

Title: Short-term cognitive conspicuity training does not improve driver detection of motorcycles at road junctions: A reply to Crundall, Howard & Young (2017)

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Abstract

A common cause of road accidents is driver failure to perceive an approaching motorcycle. In a lab-based study, we investigated whether a simple naturalistic training intervention designed to increase the cognitive conspicuity of motorcycles could improve drivers' recognition of approaching motorcycles. Experienced drivers completed a series of motorcycle search tasks (training condition) or passively viewed scenes from nature (control) prior to performing a vehicle recognition task from the perspective of a driver approaching a T-junction. Results confirm established findings that drivers perform poorly at recognising motorcycles compared to cars, especially at far distances. However, motorcycle search training had no effect on driver accuracy in recognising approaching vehicles. Training lead to increased response times for recognising approaching cars relative to motorcycles, which could suggest a more thorough consideration of the road scene following training. We conclude that using motorcycle search training to raise the cognitive conspicuity of motorcycles is not effective in increasing their detection from a single delivery of training. Focusing on increasing motorcyclist visibility may be a more effective way to improve driver responses to motorcycles at junctions.

Keywords: Motorcycles, Training, Experienced Drivers, LBFS errors, T-junctions

Introduction

Motorcycle riders are vulnerable road users, with a population of 1% of total road users representing 19% of road fatalities in the UK (Department for Transport, 2015). Indeed, motorcyclists are 20 times more likely to be involved in a fatal accident per kilometre travelled than car drivers (Guyot, 2008). The most common type of motorcycle accident is a right of way violation, with a car turning onto a road where an approaching motorcycle has priority (Hurt, Ouellet & Thom, 1981; Wulf, Hancock & Rahimi, 1989; Clarke, Ward, Bartle & Truman, 2004; Peek-Asa & Kraus, 1996; Williams and Hoffmann, 1979). These driver errors are commonly identified as Look-But-Fail-To-See (LBFS) errors, where drivers report that they looked in the direction of the approaching motorcycle but failed to notice it (Crundall, Crundall, Clarke & Shahr, 2012).

Research investigating this phenomenon has focused on two main areas: the salient properties of the motorcycle and the cognitive processes of the driver. That is, we can approach the problem of motorcycle detectability by focusing on sensorial conspicuity or cognitive conspicuity (Hancock, Wulf, Thom & Fassnacht, 1990; Cavallo & Pinto, 2012). Sensorial conspicuity approaches take a bottom-up processing perspective, and suggest that increasing the visual salience of a motorcycle relative to its background should improve driver perception. Indeed, drivers are more susceptible to LBFS errors in urban environments (Beanland, Filtner & Jeans, 2017), where visually noisy background properties decrease motorcycle salience. Efforts to increase the sensorial conspicuity of motorcycles – for example through the use of daytime running lights (DRLs) – have been successful (e.g. Muller, 1984; Olson et al., 1981; Thomson, 1980; Zador, 1985). The adoption of DRLs by car users has led to significantly diminished detection of motorcycles (Cavallo & Pinto, 2012; Knight et al., 2006) due to a lowering of sensorial conspicuity, leading several research groups to propose to use of innovative configuration of motorcycle lights to make motorcycles more conspicuous on the road (Cavallo et al., 2015; Maruyama, Tsutsumi & Murata, 2009; Rößger, Hagen, Krzywinski & Schlag, 2010; Gershon & Shinar, 2013; Pinto, Cavallo & Saint-Pierre, 2014).

Many researchers suggest that factors other than the sensorial conspicuity of motorcycles contribute to the high rate of accidents caused by LBFS errors. In

particular, the cognitive conspicuity of motorcycles – that is, drivers’ propensity to attend to motorcycles – is of interest. This approach suggests that the top-down experience-related processes involved in driver road scene searches may lead to the failure of a driver to perceive an approaching motorcyclist. In short, LBFS errors may occur when a driver looks for what they expect to see, and this expectation does not automatically include motorcycles. Here, the implicit learning gained through experience comes to form top-down expectations when looking at a road scene. Several avenues of research support this approach. Dual drivers who hold both motorcycle and automobile licences (Magazzù, Comelli & Marinoni, 2006) as well as drivers with family members who are motorcyclists (Brooks & Guppy, 1990) are less prone to accidents involving motorcycles. Interestingly, experienced drivers are most susceptible to LBFS errors (Herslund & Jorgensen, 2003; Crundall, Bibby, Clarke, Ward & Bartle, 2008a; Crundall et al., 2012). This may be because they perform searches and focus their attention in a manner that is most efficient based on their accumulated driving experience – that is, they search for the most common dangers (oncoming cars) and can overlook less frequently occurring traffic (motorcycles, bicycles) in their attentional searches (Chun & Jiang, 1998, 1999). Indeed, developing expectations formulated through experience can lead to poor performance when presented with less frequently experienced road events (Koustanai, Boloix, Van Elslande & Bastien, 2008), a negative effect of experience influencing expectation (Herslund & Jorgensen, 2003). An important question, therefore, is whether increasing the cognitive conspicuity of motorcycles can lead to increased detection in experienced drivers.

While it has been demonstrated that long-term exposure to motorcycles reduces a driver’s propensity to crash into them (Magazzù et al., 2006; Brooks & Guppy, 1990) and increases their ability to detect them at junctions (Lee, Sheppard & Crundall, 2015; Crundall, Howard & Young, 2017; Experiment 1), it is less well known whether short-term perceptual training can similarly increase the cognitive conspicuity of motorcycles, resulting in greater detection by drivers. There is some evidence that perceptual training can increase expertise with a set of stimuli to the extent that they are processed in a fundamentally enhanced way (Gauthier & Tarr, 1997). In particular, Baluch & Itti (2010) showed that visual search training can lead to improvements in detecting similar stimuli in subsequent tasks via a top-down

mechanism. That is, they showed that top-down attention-based search expertise can transfer across visual tasks. The potential for *short-term* exposure to a set of motorcycle-related stimuli to increase the cognitive conspicuity – and detection rates – of motorcycles forms the basis of the current study.

Aims

Here, we investigate whether a naturalistic search task could be useful in training experienced drivers to detect motorcycles in a road scene. By naturalistic, we mean training that is realistic to a driver's normal environment. If low cognitive conspicuity contributes to poor detection rates for motorcycles, then performing a task that puts drivers "in mind" of motorcycles should increase detection rates. We expect that drivers who take part in a naturalistic search training task (searching for motorcycles in car park scenes) will show increased detection of motorcycles in a subsequent vehicle detection road scene task, compared with drivers who did not take part in the training.

Crundall and colleagues (2017) used a Pelmanism task in an effort to raise the cognitive conspicuity of motorcycles. While those authors report a pre-post effect of this training, they didn't demonstrate differences in motorcycle detection between the training and control groups. In contrast to Crundall and colleagues (2017), we use a naturalistic search task (searching for motorcycles in a scene with cars) to increase the cognitive conspicuity of motorcycles. Crundall and colleagues (2017) argue for a perceptual training task that allows visual rather than verbal discrimination while gamifying the learning to increase engagement. The current study applies these principles, but employs a more accessible, cost-effective way of delivering the perceptual training. We favour the design of our training task as it is achievable for most drivers in a natural driving scene – i.e. drivers could carry out a motorcycle "count" of their own driving scene (car park; estate road; town street) before beginning a journey.

Methods

Participants

Forty-four participants (25 female) with a mean age of 38.09 years (SD = 13.32) took part in the study. Participants were required to hold a full, clean driving licence, and to have at least three years' driving experience in the UK. These participants were pseudo-randomly assigned to the training condition (23 participants) or the control condition (21 participants). Data from two participants were excluded due to computer error. Of the remaining participants, 22 took part in the training condition (8 female) with a mean age of 39.18 (SD = 11.92) and average driving experience of 19.84 years (SD = 12.31). Twenty took part in the control condition (15 female) with a mean age of 37.4 years (SD = 14.90) and average driving experience of 16.89 years (SD = 11.71). Level of driving experience did not differ between training and control groups, $t(40) = 0.79$, *n.s.* Participants all had normal or corrected-to-normal vision, and were instructed to wear any glasses or contact lenses that they would normally wear while driving. The study was approved by the Departmental Research Ethics Panel at Anglia Ruskin University.

Stimuli

Training condition stimuli

Training stimuli comprised colour images of car parks with a number of motorcycles visible. Aerial view car park images and side-on view car park images were taken from Google Maps. Images of motorcycles were inserted into the car park scenes using Adobe Photoshop CS5, with between 3-9 motorcycles added to each scene. A total of 20 scenes were created in this way. See Figure 1 for examples of a training condition stimuli.



Figure 1: Example of aerial view (top panel) and side view (bottom panel) training condition stimulus with nine (top) and three (bottom) motorcycles visible.

Control condition stimuli

Control condition stimuli comprised 30 colour images of natural scenes which did not feature any roads. These images were taken from Pexels, and are freely available for public use.

Testing stimuli

See Crundall, Humphrey and Clarke (2008b) for a full description of the testing stimuli, which were used here with permission. In summary, stimuli comprised ten colour images of roads, as viewed from the position of a car which is stationary at a T-junction, about to join a road. Cars and motorcycles were edited onto the road images by those authors, such that they appeared to be approaching from the right at a distance near to the viewer (approximately 1 s to contact), at a middle distance (approximately 2 s to contact) or at a far distance (approximately 3 s). This provided a total of 70 different stimuli: 10 images of roads with no traffic, 10 images of roads with cars appearing to be near to the viewer, 10 with cars appearing to be at a middle distance, 10 with cars appearing to be at a far distance, 10 with motorcycles appearing to be near to the viewer, 10 with motorcycles appearing to be at a middle distance, and 10 with motorcycles appearing to be at a far distance. Images subtended a visual angle of 12.73° by 9.54° when viewed on a 21" Dell PC screen at a distance of approximately 80 cm. At far distances, cars subtended 0.5° by 0.72° and motorcycles subtended 0.5° by 0.36° . At middle distances, cars subtended 0.93° by 1.15° and motorcycles subtended 0.93° by 0.50° . At near distances, cars subtended 1.36° by 1.72° and motorcycles subtended 1.36° by 0.79° . See Figure 2 for examples of testing stimuli.

Procedure

Training condition

Participants in the training condition were presented with a series of 20 trials. During each trial, participants were presented with a carpark scene and were required to search the image for motorcycles. Images remained on the screen until the participant entered a response indicating the number of motorcycles present in the scene using a keyboard number pad. Following each trial, participants were presented with a screen informing them as to whether they had answered correctly on the preceding trial. There was an inter-stimulus interval (ISI) of 1 s between trials.

Control condition

Participants were instructed to passively view images of natural scenes. Participants saw 30 natural scenes in total, with each scene presented for 5 s (ISI = 1 s). This gave a comparable overall viewing time to the training condition.



Figure 2: Examples of testing stimuli with a car (left panel) and motorcycle (right panel) approaching in the far distance

Testing procedure

Following exposure to either the training or control stimuli, all participants took part in the testing procedure. In order to simulate driver glancing behaviour, we follow several others (Crundall et al., 2008b; Gershon, Ben-Asher & Shiner, 2012; Cavallo & Pinto, 2012; Lee, Sheppard & Crundall, 2015; Crundall et al., 2017) in asking participants to perform a naturalistic spontaneous and economical search of a road scene in our experimental task, as opposed to performing an artificial extended search task. As such, a trial began with the presentation of a fixation cross to the left of the screen for a duration varying randomly between 500-1,250 ms. A road scene image was then presented centrally for 250 ms, such that the participant needed to move their eyes to the right to check the road scene for the presence of an approaching vehicle. Immediately following this, participants were required to indicate by pressing the “m” or “n” keys on a keyboard whether or not a vehicle of any kind was approaching in the scene. The “m” and “n” keys were covered with coloured stickers for ease of instruction. The allocation of the keys to indicate “vehicle approaching”

and “no vehicle approaching” was counterbalanced across participants. Participants were instructed to respond as quickly and accurately as possible, and received feedback of “correct” or “incorrect” following their response, presented to the left of the screen for 1.5 s. Participants completed ten practice trials followed by two blocks of testing trials. Each block comprised 60 road scenes with no vehicles approaching (10 images repeated six times each) and 60 road scenes with a vehicle approaching (10 near distance car, 10 middle distance car, 10 far distance car, 10 near distance motorcycle, 10 middle distance motorcycle, 10 far distance motorcycle). These images were presented in a random order. In this way, participants completed 240 trials each.

Results

Three-way mixed factorial ANOVAs, with repeated measures factors of distance (near, middle distance, far) and vehicle type (car, motorcycle) and a between-subjects factor of training group (training, no training) were carried out on both accuracy and reaction time data in response to the presence of an approaching vehicle in the road scene. Data can be found here: <https://data.mendeley.com/datasets/ygmkvxxtsw/2> (Keyes, Green, Compton & Staton, 2019).

Accuracy

A 3-way ANOVA revealed a significant effect of distance on participants’ accuracy in recognising the presence of an approaching vehicle, $F(2,80) = 118.97, p < .001, \eta_p^2 = .748$, such that participants were significantly worse at recognising the presence of vehicles in the far distance compared to either the near, $t(41) = 11.17, p < .001$, or the middle distances, $t(41) = 11.55, p < .001$. Participants were better at recognising the presence of vehicles in the near condition compared to the middle distance condition, $t(41) = 2.64, p = .015$. Alpha is Bonferroni-adjusted to .017 for three one-tailed comparisons.

A significant effect of vehicle type demonstrated that participants were more accurate in identifying the presence of a car compared to a motorcycle, $F(1,40) = 23.30, p < .001, \eta_p^2 = .368$.

A significant interaction between distance and vehicle type, $F(2,80) = 77.77, p < .001, \eta_p^2 = .660$, showed that, while there were no differences in participants’ ability

285 to recognise cars and motorcycles at near, $t(41) = 0.02$, *n.s.*, or middle distances, $t(41)$
286 $= 0.38$, *n.s.*, at far distances, participants were significantly worse at recognising the
287 presence of motorcycles compared to cars, $t(41) = 9.25$, $p < .001$. Alpha is Bonferroni-
288 adjusted to .017 for three comparisons. Accuracy effects are illustrated in Figure 3.

289 There was no effect of training on participants' accuracy in recognising the
290 presence of approaching vehicles, $F(1,40) = 0.65$, *n.s.*, nor did training group interact
291 with recognition accuracy at different distances, $F(2,80) = 0.39$, *n.s.*, or recognition
292 accuracy for different vehicle types (cars, motorcycles), $F(1,40) = 0.26$, *n.s.* Finally, no
293 three-way interaction between training group, vehicle type and distance was
294 observed, $F(2,80) = 0.12$, *n.s.*

295 Trials where no approaching vehicles were present in the road scene acted as
296 a task control. Participants in the training and control groups showed no differences
297 in accuracy (false alarms) in response to these trials, $t(40) = 1.19$, *n.s.*

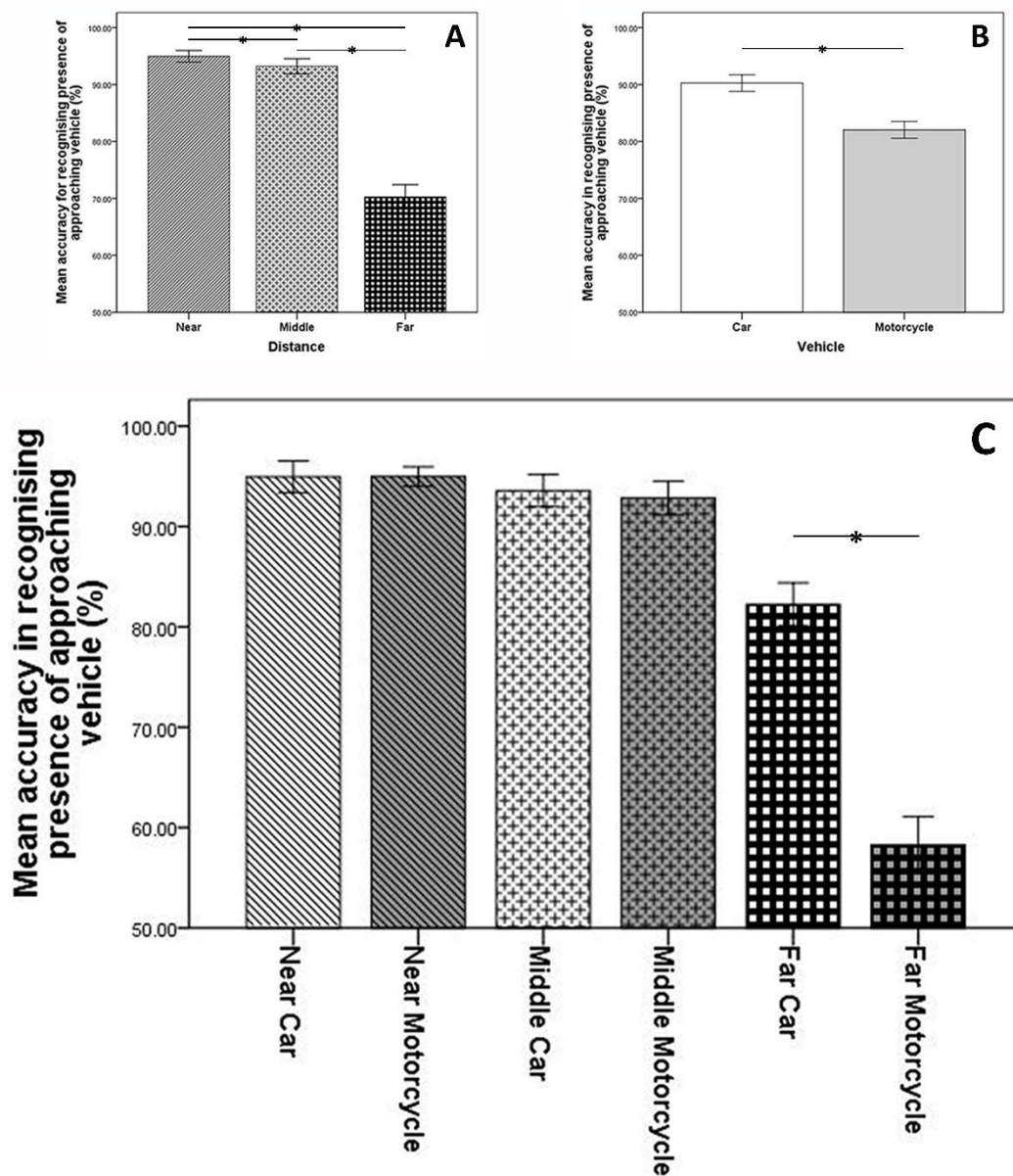


Figure 3: Accuracy data for distance main effect (Panel A), vehicle main effect (Panel B) and distance X vehicle interaction effect (Panel C). Across panels, diagonal lines represent near distances, crosses represent middle distances and boxes represent far distances for cars (white) and motorcycles (grey). Error bars represent 1 SE.

Reaction time

Reaction times for correct responses were analysed, with response times further than 2 SD away from each participant's mean excluded as outliers (Ratcliff, 1993). A 3-way

ANOVA revealed a significant main effect of vehicle type, such that cars were recognised faster than motorcycles, $F(1,40) = 5.82, p < .05, \eta_p^2 = .127$.

A significant main effect of distance, $F(2,80) = 64.84, p < .001, \eta_p^2 = .618$, showed that all vehicles were recognised faster at near distances compared to either middle, $t(41) = 3.79, p < .001$, or far distances, $t(41) = 10.93, p < .001$. Participants were slower at recognising vehicles at far compared to middle distances, $t(41) = 6.82, p < .001$. Alpha is Bonferroni-adjusted to .017 for three comparisons. Vehicle type and distance did not interact in their effect on reaction time, $F(2,80) = 0.08, n.s.$

Interestingly, the effect of training significantly interacted with vehicle type, $F(1,40) = 4.66, p < .05$. Here, participants in the control group were significantly faster at correctly identifying the presence of cars compared to motorcycles, $t(19) = 3.87, p < .001$. However, participants in the training group showed no difference in their response times to cars and motorcycles, $t(21) = 0.16, n.s.$ Reaction time effects are illustrated in Figure 4, and you will see from Panel C that this interaction effect is driven by participants in the training group having slowed responses to cars, rather than speeded responses to motorcycles.

No main effect of training was observed on response times, $F(1,40) = 1.54, n.s.$ There was no interaction between training group and distance, $F(2,80) = 1.12, n.s.$, between distance and vehicle, $F(2,80) = 0.08, n.s.$ ¹, nor between training group, distance and vehicle, $F(2,80) = 0.08, n.s.$

Participants in the training and control groups showed no differences in response times for task control trials where no approaching vehicles were present in the road scene, $t(40) = 1.31, n.s.$

¹ At the request of a reviewer, this non-significant interaction is illustrated in a supplementary figure (Fig 5).

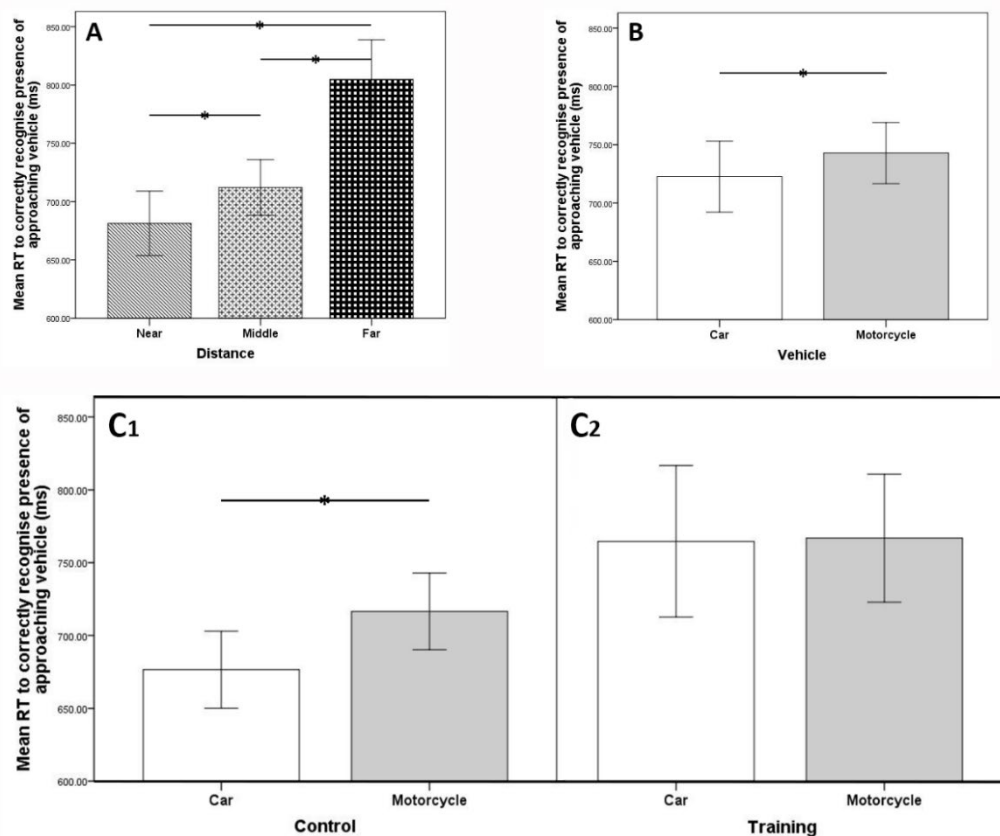


Figure 4: Reaction time data for distance main effect (Panel A), vehicle main effect (Panel B) and training group X vehicle interaction effect (Panel C). Panel C₁ depicts data from the control group and Panel C₂ depicts data from the training group. In Panel A, diagonal lines represent near distances, crosses represent middle distances. In Panels B and C, white boxes represent cars and grey boxes represent motorcycles. Error bars represent 1 SE.

Discussion

In a lab-based study investigating driver perception of approaching cars and motorcycles at a road junction, we report that experienced drivers' accuracy in perceiving approaching vehicles suffers with distance, and is worse for motorcycles compared to cars. In particular, drivers performed poorly in recognising approaching motorcycles at far distances, compared to cars. This replicates several previous findings (Crundall et al., 2008b; Gershon et al., 2012; Cavallo & Pinto, 2012; Lee et al., 2015; Crundall et al., 2017). We report no effect of cognitive conspicuity training on drivers' accuracy scores in recognising the presence of an approaching motorcycle.

349 This finding suggests that detection rates of approaching motorcycles cannot
350 be improved by a short period of training involving a naturalistic search task. This leads
351 to one of two possible conclusions: 1) a short period of training on a motorcycle search
352 task (< 10 mins) is not sufficient to increase the cognitive conspicuity of motorcycles
353 or 2) increasing the cognitive conspicuity of motorcycles is not sufficient to increase
354 perception at far distances. We consider both of these options here. In terms of our
355 perceptual training task: both Baulch and Itti (2010) and Gauthier & Tarr (1997)
356 exposed participants to thousands of training trials before they felt confident that true
357 perceptual learning had taken place. In the current study and Crundall and colleagues'
358 (2017) study, participants were exposed to < 10 mins of perceptual training. In order
359 to investigate whether perceptual training can increase the cognitive conspicuity of
360 motorcycles in a way that increases drivers' ability to attend to them, intensive 1000
361 + trial perceptual training may be required. The current study cannot rule out the
362 usefulness of perceptual training in increasing the cognitive conspicuity of
363 motorcycles. Rather, we demonstrate that a short visual search training paradigm is
364 unlikely to yield this result. Indeed, demonstrating the extent to which cognitive
365 conspicuity has been increased will be an important consideration for future work
366 involving perceptual training for motorcycle detection.

367 We now turn to the second interpretation – that increasing the cognitive
368 conspicuity of motorcycles is not sufficient to increase detection at far distances.
369 Considering the physical differences between cars and motorcycles, and considering
370 the success of interventions raising the sensorial conspicuity of motorcycles (e.g.
371 Cavello et al., 2015; Maruyama et al., 2009; Rößger et al., 2010; Gershon & Shinar,
372 2013; Pinto et al., 2014), it is likely that a continuing focus on increasing motorcycle
373 visibility will lead to the greatest improvement in detection rates.

374 We note with interest the differences (and similarities) between the findings
375 of Crundall and colleagues (2017) and our findings reported here. In a mixed-factorial
376 design, they report that Pelmanism training with motorcycle stimuli resulted in a pre-
377 post improvement in the detection of motorcycles in a road scene task, while
378 Pelmanism training with fruit stimuli (control) improved pre-post detection of cars.
379 Notably however, they report no differences across groups – that is, drivers receiving
380 the Pelmanism motorcycle training did not appear to perform any better than drivers

in the control condition. This finding mirrors our own results, and while the pre-post within-group differences observed in Crundall and colleagues' paper may preserve some reason to remain hopeful about the potential efficacy of cognitive conspicuity training for motorcycle detection, no studies to date have demonstrated a between group effect of short-term cognitive conspicuity training on motorcycle detection.

We also report here that – similar to its effect on accuracy – distance negatively affects drivers' response times to recognise an approaching vehicle, and drivers generally respond more quickly to the presence of an approaching car than a motorcycle. Interestingly, drivers who didn't receive the cognitive conspicuity training responded faster to cars than to motorcycles; however, drivers who received the training showed no difference in their response times to recognising the presence of approaching cars and motorcycles. This was driven by slower response times to recognising the presence of cars, rather than speeded responses to motorcycles for this group. This increase in reaction time may reflect a more thorough consideration of the road scene (i.e. searching for the presence of motorcycles) following the cognitive conspicuity training, and suggests that the training had some effect on the participants. This effect was not driven by overall changes in sensitivity following training, as demonstrated by similar false alarm rates and overall response times for trained and control groups for trials not containing an oncoming vehicle.

We must exercise caution when evaluating training interventions; as the results presented here indicate, eliciting a desired effect (raising the cognitive conspicuity of motorcycles) may not result in the desired outcome (improved responses to approaching motorcycles). Indeed, in this instance, partaking in a motorcycle conspicuity training task has the potential to disadvantage drivers, as the resulting thorough road scene consideration can slow their response to recognising oncoming cars. As this increase in response times to recognising cars is not paired with an accompanying increase in accuracy in spotting motorcycles at far distances, there is no road safety advantage associated with using a naturalistic motorcycle search task training intervention to improve the cognitive conspicuity of motorcycles.

Limitations

Because we were interested in the effects of perceptual learning, providing feedback following each trial in the testing phase may have diluted the results. Specifically, perceptual learning could have occurred for both the experimental and control groups during the testing task itself. However, we note that Lee and colleagues (2015) use an identical approach and report clear perceptual learning effects from longer-term motorcycle exposure compared to a control group, so it is likely that using this approach can detect perceptual training advantages where they are present.

A Pelmanism task involves visual discrimination at a subordinate category level (i.e. discriminating between motorcycles) discrimination as opposed to the categorical level discrimination (discriminating between motorcycles and cars) used in the training task here. Because subordinate level processing should improve base-level detection (see Crundall et al., 2017), using such an approach may more robustly underpin perceptual learning. However, we note that perceptual training using a Pelmanism task did not elicit motorcycle detection advantages for trained compared to control groups (Crundall et al., 2017), and we propose that short-term visual training may not be sufficient for perceptual learning.

It is difficult to disentangle the effects of driving experience from those of age. In this study, our theoretical approach led us to focus on experienced drivers, with participants having an average of 18 years' driving experience. We must remain open to the possibility that errors in motorcycle detection observed in the experienced driving population may result in part from age effects. Larger-scale studies are needed to disentangle age- and experience-related effects in LBFS errors.

Conclusion

A single delivery of visual search cognitive conspicuity training does not improve experienced drivers' detection of approaching motorcycles at a T-junction in a lab-based task. Indeed, training to put drivers "in mind" of motorcycles has the effect of slowing their responses to detecting approaching cars, possibly reflecting a more considered search for motorcycles. We suggest that short-term cognitive conspicuity training is not an effective approach to reducing the number of LBFS errors for motorcycles.

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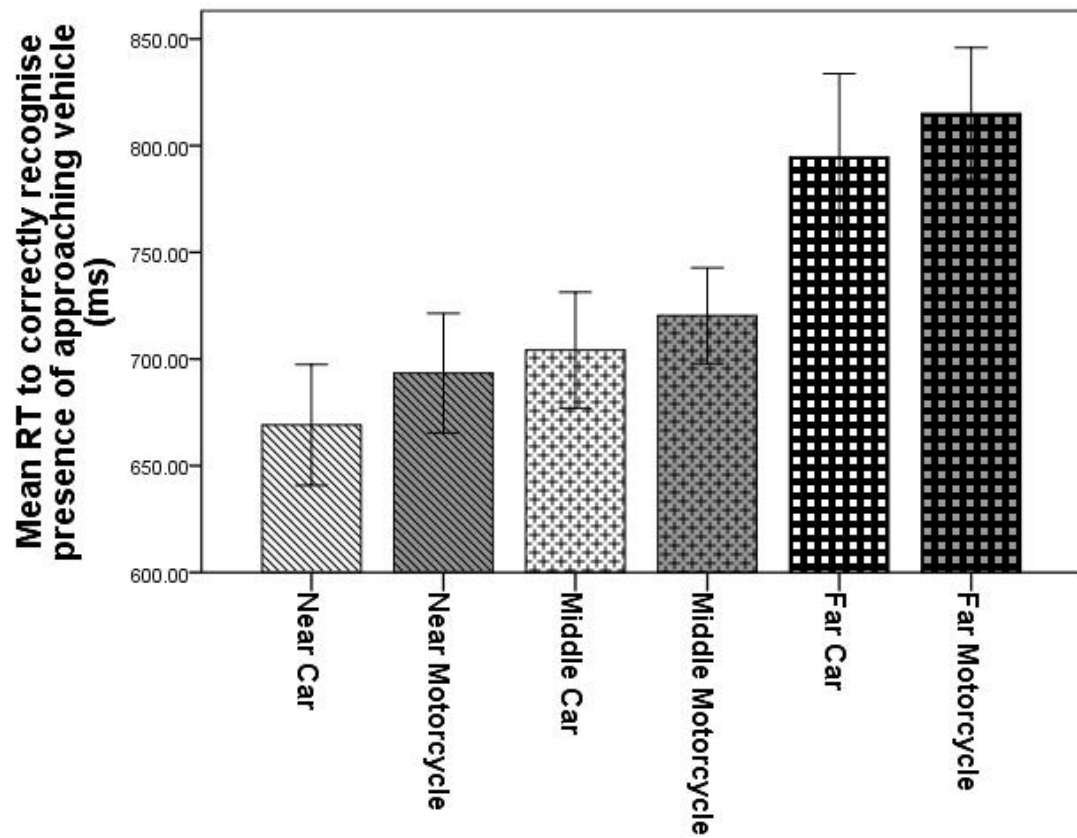
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541 Figure 5: Supplementary figure. Reaction time data the non-significant distance X
 542 vehicle interaction effect. Diagonal lines represent near distances, crosses represent
 543 middle distances and boxes represent far distances for cars (white) and motorcycles
 544 (grey). Error bars represent 1 SE.