Attention and search conspicuity as a function of their visual context

ARTICLE *in* ACCIDENT; ANALYSIS AND PREVENTION · JANUARY 2012

Impact Factor: 1.65 · DOI: 10.1016/j.aap.2010.12.015 · Source: PubMed

3 AUTHORS:

Pnina Gershon
Carnegie Mellon University
12 PUBLICATIONS **158** CITATIONS

Noam Ben-Asher
Army Research Laboratory
23 PUBLICATIONS **97** CITATIONS

David Shinar
Ben-Gurion University of the Negev
126 PUBLICATIONS **3,111** CITATIONS

Accident Analysis and Prevention 44 (2012) 97–103

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Attention and search conspicuity of motorcycles as a function of their visual context

Pnina Gershon*, Noam Ben-Asher, David Shinar

Department of Industrial Engineering and Management, Ben-Gurion University of the Negev, Beer Sheva, Israel

ARTICLE INFO

Article history:
Received 14 June 2010
Received in revised form
13 December 2010
Accepted 14 December 2010

Keywords:
Powered two-wheel (PTW)
Search conspicuity
Attention conspicuity

ABSTRACT

Background: Over the years, PTWs' number of accidents have increased dramatically and have accounted for a high percentage of the total traffic fatalities. The majority of those accidents occur in daylight, clear weather, and at light to moderate traffic conditions. The current study included two experiments. The first experiment evaluated the influence of PTW attention conspicuity on the ability of un-alerted viewers to detect it, whereas the second experiment evaluated the PTWs search conspicuity to alerted viewers. The independent variables in both experiments included driving scenarios (urban and inter-urban), PTW rider's outfit (black, white, and reflective) and PTW distance from the viewer.

Method: 66 students participated in experiment 1. Every participant was presented with a series of pictures and was asked to report all the vehicle types present in each picture. Experiment 2 included 64 participants and incorporated the same pictures as experiment 1. However, in this experiment the participants were instructed to search the pictures for a PTW and to report its presence or absence as soon as they reach a decision.

Results: In experiment 1 the detection of a PTW depended on the interaction between its distance from the viewer, the driving scenario and PTW rider's outfit. For an un-alerted viewer when the PTW was distant the different outfit conditions affected its' attention conspicuity. In urban roads, where the background surrounding the PTW was more complex and multi-colored, the reflective and white outfits increased its attention conspicuity compared to the black outfit condition. In contrast, in inter-urban roads, where the background was solely a bright sky, the black outfit provided an advantage for the PTW detectability. In experiment 2, the average PTW detection rate of the alerted viewers was very high and the average reaction time to identify the presence of a PTW was the shortest in the inter-urban environment. Similar to the results of experiment 1, in urban environments the reflective and white clothing provided an advantage to the detection of the PTW, while in the inter-urban environment the black outfit presented an advantage. Comparing the results of the two experiments revealed that at the farthest distance, the increased awareness in the search conspicuity detection rates were three times higher than in the attention conspicuity.

Conclusions: The conspicuity of a PTW can be increased by using an appropriate rider's outfit that distinguishes him/her from the background scenery. Thus, PTW riders can actively increase their conspicuity by taking into account the driving route (crowded urban/inter urban), eventually increasing the probability of being detected by the other road users. In addition, increasing the alertness and expectancy of drivers to the presence of PTWs can increase their search conspicuity.

1. Introduction

Powered two-wheelers (PTWs) add up to a small share of the total motorized traffic. However, they are highly over-involved in the accidents statistics (Shinar, 2007). According to the U.S. National Highway Traffic Safety Administration's 2008 Traffic Safety Annual Assessment (2009), motorcyclist fatalities increased dramatically in the recent decade, accounting for 14% of the total U.S. traffic fatalities. Similar statistics were collected in Great Britain, where motorcycles were involved in 14% of all fatal injuries although they accounted for less than 1% of the vehicle population (Clarke et al., 2004). The increase in the number of PTWs (especially the heavy ones), the increase in accidents involving PTWs, and the vulnerability of the riders, all together contribute to the concern for motorcyclists' safety (Shinar, 2007). An in-depth study (MAIDS) conducted in Europe revealed that 73% of PTWs' accidents occurred at daytime, 90% of them were in clear weather conditions and 85% in light to medium traffic density (ACEM, 2004). Similar findings

* Corresponding author.
E-mail address: pninage@bgu.ac.il (P. Gershon).

0001-4575/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.aap.2010.12.015

were obtained in a study conducted in New Zealand, which showed that 64% of the PTWs' crashes occurred in daylight and 72% of these crashes occurred in clear weather (Wells et al., 2004). Given the fact that a large proportion of the accidents involving PTW occurs under fairly safe and favorable environmental conditions, one must ask what might be the main factors that contribute to these accidents.

It is common to distinguish between three types of factors that are responsible for the occurrence of an accident: the human factor, the environmental factor and the vehicular factor (Gershon et al., 2009; Shinar, 2007). In the MAIDS study, the human factor was found to be the dominant contributor (87.9%) in accidents involving PTWs (ACEM, 2004). In general, around 70% of the accidents occurred due to delays in PTW detection. The majority of these accidents were attributed to perceptual human errors, including the failure to notice the PTW within the dynamic traffic environment, lack of driver's attention, temporary view obstructions and low conspicuity and visibility (ACEM, 2004; Williams and Hoffmann, 1979). These perception failures occurred mostly when crossing a junction without giving the right of way to the PTW (Wulf et al., 1989). In 65% of the accidents analyzed by Hurt et al. (1981), the drivers of the other vehicles failed to give the PTW the right of way. Surprisingly, in many documented cases although the PTW was quite close to the junction, the other vehicle's driver failed to detect and distinguish it from the surroundings even when gazing directly at it (see review article of Wulf et al., 1989). Mannering and Grodsky (1995) offered possible reasons to why other vehicle drivers do not give the PTW the right of the way. They claim that car drivers tend to identify other cars as threat while PTWs are not perceived as an endangering factor, and therefore car drivers do not pay much effort searching for them. Another explanation – specific to intersection accidents – is that drivers who are waiting to enter the junction find it difficult to estimate the time-to-collision with an approaching PTW. Apparently, car drivers overestimate the time that it will take the PTW to enter the junction, probably due to its small dimensions (i.e., "size-arrival illusion") (Horswill et al., 2005).

Shinar (2007) suggested two contributing factors to accidents in general and to accidents involving PTWs in particular. The first is inattention and the limited ability to sustain attention for long periods of time. The second is the PTW and PTW rider's conspicuity. The current study addresses the latter, and evaluates the influence of different contributing factors to the attention and search conspicuity of the PTW. Attention conspicuity is defined here as the ability to detect a PTW when it is unexpected, where search conspicuity is the ability to detect a PTW while actively searching for it.

In their review, Wulf et al. (1989) indicated that the detectability of a PTW was mainly affected by its size, surrounding luminance, PTWs contrast from the background, and color (of both PTW and rider's outfit). The size and dynamics of the PTW are such that they have lower sensorial conspicuity (visual distinction of an object due to its physical characteristics) making them more likely to blend in with the surrounding background and more likely to be obscured by cars or blind areas of the other vehicles. In addition, their cognitive attention conspicuity (distinction of an object based on the observer's experiences and interests) is also poor due to the low exposure frequencies, unexpected locations, and unusual behaviours, such as high speeds and straddling the lane markers (Shinar, 2007; Wulf et al., 1989).

In the past, the sensorial conspicuity of PTWs was improved by the use of daytime running lights (DRL) that became compulsory for PTWs in many countries (Williams and Hoffmann, 1979). DRL can increase the contrast from the background and it is likely that this attention-attracting feature can compensate to some extent for low expectancies and attentional failures (Shinar, 2007). Furthermore, as long as PTWs were the only vehicles using headlights at daytime, DRL provided PTWs with a consistent feature that facilitated their detection and identification by the other vehicle drivers (Brouwer et al., 2004; Olson et al., 1981). However, the relative advantage of the exclusive use of the DRL by PTWs is presently diminishing because of the increasing (and in some countries mandatory) use of the DRL by passenger cars. It therefore seems necessary to understand and map the intervening factors that affect PTWs conspicuity. This knowledge can help in finding new ways to enhance PTWs conspicuity and provide the riders with a unique signature that will make them clearly distinguishable from their background and from other road users.

One of the main contributing factors to PTWs conspicuity is its distance from the viewer. Hole et al. (1996) showed that the proximity of the PTW influenced the effectiveness of different aids in increasing its conspicuity. The use of headlights for example, increased PTWs conspicuity only when it exceeded a certain distance from the viewer. The influence of the contrast between the PTW and its surrounding background has been noted in number of studies (ACEM, 2004; Hole et al., 1996; Shinar, 2007; Wulf et al., 1989). For example, Hole et al. (1996) found that the potency of different conspicuity treatments was primarily affected by environmental factors, and the utility of different conspicuity aids such as headlights and riders' outfits differ according to the environmental characteristics. In a semi-rural environment headlights improved PTWs' conspicuity whereas in an urban environment their influence was inconsistent. In the MAIDS study the background seemed to have a positive effect on conspicuity in 7.5% of the cases and a negative effect in 14.4% of the cases (ACEM, 2004). Wells et al. (2004) in their case control study found that wearing a reflective or fluorescent garment decreased the risk of crash related injury by 37%. A study conducted by Olson et al. (1981) evaluated the influence of different treatments including headlamp, fluorescent garments and fluorescent fairing on PTWs conspicuity. They found that both headlamps and fluorescent garments had the potential to increase PTWs' conspicuity, as illustrated by bigger gap acceptance. In the MAIDS study, motorcycle riders' use of dark clothing decreased their conspicuity by 13%. However, in only 5% of the cases the rider's bright clothing enhanced the PTW conspicuity (ACEM, 2004).

The current study consisted of two complementary experiments, the first focused on PTWs' attention conspicuity and the second evaluated PTWs' search conspicuity. Based on the reviewed literature, the influence of the driving environment, rider's outfit, and PTWs distance from the viewer were evaluated. In the present experiments we studied the complex relations between these variables in parallel on both attention and search conspicuity. Thus, in both experiments the same sets of stimuli were used. By doing so, the influence of awareness on PTWs detection could be evaluated. The distinction between attention conspicuity and search conspicuity was expressed in two different levels of awareness to the presence of a PTW which can ultimately reflect the effect of 'set' or 'priming' (Tulving and Schacter, 1990).

Because the visual search behaviour is – at least in part – governed by the viewer's attention mechanism, we expected to find similar effects of the independent variables on attention conspicuity and on search conspicuity. Moreover, we assumed that the different riders' outfits will influence its attention-drawing effect in all environments, but that the effects will be specific to the contrast effects that are created in the different environments. The nature of the environment is important as there is a body of research that demonstrates that visual search and target detection deteriorate as the number of distractors and their similarity to the target object increases (Posner and Dehaene, 1994). Finally, we hypothesized that the detection rates will increase and reaction time will decrease as the PTW gets closer to the viewer, and when the viewer is cued to search for a PTW (in the search conspicuity experiment).

2. Experiment 1: attention conspicuity

This experiment focused on PTW conspicuity in terms of the probability that a PTW will be detected by un-alerted viewers (i.e., when viewers are not primed to expect a PTW within a realistic driving scene). Conspicuity was evaluated at various distances from the viewer, at different traffic environments and with different PTW rider's outfits.

2.1. Methods

2.1.1. Participants

A total of 66 undergraduate Ergonomics students (36 males and 30 females) participated in this experiment, with an average age of 25.8 years (SD = 4.95). All had a valid driver license, and 6 also had a PTW license. The average driving experience was 8.3 years (SD = 4.18). Visual acuity was measured to ensure that the results would not be biased by differences between the participants in the two experiments due to differences in acuity. All participants had (corrected) Snellen visual acuity of 6/9 (20/30) or better. The experiment was conducted under laboratory conditions, and the participants were recruited by advertisements on the Ergonomics course website. No other selection criteria were applied.

2.1.2. Driving sceneries

Twelve video clips of three driving scenes were staged and captured using a high definition video camera. The driving scenes included: (i) urban straight road, (ii) urban traffic circle and (iii) inter-urban road. Each driving scene included multiple motor vehicles from different categories (e.g., cars, trucks, motorcycles, etc.). The use of headlights by the other motor vehicles was not controlled. Four video clips were sampled from each of the driving scenes: three with a PTW and one without a PTW (a control clip). The three PTW video clips in every driving scenario differed in the PTW rider's outfit. The outfits included: (i) black clothing with a black helmet, (ii) white clothing with a bright colored helmet and (iii) reflective vest with a bright colored helmet. The PTWs headlights were activated in all tested conditions. The pictures of the driving scenarios used in the experiment were systematically sampled from these video clips, to obtain pictures of the PTW at different distances from the viewer.

The field of view presented in the driving scenes was 28° horizontal, and 19° vertical. The PTW distance from the viewer was represented by the height of the PTW figure measured in pixels (the smaller the height, the farther away the PTW) and was labeled: "very small" (15 pixels), "small" (30 pixels), "medium" (60 pixels), and "large" (120 pixels). Given the height of the PTW figures in pixels, and average of 65 cm viewing distance from the screen the angular size of the angular size of the "very small" PTW was 0.44°, "small" was 0.88°, "medium" was 1.76°, and "large" was 3.52°.

2.1.3. Procedure and experimental design

The experiment was divided into four successive phases. First, the participants filled out a demographic and driving experience questionnaire. Following that they were presented with the instructions and received six training trials (with the ability to perform additional training if the participant felt that he/she needed them). The last phase was the experimental session in which the participants were presented with a series of 72 pictures: 36 with a PTW and 36 control pictures without one. All participants were exposed to the same set of pictures. The pictures were randomly presented and each picture was presented for a fixed duration of 600 ms. After the picture disappeared, the participant had to report what kinds of motor vehicles were present in the picture. The reporting process was computerized and the participants simply had to select the vehicle types from a list on the screen.

Table 1
Summary of detection rates for the independent variables.

	Detection rate (%)
PTW size (in pixels)	
15	26
30	48
60	89
120	97
PTW outfit	
Black	63
Reflective	66
White	67
Driving environment	
Urban straight road	53
Urban traffic circle	57
Inter-urban road	86

2.1.4. Software and display

The experiment was conducted using a desktop PC and a 17″ in 1024 × 768 resolution LCD monitor. The dedicated experimental platform which controlled the picture presentation and logged the participants' responses was written in C#.

2.1.5. Data analysis

The independent variables were: (i) driving environment, (ii) PTW rider's outfit, and (iii) PTWs distance from the viewer. The dependent variable was whether the PTW was detected or not. The analysis examined the probability to detect a PTW in each of the conditions using generalized linear models (GLM). The GLM included the driving scenarios and PTW rider's outfit as independent factors and the PTW distance from the viewer as a covariate. The final model included all main effects and all interactions. A stepwise model selection based on Akaike Information Criterion (AIC) did not yield a better model. There was a significant 3-way interaction, so in order to have a better understanding on the way the driving scenarios and PTW rider's outfit affect the detection, a reduced GLM was produced for each driving environment (Harrell, 2001).

2.2. Results

Overall, out of 2376 pictures that included PTW, only 1554 PTWs were detected (65.4%). The detection rates summarized in Table 1 illustrate the effect of each independent variable on PTW detection. The PTWs size represents its distance from the viewer, where 15 pixels are the smallest (i.e., the farthest) and 120 pixels are the largest (i.e., the closest). For an un-alerted viewer, at the closest distance (120 pixels), the PTW was almost always identified [mean = 97% SD = 3%]. The detection rates in all the PTW rider's outfit conditions were similar at about 65%. When looking at the detection rate as a function of the driving environment, we can see that the detection in the inter-urban environment was better than the rates obtained in the urban environments.

Fig. 1 illustrates the detection rates of a PTW as a function of its size (distance from the viewer) and the PTW rider's outfit. The GLM analysis of PTW detection rates yielded a significant main effect of the distance from the viewer ($\chi^2(3) = 76.01$, $p < .001$). As expected, the detection rates increased as the PTWs distance from the viewer decreased. The rider's outfit had a marginally significant main effect on detection ($\chi^2(2) = 5.95$, $p = .051$). However, both interactions of the PTWs distance from the viewer with the rider's outfit and with the driving environment were significant ($\chi^2(6) = 79.36$, $p < .001$ and $\chi^2(6) = 85.85$, $p < .001$, respectively).

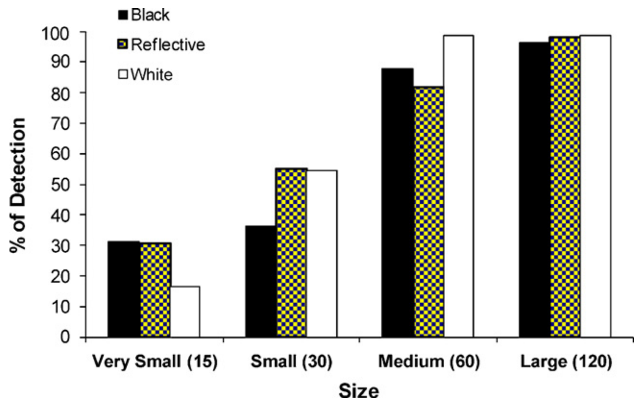

Fig. 1. Percent of PTW detection rates as a function of the PTW size and the rider's outfit.

The results shown in Fig. 1 do not take into consideration the significant three way interaction between driving environment, PTW size and PTW rider's outfit ($\chi^2(6) = 102.06$, $p < .001$). Based on the relation between contrast and conspicuity, the following analysis examined the effect of the PTW rider's outfit and its distance from the viewer on the detection rates in each driving environment separately.

Table 2 shows the detection rates of the PTW in each driving environment. The analysis of detection rates in the urban straight road indicated that the effect of outfit on PTW detection was depended on the PTWs distance from the viewer and was significant only at the "very small" to "medium" sizes ($\chi^2(3) = 18.42$, $p < .001$ and $\chi^2(3) = 16.22$, $p < .001$, respectively). In both sizes "very small" and "small" the reflective outfit significantly increased the detection rates compared to the black and white outfits ($\chi^2(6) = 19.27$, $p = .003$ and $\chi^2(6) = 32.54$, $p < .001$, respectively). However, at "medium" size, when the PTW was relatively close to the viewer, the detection rate of a rider wearing a white outfit was significantly higher than both reflective and black outfits ($\chi^2(6) = 24.57$, $p < .001$ and $\chi^2(6) = 14.10$, $p = .028$).

In the urban traffic circle environment the white outfit presented an advantage when trying to detect a PTW. When the PTW was "very small" or "small" the detection rates for the white outfit were significantly higher than when the outfit was black ($\chi^2(6) = 13.97$, $p = .030$ and $\chi^2(6) = 20.79$, $p = .002$, respectively). A linear contrast analysis yielded a marginally significant difference between the detection rates of the black and reflective outfits in the "small" size condition ($\chi^2(6) = 12.28$, $p = .056$). In the inter-urban road environment, a significant difference was found only in the "very small" PTWs size. The detection rates of the black outfit were significantly higher than the rates obtained in both white and reflective clothing ($\chi^2(6) = 82.79$, $p < .001$ and $\chi^2(6) = 63.33$, $p < .001$, respectively). In addition, the comparison between the reflective and white detection rates yielded higher detection rates for the reflective outfit ($\chi^2(6) = 18.73$, $p = .004$).

Table 2
Summary of the PTW detection rates (%) by driving environment.

Outfit	PTWs' size			
	Very small (15)	Small (30)	Medium (60)	Large (120)
Urban straight road				
Black	5	6	85	97
Reflective	24[a]	44[a]	68	98
White	5	11	97[b]	100
Urban traffic circle				
Black	3	3	79	92
Reflective	14	23	77	95
White	36[b]	67[b]	100	95
Inter-urban road				
Black	86[c]	100	100	100
Reflective	55	98	100	100
White	9	86	98	100

[a] The reflective outfit significantly increased detection compared to the black and white outfits.
[b] The white outfit significantly increased detection compared to the black and reflective outfits.
[c] The black outfit significantly increased detection compared to the white and reflective outfits.

2.3. Discussion

This study examined factors that can influence the attention conspicuity of a PTW as measured in terms of its detectability. The results demonstrated the complex relations among the three factors studied: rider's clothing, traffic environment, and PTWs distance. As expected, and similarly to previous studies (Hole et al., 1996; Janoff and Cassel, 1971b in Thomson, 1980), the PTWs distance from the viewer had a consistent significant effect on detection regardless of the driving environment and conspicuity treatments. Even though the participants were not specifically instructed to search for a PTW in the pictures, below a certain distance the detection rate was very high and unaffected by the conspicuity treatments. At the closest distance, the PTW was almost always detected (97%), while at the farthest distance the detection rate was only 26%.

Similarly to previous findings documented in the literature (e.g., Hole et al., 1996; Thomson, 1980; Williams and Hoffmann, 1979; Wulf et al., 1989) this study demonstrated how PTWs conspicuity depends on environmental features. When the PTW was distant from the viewer ("very small" and "small"), the different outfit conditions and the driving environments affected the conspicuity. In the urban streets, where the PTWs background was more multi-colored (i.e., varied) the reflective and white outfits increased the conspicuity compared to the dark clothing condition. In contrast, on the inter-urban road, where the background was only the bright blue sky, the dark outfit provided an advantage and increased the conspicuity of the PTW. These findings are consistent with the results presented in Thomson's review paper (1980) which stated that the higher the contrast between a target and its surrounding the greater the probability of detecting it.

3. Experiment 2: search conspicuity

This experiment focused on PTWs search conspicuity, where search conspicuity is defined as the ability to detect a PTW while actively searching for it. We evaluated search conspicuity in terms of the probability of detecting a PTW and the detection reaction time to its presence. The search conspicuity was evaluated in the same traffic environments, the same PTW conspicuity treatments, and the same PTW distances from the viewer as in experiment 1.

3.1. Methods

The same pictures used in experiment 1 were used in this experiment. The experimental platform used to display the pictures in this experiment was identical to the one described in experiment 1 except for the following:

- Participants were instructed to search for a PTW in each of the pictures and report its presence or absence as soon as they reached a decision. They were not asked about any other vehicle types.
- While viewing the picture, the participants were instructed to click on a button as soon as they reached the decision whether a PTW was present in the picture or not.

Table 3
Summary of the PTW detection rates and RT for the independent variables.

	Detection rate(%)	Reaction time (ms)
PTW size (in pixels)		
15	92	1972
30	96	1622
60	99	1187
120	100	1077
PTW outfit		
Black	96	1455
Reflective	98	1451
White	96	1451
Driving environment		
Urban straight road (1)	96	1635
Urban traffic circle (2)	95	1539
Inter-urban road (3)	99	1191

- Reaction time (RT) was measured in milliseconds and the maximal presentation time of each picture was 10 s, after which the picture disappeared.

3.1.1. *Participants*

A total of 64 undergraduate Ergonomics students with a valid driver license (32 males and 32 females) participated in this experiment, with average age of 25.4 years (SD = 1.70). The average driving experience was 7.6 years (SD = 2.04), and 5 drivers were also licensed to ride a PTW (of whom 1 driver had a scooter license). All participants had (corrected) Snellen visual acuity of 6/9 (20/30) or better. In all other respects the participants and selection criteria were identical to experiment 1.

3.1.2. *Data analysis*

Similarly to experiment 1, the independent variables included the different driving scenarios, PTW rider's outfit, and the PTWs distance from the viewer. The detection rate was analyzed using GLM and the reaction time was analyzed by linear regression. As in experiment 1, a significant 3-way interaction was found. Therefore, reduced GLM and linear regression models were produced separately for each driving environment.

3.2. *Results*

The average PTW detection rate of the alerted viewers was 97% across all tested conditions (2195 out of 2268 PTWs were detected). The average RT to detect a PTW was 1452 ms (SD = 896.60) across all driving environments, versus 2840 ms (SD = 1673.91) to decide that there was no PTW in the picture. Table 3 shows the detection rates and reaction times across the three experimental conditions. The difference between the detection rates of the largest and the smallest sizes (120 pixels and 15 pixels, respectively) was only 8%. Correspondingly, the RT to the smallest PTW size was approximately twice as long (1 s longer) as to the largest size of the PTW. Similarly to the results obtained in experiment 1, detection rates on the inter-urban open road environment were the highest and – in parallel – the RT was the shortest.

Linear regression analysis of the reaction times yielded significant main effects of PTWs' distance from the viewer and driving environment [$F(3, 2228) = 151.42$, $p < .001$; $F(2, 2228) = 64.05$, $p < .001$, respectively]. Significant two way interactions were found between the PTWs distance from the viewer and the driving environment [$F(6, 2228) = 11.42$, $p < .001$], and between the PTW rider outfit and the driving environment [$F(4, 2228) = 8.47$, $p < .001$]. Moreover, there was also a significant three way interaction among all three independent variables (PTWs distance from the viewer × PTW rider's outfit × driving environment) [$F(12, 2228) = 2.78$, $p = .001$].

Table 4
Summary of PTW RT (ms) by driving environments.

Outfit	PTWs' size			
	Very small (15)	Small (30)	Medium (60)	Large (120)
Urban straight road				
Black	2087	1867	1431	1055
Reflective	1888[a]	2102	1564	1117
White	2393	2063[b]	1302	1086
Urban traffic circle				
Black	2573	2328	1119	1250
Reflective	2093[c]	1788[c]	1224	1069
White	2253[c]	1497[c]	1037	1090
Inter-urban road				
Black	1202[d]	1072	1046	1010
Reflective	1676	1224	969	1052
White	1994	1231	1064	1020

[a] The reflective outfit significantly decreased RT compared to the white outfit.
[b] The white outfit significantly decreased RT compared to the reflective outfit.
[c] The white and reflective outfits significantly decreased RT compared to the black outfit.
[d] The black outfit significantly decreased RT compared to the white and reflective outfits.

In general, the RT increased as the PTW distance from the viewer decreased. Similarly to the trend established in experiment 1, the reaction time required to detect the "very small", "small" and "medium" PTWs in the inter urban open environment were significantly lower than the ones obtained in both urban roads. The reaction times obtained in the urban environments (straight road and traffic circle) also differed significantly from each other. For the "very small" PTW size the longest RT was in the crowded traffic circle, whereas for the "small" to "medium" PTW sizes, the straight crowded road yielded the longest RT.

Table 4 illustrates the influence of the PTW rider's outfit on its detection time in each of the driving environments. The analysis of RT obtained in the straight urban road yielded a significant main effect of the PTWs distance from the viewer [$F(3, 743) = 51.38$, $p < .001$]; the smaller the PTW the longer the RT. Moreover, a marginally significant interaction was found between the PTWs distance from the viewer and the rider's outfit [$F(6, 743) = 1.87$, $p = .08$]. It seems that the RT to the white and reflective outfits differed in the "very small" and "small" sizes. At the farthest distance, the reflective vest significantly decreased the time to detect a PTW, compared to the white outfit condition. However, in the "small" size, where the PTW was twice as close, the RT was significantly higher with the reflective outfit than with the white outfit ($p = .039$).

RT in the urban traffic circle was significantly affected by the interaction between the rider's outfit and PTWs distance from the viewer [$F(6, 741) = 2.75$, $p = .012$]. Linear contrast analysis showed that the RTs in both "very small" and "small" sizes were significantly shorter when the rider was wearing reflective or white outfits, than when wearing a black outfit ($p < .001$ and $p < .001$, respectively).

In general, the RT required to detect a PTW was the shortest on the inter urban road (see Table 3). The significant interaction between the PTWs distance from the viewer and the PTW rider's outfit in the inter-urban environment [$F(6, 744) = 5.639$, $p < .001$] indicated that the black outfit significantly decreased the RT when detecting a distant PTW. Linear contrast analysis showed that the RT to the "very small" black outfit was significantly shorter than the RTs of both reflective ($p = .007$) and white ($p < .001$) outfits.

3.3. *Discussion*

The second experiment examined search conspicuity of a PTW in terms of the ability and the time needed to detect a PTW by an alerted viewer. The RT was found to be a more sensitive and adequate measure than probability of detection when evaluating the influence of the different treatments on PTWs search conspicuity. In general, the RT decreased as the distance from the viewer decreased. When the PTW was close ("large") the average reaction time required to detect it was approximately 1 s in all treatments. Therefore, given the importance of early PTW detection, the results of this experiment focused on the ability to detect the PTW when it was distant from the viewer (sizes: "very small" and "small").

The environmental characteristics significantly influenced the time needed to detect a PTW. The reaction times obtained in both urban environments were significantly longer than the ones obtained in the inter-urban environment. A possible explanation is that the urban environment contains a large and diverse repertoire of objects, and each object can act as a distractor and consume some of the mental resources that are required to detect the PTW.

Similarly to the results obtained in experiment 1 and previous studies, the effectiveness of the conspicuity treatment depended on the contrast between the target (PTW) and its background. The reflective and white clothing provided an advantage to the detection of the PTW in the urban environments only when the PTW was far from the viewer. In contrast, in the inter-urban environment the bright surroundings enhanced the detection of the PTW rider wearing a black outfit. These results are partly in line with the results presented by Hole et al. (1996) who evaluated the influence of different types of riders' clothing and the use of headlights on PTWs visibility. Hole et al. (1996) showed that in a semi-rural environment with a relatively uncluttered background, dark clothing was superior to bright clothing in terms of PTW visibility. However, their results in the urban environment were not so consistent, and the reaction times to the different clothing conditions were influenced by the presence or absence of the headlights.

3.4. General discussion and conclusions

This study consisted of two complementary experiments that illustrated the contribution of various factors to PTW detection. The first experiment addressed the issue of detection in terms of attention conspicuity, while in the second experiment we addressed the search conspicuity of the PTW. In both experiments the aim was to identify factors that can increase the ability of a road user to detect a PTW. Each experiment represented a different level of awareness. In the attention conspicuity experiment, participants were not cued to search for or detect a PTW and were instructed to report all types of motor vehicles present in the driving scenes, while in the search conspicuity experiment they were cued and instructed to report on the presence or absence of a PTW in the same driving scenes.

The detectability of a PTW is influenced by a blend of visual aspects that are related to the PTW, its rider, the driving environment, and the viewers' level of awareness. When the PTW was very close and subtended a large visual angle of the observer's visual scene, both un-alerted and alerted viewers had near perfect detection rates (97% and 100%, respectively). However, at this proximity it may be too late to prevent an accident. Thus, it is important to evaluate potential measures to increase early detection of the PTW; when it is still distant from the viewer. As such, at the farthest distance the increased awareness (search conspicuity experiment) yielded detection rates three times higher than in the attention conspicuity experiment (92% versus 26%). Since the level of awareness in the attention conspicuity experiment was not manipulated, it can be regarded as a reflection of PTWs attention conspicuity at 'normal' levels of expectancy; which are typically low due to the low exposure frequencies. However, the increase in awareness level in the search conspicuity experiment, can give an indication on the maximal enhancement possible to detect a PTW in spite of the low exposure frequencies. Hence, increasing awareness of the potential presence of a PTW can counteract the negative influence of its low exposure frequencies.

The use of color and contrast as means to increase conspicuity is familiar in different fields. The color attributes of an outfit are frequently used for different and sometimes opposite purposes. For example, camouflage (in army clothing) and prominence (yellow outer clothing of maintenance workers). However, the attempt to implement the benefits of contrast and color on a PTW rider's outfit can be complicated due to the ever changing environments and the PTWs dynamics. As demonstrated in the two experiments, the attention conspicuity and search conspicuity of a PTW rider can be increased by using an appropriate outfit that distinguishes the rider from a given background scenery. Unfortunately, detectability – especially attention conspicuity – is compromised by the perceptual characteristics of the environment that change continuously along a route. Thus, to increase detectability, PTW riders need to be aware of the perceptual aspects of their riding environment. In parallel, the results of the second experiment with alerted viewers demonstrate that other road users (e.g., car drivers) can improve their detection performance when they increase their level of expectancy and awareness concerning a possible existence of a PTW on the road (as drivers with high expectation obtained nearly 100% detection rates).

In summary, the results of the two experiments emphasize the need to direct efforts to enhance the PTW conspicuity in a manner that would be relevant, applicable, and efficient in multiple, varied environments. In addition, the increase in awareness of all road users to the possible presence of PTW (perhaps as part of the driving learning process, or through advertisements) can dramatically enhance its detectability.

4. Limitations and recommendations

The current experiments addressed the attention and search conspicuity of a PTW using pictures as stimuli. The results obtained in both experiments illustrated the potential of increasing PTW conspicuity by increasing the motorist's level of expectancy as well as by altering the rider's outfit. However, the stimuli were limited to still pictures, and the participants were two independent groups. We, therefore, recommend that future studies explore the potential of these types of interventions by (1) evaluating the attention and search conspicuity using dynamic stimuli that will enable the assessment of both rider's outfit and other conspicuity treatments in a more realistic manner. (2) if possible, develop an experimental protocol that will enable the evaluation of both attention and search conspicuity in a within-subject design.

Acknowledgments

Work on this study was supported in part by the EC 2BeSafe project of the 7th European Framework.

References

ACEM, 2004. MAIDS: In-Depth Investigations of Accidents Involving Powered-Two-Wheelers. Association de Constructeurs Européens de Motorcycles (ACEM), Brussels, BG, http://www.maids-study.eu.

Brouwer, R.F.T., Janssen, W.H., Theeuwes, J., Duistermaat, M., Alferdinck, J.W.A.M., 2004. Do Other Road Users Suffer From the Presence of Cars That Have Their Daytime Running Lights on? TNO Human Factors Research Institute TM, Soesterberg, p. 28, (26 ref.; Report TNO TM-04-C001).

Clarke, D.D., Ward, P., Bartle, C., Truman, W., 2004. In-depth Study of Motorcycle Accident. Road Safety Research. Report No. 54. Department for Transport, London.

Gershon, P., Ronen, A., Oron-Gilad, T., Shinar, D., 2009. The effects of an interactive cognitive task (ICT) in delaying fatigue symptoms in driving. Transport. Res. F (Traffic Psychology and Behavior) 12, 21–28.

Harrell, F.E., 2001. Regression Modeling Strategies with Applications to Linear Models, Logistic Regression and Survival Analysis. Springer.

Hole, G.J., Tyrrell, L., Langham, M., 1996. Some factors affecting motorcyclists' conspicuity. Ergonomics 39, 946–965.
Horswill, M.S., Helman, S., Ardiles, P., Wann, J.P., 2005. Motorcycle accident risk could be inflated by a time to arrival illusion. Optometry Vision Sci. 82 (8), 740–746.
Hurt Jr., H.H., Ouellet, J.V., Thom, D.R., 1981. Motorcycle Accident Cause Factors and Identification of Countermeasures: volume 1: technical report. National Highway Traffic Safety Administration. Report DOT-HS-805-862.US. Department of Transportation, Washington, DC.
Mannering, F.L., Grodsky, L.L., 1995. Statistical analysis of motorcyclists' perceived accident risk. Accident Anal. Prev. 27, 21–31.
NHTSA, 2009. Trafic Safety Facts 2008 Data-Motorcycles. National Highway Traffic Safety Administration. Report HS811 159. US. Department of Transportation, Washington, DC.
Olson, P.L., Halstead-Nussloch, R., Sivak, M., 1981. The effect of improvements in motorcycle/motorcyclist conspicuity on driver behavior. Hum. Factors 23 (2), 237–248.
Posner, M.I., Dehaene, S., 1994. Attentional networks. Trends Neurosci. 17, 75–79.
Shinar, D., 2007. Traffic safety and human behavior. Motorcyclists and Riders of Other Powered Two-Wheelers, vol. 16. Elsevier, Oxford, UK, pp. 657–694.
Thomson, G.A., 1980. The role frontal motorcycle conspicuity has on road accidents. Accident Anal. Prev. 12, 165–178.
Tulving, E., Schacter, D.L., 1990. Priming and human memory systems. Science 247 (4940), 301–306 [JDR].
Wells, S., Mullin, B., Norton, R., Langley, J., Connor, J., Lay-Yee, R., Jackson, R., 2004. Motorcycle rider conspicuity and crash related injury case-control study. Brit. Med. J. 328, 857–863.
Williams, M.J., Hoffmann, E.R., 1979. Motorcycle conspicuity and traffic accidents. Accident Anal. Prev. 11, 209–224.
Wulf, G., Hancock, P.A., Rahimi, M., 1989. Motorcycle conspicuity: an evaluation and synthesis of influential factors. J. Safety Res. 20, 153–176.