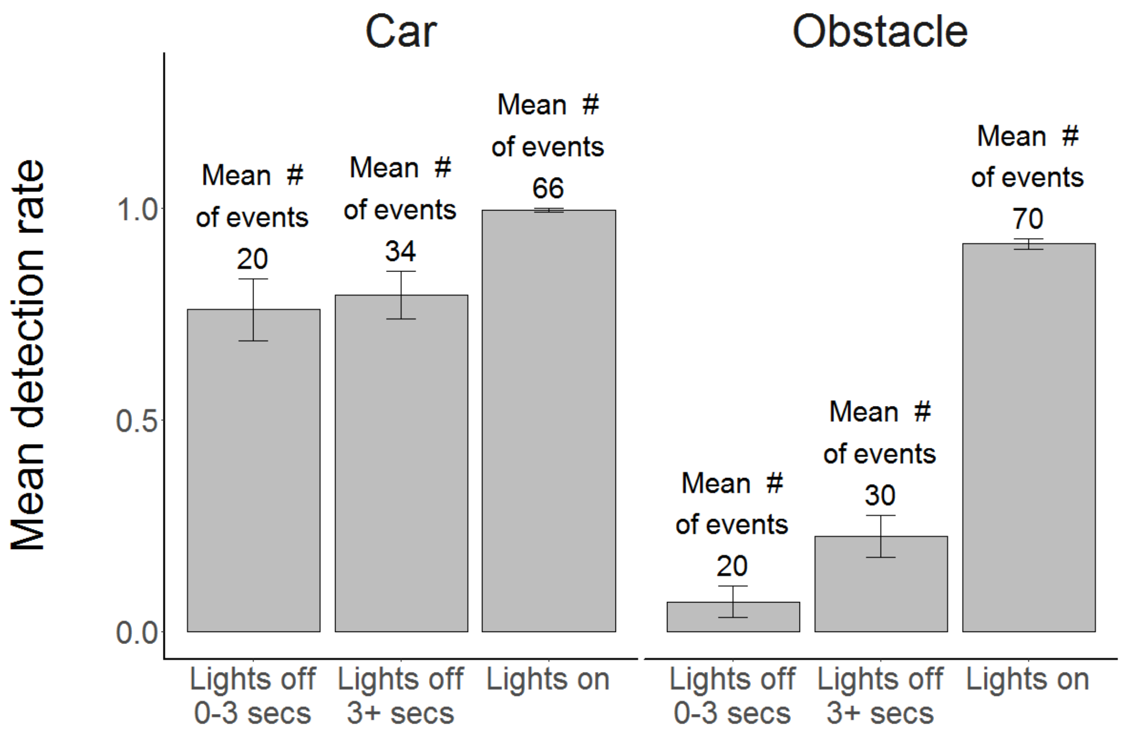

Figure 1. Mean detection rates for car and obstacle initiated during first 3 seconds after light switch and 3+ seconds after light switch, with overhead lights on or off. Error bars shown standard error of the mean. N = 5. Mean number of target events per participant during each period shown above bar.

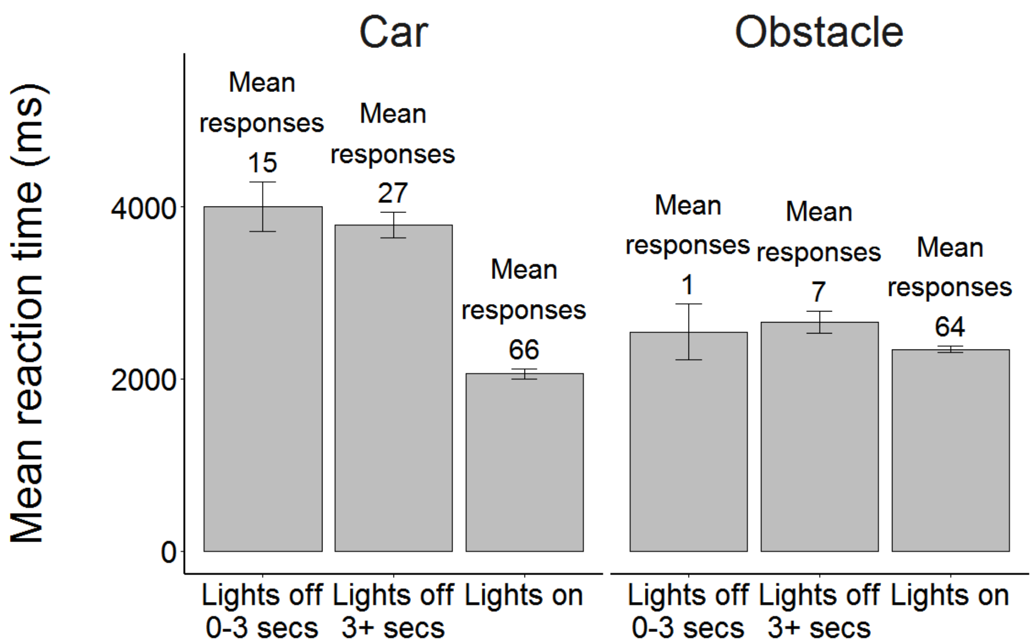

Figure 2. Mean reaction times for car and obstacle initiated during first 3 seconds after light switch and 3+ seconds after light switch, with overhead lights on or off. Error bars shown standard error of the mean. Mean number of responses per participant during each period shown above bar. While this experiment used a sample of N=5, for the obstacle, in the 0-3s period, the reaction time data are based on the results of the 3 test participant who successfully detected at least one obstacle.

The linear model was used to compare detection rates between the three periods – On, 0-3 seconds following switch off, and the remaining Off period. For lane change a significant difference is suggested ($p = 0.009$). Paired comparisons using the Wilcoxon signed-rank test and paired-samples t-test suggested detection rates to targets initiated in the first 3 seconds after the lights were switched off did not significantly differ from detection rates in the remaining time with the lights off (Wilcoxon $p = 0.63$, t-test $p = 0.56$). Detection rates in the early and remaining parts of the Off period were both significantly lower than when the overhead lights were switched on (Wilcoxon and t-test p-values ranged between 0.02 and 0.06).

The linear model for detection rates of the obstacle also suggested significant differences between the three periods ($p < 0.001$). Paired comparisons using both the Wilcoxon signed-rank test and paired-sample t-test suggested there were significant differences between all three periods (p-values ranged between < 0.001 and 0.06).

Mean reaction times for detection events initiated within the first 3 seconds following a light switch from On to Off and after the first 3 seconds are shown in Figure 2, alongside reaction times when the overhead lights were on. Reaction times to the car appear better with the overhead lights on than off, but there appears little difference for the obstacle. There appears to be little difference between reaction times to target events initiated during the first 3 seconds after the lights were switched off, and the rest of the period with the lights off, for both the car and obstacle targets. Note however the relatively low number of responses provided by participants, particularly to the obstacle, due to the low detection rates.

The linear model for reaction times to the car suggested significant differences were present between the three periods ($p < 0.001$). Paired comparisons using both Wilcoxon signed-rank tests and paired-sample t-tests suggested no difference between the first 3 seconds when the lights were off and the rest of the period when the lights were off (Wilcoxon and t-test p-values = 0.44 and 0.40). Both these periods had significantly longer reaction times than when the lights were on however (Wilcoxon and t-test p-values ranged between < 0.001 and 0.06).

The linear model for reaction times to the obstacle did not suggest any significant differences between the three periods within the On-Off cycle ($p = 0.45$). Paired comparisons between the periods using the Wilcoxon signed-rank test and paired-samples t-test confirmed there were no statistically significant differences between the three periods within the On-Off cycle (Wilcoxon and t-test p-values ranged between 0.06 and 0.75).

4 Conclusion

Post-hoc analysis of the original transition experiment revealed that 31 target events began within the first 3 seconds after the overhead lights were switched off, all of these being the car lane change. Statistical analysis did not suggest any difference in reaction times between these initial events and the next car lane change event.

A further experiment was carried out with the deliberate aim of comparing responses to target events that began in the first 3 seconds after lights were switched from on to off against responses to target events that were initiated at other times. For detection in the period when the lighting was switched off, detection rates for the obstacle were significantly lower for events initiated in the first 3 seconds (mean = 0.07) compared with those initiated at other times (mean = 0.23, paired-samples t-test p-value = 0.01). No other comparisons between the first 3 seconds and the subsequent period of the Off cycle were significant.

It should be noted however that comparisons of reaction times to the obstacle were based on very small numbers of responses due to the low detection rates when the lights were off, particularly for events initiated during the first 3 seconds. Further work with a larger sample is needed to confirm the current findings.

In summary, some evidence was found that detection of the obstacle was worse in the first seconds after overhead lights were switched off compared with at a later time when the road scene was still unlit. This conclusion should, however, be considered tentative due to the relatively small sample of participants and the lack of data, owing to a low detection rate, for reaction times when the lights were switched off. Further work would be required to establish more robust conclusions about the immediate effects of transitioning between lit and unlit areas.

References

Cheal C, Fotios S, Fox S, Uttley J. Impairment to peripheral detection when driving. Experiments investigating the effect of fog and the transition between lit and unlit sections of road. Final report for Highways England. March 2017.

Fotios SA, Cheal C. Obstacle detection: A pilot study investigating the effects of lamp type, illuminance and age. Lighting Research & Technology, 2009; 41(4); 321-342