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Testing for effects of racial attitudes and visual contrast on the speed of a driver's response to a pedestrian

Robert D. Mather *, Patricia R. DeLucia

Department of Psychology, Texas Tech University, Lubbock, TX 79409-2051, USA

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Abstract

Although ethnic minorities are overrepresented in pedestrian-vehicle collisions, previous driving studies did not examine racial attitudes in such collisions. Our objective was to determine whether the speed of a driver's response to a pedestrian was affected by the driver's racial attitudes and the contrast between the pedestrian's skin colour and background. Participants viewed simulated driving scenes of a pedestrian on a road and pressed a button as soon as they saw an obstacle. Visual information, but not racial attitudes, affected the time it took observers to respond to pedestrian and non-pedestrian stimuli in driving scenes. Results indicated that contrast affected response time even when the stimulus was subliminal. We believe this is the first demonstration of contrast effects with subliminal stimuli in a driving context. Results have implications for traffic safety and for methodology used to study racial attitudes.

Keywords: Visual contrast; Pedestrian conspicuity; Driving; Visual performance; Attitudes; Social cognition; Human factors

1. Introduction

In the United States, ethnic minorities are overrepresented in pedestrian-vehicle collisions (Hilton, 2006; US Department of Transportation, 1999). From January 1995 to May 1996, 51.3% of pedestrians struck in a roadway were Blacks and Hispanics, while 45.0% were Whites (US Department of Transportation, 1999). From 1999 to 2004, the number of White "non-occupant" fatalities comprised a lower percentage of all motor vehicle fatalities compared to ethnic minority non-occupant fatalities in every age group older than 16 years (Hilton, 2006). What is the basis for these findings? We consider two factors: Visual information and racial attitudes.

* Corresponding author. Address: University of Central Oklahoma, Department of Psychology, 100 North University Drive, Edmond, OK 73034, USA. Tel.: +1 405 974 5474; fax: +1 405 974 3822.

E-mail address: rmather@ucok.edu (R.D. Mather).

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1.1. Visual information

Driving performance relies heavily on vision. Many visual factors can contribute to pedestrian-vehicle collisions. One critical factor is the visibility of the pedestrian to the driver. Sleight (1972) proposed visual contrast as one factor that affects such visibility. We focus on the contrast between the pedestrian and environmental background.

To avoid pedestrian-vehicle collisions, drivers must detect the pedestrian by visually separating the pedestrian from the background of the road, sky, and other objects. To the extent that a pedestrian's skin is exposed, a person's skin colour contributes to contrast. A light-skinned person should be more difficult to detect during daylight compared with nighttime. Similarly, a dark-skinned person should be more difficult to detect during nighttime. Indeed, in the United States, the rate of *fatal* pedestrian-vehicle collisions is higher for Whites than Blacks during daylight conditions; the converse is true during nighttime (US Department of Transportation, 2004). This suggests that a pedestrian's skin colour contributes to the visibility of a pedestrian.

1.2. Attitudes

An observer's expectations also affect detection. Shinar (1985) demonstrated that the distance at which an observer detected a pedestrian was greater when the pedestrian wore a reflective tag compared with no tag. When informed that the tag represented a pedestrian, observers' detection distances increased. Therefore, it is important to consider expectations when investigating factors that contribute to pedestrian-vehicle collisions.

An attitude, or evaluation, can contribute to expectations about members of a group; attitude-consistent behaviour has been observed through subliminal primes (e.g., Bargh, Chen, & Burrows, 1996). Attitudes can be implicit (not open to awareness) or explicit (open to awareness) (Greenwald & Banaji, 1995). Indeed, it has been shown that racial attitudes can influence a person's behaviour without their awareness (e.g., Bargh et al., 1996, Experiment 3; Chen & Bargh, 1997; Dovidio, Kawakami, Johnson, Johnson, & Howard, 1997, Experiment 3).

Previous driving studies did not consider the role of racial attitudes in pedestrian-vehicle collisions (e.g., Shinar, 1985; Wood, Tyrrell, & Carberry, 2005). However, racial attitudes affected visual performance in other tasks. Using computer-generated scenes, Greenwald, Oakes, and Hoffman (2003) demonstrated that racial attitudes affected the classification of people (criminal, police officer, citizen) in a weapon identification task. Also, participants had more difficulty distinguishing guns from harmless objects when guns were held by Blacks compared with Whites, suggesting that visual information affected performance.

The US Department of Transportation (Hilton, 2006) recommended more research examining the relationship between race and traffic crashes. Our experiments are the first to manipulate a pedestrian's race to test effects of racial attitudes and visual information on pedestrian-vehicle collisions. We focused on two questions. Is the speed of a driver's response to a pedestrian affected by the driver's racial attitudes? Is the speed of a driver's response to a pedestrian affected by the contrast between the pedestrian's skin colour and the background?

2. Experiment 1

2.1. Method

2.1.1. Participants

Twenty-nine students (14 women; 15 men) at Texas Tech University received credit toward a psychology course. All had normal or corrected visual acuity and were naïve as to the hypotheses of the experiment. Five participants (2 women; 3 men) were not included in the analysis because they indicated awareness of the stimuli during an awareness check; the latter method is described subsequently. The final sample included twenty-four participants (12 women; 12 men; 21 White; 1 Hispanic; 1 Asian; 1 unknown).

2.1.2. Displays

Computer simulations were generated by a computer and presented in 640×480-pixel resolution on a 43.18-cm colour monitor with a 120 Hz refresh rate. Displays consisted of perspective drawings of a three-dimensional scene in which the virtual self moved along a road (see Fig. 1).

During self motion, a *subliminal stimulus* was presented for 25 ms, followed by a *pattern mask* for 75 ms. The mask consisted of white dots against a black background with a bell-shape similar to the shape of the pedestrians. A square *obstacle* followed the mask and expanded optically until the participant responded.

The stimulus was presented subliminally to avoid response biases due to demand characteristics of the experiment (Bargh & Chartrand, 2000; Bargh et al., 1996). The design of the subliminal stimulus and mask was based on prior studies that used similar stimuli to activate implicit racial attitudes (see Bargh et al., 1996, Experiment 3; Dovidio et al., 1997, Experiment 1).

Several characteristics of the scene were manipulated. The *stimulus* depicted a male person or a square. The *stimulus colour* was black or white. The person stimuli were of the White or Black race and were adapted from Greenwald et al. (2003) who showed that these pictures activated racial attitudes. Each person stimulus was embedded within a square with a colour that matched the road colour of the scene. Each picture showed a person in a white T-shirt with their face and arms exposed. Thus, the same amount of skin was present in each picture. Clothing was held constant, resulting in a greater mean luminance for the White pedestrian than the Black pedestrian. The square stimuli had a white or black hue and served as control stimuli to distinguish effects of racial attitudes from visual information (contrast). The *road colour* and *sky colour* were light grey or dark grey. This allowed a measure of the effect of contrast between stimulus and the background. The *obstacle colour* was black or white. Finally, the stimulus appeared 4.23 s or 6.73 s after the scene started. The order of these *onset times* was randomized across trials so that observers could not predict when the stimulus would appear. Each scene was replicated six times in a randomized order for a total of 384 trials.

2.1.3. Awareness checks

The awareness checks were conducted as follows: Immediately following data collection, participants were shown two sample scenes and asked to draw the scenes. Only one scene contained a subliminal person. Subsequently, participants were asked a series of questions regarding their awareness, without specifically mentioning the subliminal object. (i.e., Did you notice anything unusual about the squares?)

2.1.4. Procedure

Participants viewed the scenes through a reduction tube from a distance of .46 m (the scenes subtended 48° diagonally). Participants were instructed to press a mouse button as soon as they saw the obstacle

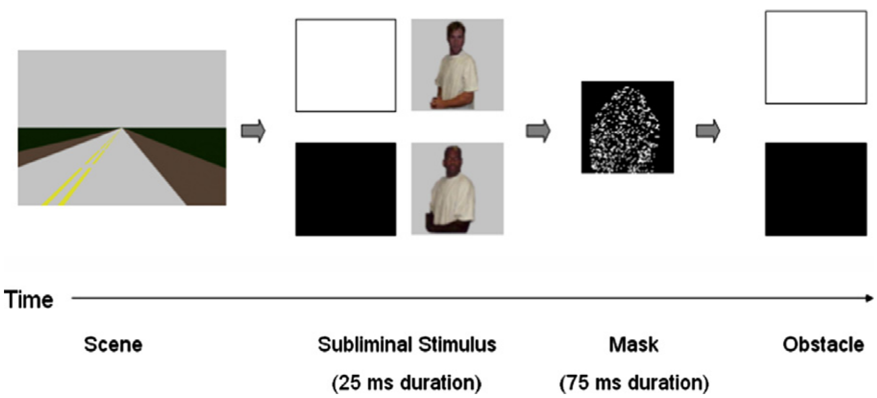

Fig. 1. Schematic representation of the temporal sequence of the displays. Time increases from left to right. (a) Driving scene (light grey sky and a light grey road). (b) Subliminal stimulus (white square, White pedestrian, black square or Black pedestrian). (c) Mask. (d) Obstacle (white square or black square).

and to do so as rapidly and as accurately as possible. No feedback was provided. Response time was measured as the time between stimulus onset (i.e., pedestrian or square) and the participant's response. After completing all trials, participants completed the Modern Racism Scale (MRS; McConahay, Hardee, & Batts, 1981) which is a measure of explicit racial attitudes. Positive scores on the MRS indicate negative attitudes toward Blacks. A dissociation between implicit and explicit measures of racial attitudes was found in which participants report non-prejudiced explicit racial attitudes but demonstrate prejudiced implicit racial attitudes (Cunningham, Preacher, & Banaji, 2001). Thus, we did not expect the sample to report racial bias on the explicit MRS. Nevertheless, we included the MRS to describe the explicit racial attitudes of the sample.

2.2. Results and discussion

The mean score on the MRS was -3.63, SD = 5.21. As expected, this sample of participants was unbiased in their explicit racial attitudes. Results are summarized in Fig. 2 and suggested that response time was determined by visual information rather than by racial attitudes. Response time was analyzed with a stimulus × stimulus colour × road colour × sky colour × obstacle colour × onset time repeated-measures ANOVA. An effect of racial attitude would be demonstrated by a stimulus × stimulus colour interaction, in which response times are faster to the White person compared to the Black person, but do not differ between white and black squares. This interaction was not significant in Experiment 1, 2, or 3.

There was a stimulus × stimulus colour × sky colour interaction, $F(1,23) = 5.41$, $p < .03$, $w^2 = .10\%$. Simple interactive effects indicated that mean response time was faster when a black square stimulus was presented against a light grey sky compared with a dark grey sky, $F(1,45) = 7.99$, $p < .01$. Similarly, response time was faster when a white square stimulus was presented against a dark grey sky than compared with a light grey sky, $F(1,45) = 6.08$, $p < .02$. Finally, when the sky was dark grey, response time was faster to a white square stimulus compared with a black square stimulus, $F(1,40) = 13.17$, $p < .01$. These results show that visual information (contrast) that characterizes a subliminal stimulus can influence response time to a stimulus during a simulated driving scene. While it is not surprising that the visual contrast of a stimulus affected performance (Wood et al., 2005), new here is the finding that such effects can occur when the stimulus is subliminal. It becomes important to determine how effects of a stimulus can be moderated when the stimulus affects drivers without their awareness (Wilson & Brekke, 1994).

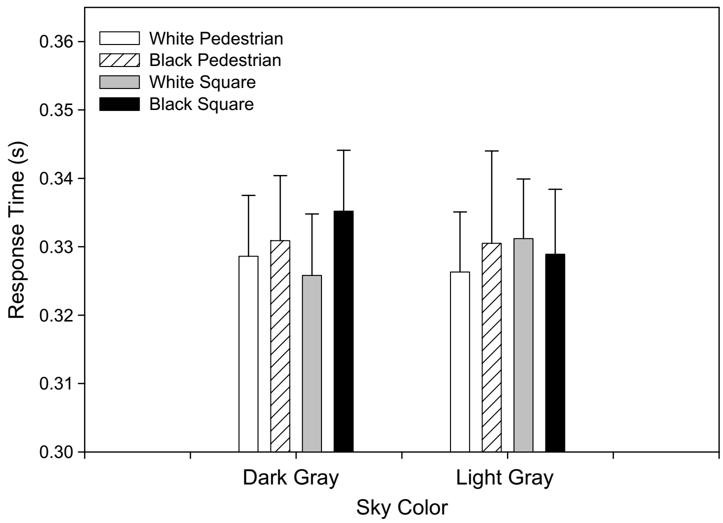

Fig. 2. Experiment 1. Mean response time as a function of stimulus type, stimulus colour, and sky colour. Error bars indicate ±1 standard error of the mean.

3. Experiment 2

We considered the possibility that our subliminal stimuli in Experiment 1 did not activate racial attitudes as they did in prior studies (e.g., Greenwald et al., 2003). That is, perhaps participants did not process the subliminal pedestrians. In Experiment 2, we replicated the experiment with supraliminal stimuli.

3.1. Method

Twenty-four different students (12 women; 12 men; 17 White; 3 Black; 1 Hispanic; 2 Asian; 1 unknown) had the same characteristics as in Experiment 1. All indicated awareness of the supraliminal stimuli during the awareness check. The displays and procedure were identical to Experiment 1 except that the pattern mask was removed, eliminating backward masking.

3.2. Results and discussion

The mean score on the MRS was −4.07, SD = 5.56 again indicating unbiased explicit racial attitudes. Results are summarized in Fig. 3 and again suggested that response time was determined by visual information rather than by racial attitudes. As in Experiment 1, the stimulus × stimulus colour interaction was not significant. Therefore, even when the stimuli were supraliminal, racial attitudes did not affect response time.

There was a stimulus × stimulus colour × sky colour interaction, $F(1,23) = 4.39$, $p < .05$, $w^2 = .18\%$. As in Experiment 1, simple interactive effects indicated that mean response time was faster to the white square than the black square when the sky was dark grey, $F(1,44) = 68.78$, $p < .01$. Unexpectedly, simple interactive effects indicated that the mean response time was faster for the White person than the white square when the sky was light grey, $F(1,45) = 5.17$, $p < .03$. Similarly, response time was faster for the Black person than the black square when the sky was dark grey, $F(1,44) = 33.59$, $p < .01$. We considered two reasons for this result. First, the results may reflect general expectations regarding the presence of pedestrians on a road. Pedestrians are likely to be on or near a road, but abstract two-dimensional squares are not. Thus, it is reasonable to expect that the response to a person (expected) is faster than the response to a square (unexpected) (Alexander & Lunenfeld, 1986). Second, the contrast of the pedestrians was different than the squares. For example, the skin of the White pedestrian was darker than the white square and the skin of the Black pedestrian was lighter than

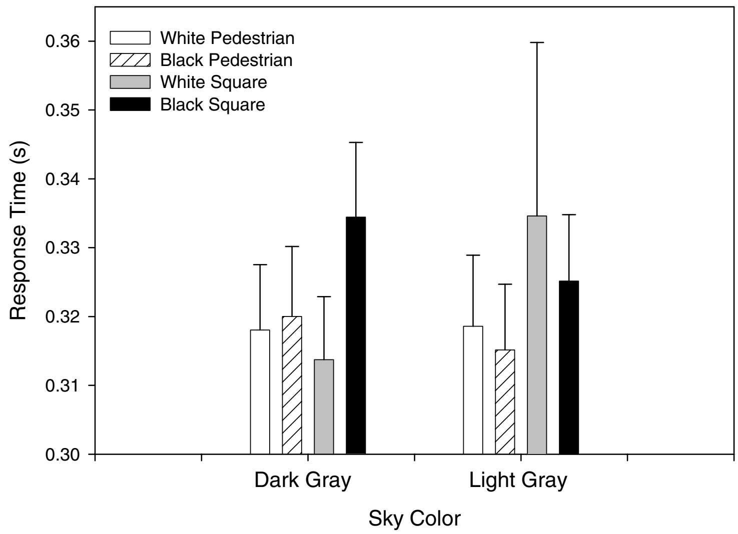

Fig. 3. Experiment 2. Mean response time as a function of stimulus type, stimulus colour, and sky colour. Error bars indicate ±1 standard error of the mean.

the black square. Thus, these results may indicate an effect of visual contrast, consistent with the results of Experiment 1. In any case, the results of supraliminal stimuli suggest that the lack of a stimulus × stimulus colour interaction in Experiment 1 was not due to a lack of processing of the subliminal pedestrians.

4. Experiment 3

The results of Experiment 2 suggest that the effect of racial attitude on performance was not significant even when racial attitudes were activated by supraliminal stimuli. We considered the possibility that racial attitudes were not activated in Experiments 1 or 2 because the stimulus, although putatively subliminal in Experiment 1 and supraliminal in Experiment 2, was too short for participants to process. We addressed this issue in Experiment 3 by using supraliminal stimuli presented for a longer duration than in the previous experiments.

4.1. Method

Twenty-four different students (12 women; 12 men; 20 White; 3 Black; 1 Hispanic) had the same characteristics as in Experiment 1. The scenes were the same as in Experiment 2 with two exceptions. First, the obstacle was removed. Hence, there was no pattern mask or obstacle. Only the pedestrian or square stimulus was presented. Second, this stimulus expanded optically until the participant pressed the mouse button (or until the virtual self passed the stimulus). The procedure was identical to Experiments 1 and 2.

4.2. Results and discussion

The mean score on the MRS was −4.79, SD = 5.62, again indicating unbiased explicit racial attitudes. Results are summarized in Fig. 4 and again suggested that response time was determined by visual information rather than racial attitudes. As in Experiments 1 and 2, the stimulus × stimulus colour interaction was not significant. Therefore, even when the pedestrian stimuli were longer in duration, the racial attitudes of the participants did not affect response time.

There was a road colour × stimulus interaction, $F(1, 23) = 13.62$, $p < .01$, $w^2 = .66\%$. Simple effects indicated that when the stimulus was a person, the response time was faster on a light grey road than on a dark

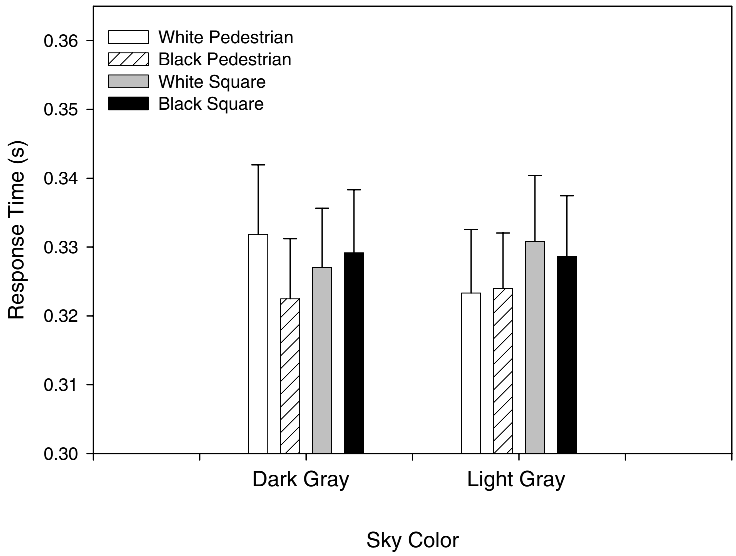

Fig. 4. Experiment 3. Mean response time as a function of stimulus type, stimulus colour, and sky colour. Error bars indicate ±1 standard error of the mean.

grey road, $F(1,44) = 19.87$, $p < .01$. There also was a stimulus × stimulus colour × sky colour interaction, $F(1,23) = 4.76$, $p = .04$, $w^2 = .13\%$. Simple interactive effects indicated that response time was faster to the White person when the sky was light grey (relatively low contrast) compared to dark grey (relatively high contrast), $F(1,45) = 8.35$, $p < .01$. This unexpected effect was not significant in Experiment 1 or 2. Further, the direction of this effect is opposite to an analogous effect obtained with squares in Experiment 1 in which response time was faster when a white square stimulus was presented against a dark grey sky (relatively high contrast) compared with a light grey sky (relatively low contrast). Further research is warranted.

Similarly, in Experiment 3, response time was faster to the Black person (relatively low contrast) than to the White person (relatively high contrast) when the sky was dark grey, $F(1,45) = 8.45$, $p < .01$. This unexpected effect also was not significant in Experiments 1 and 2. Further, the direction of this effect in Experiment 3 is opposite to an analogous effect obtained with squares in Experiment 1 in which response time was faster to a white square stimulus (relatively high contrast) than to a black square stimulus (relatively low contrast) when the sky was dark grey.

In Experiment 3, the finding that response times were faster to the Black person than to the White person when the sky was dark grey showed that the supraliminal stimuli were indeed processed by participants. The implication is that the absence of racial attitude effects in Experiments 1 and 2 was not due to a lack of stimulus processing. Experiment 3 also showed that response time was affected by visual contrast, although it is not clear why responses were faster to the stimuli that were relatively lower in contrast.

5. General discussion

The purpose of this study was to examine effects of attitudes and visual information on performance in a driving context. We focused on two questions. First, is the speed of a driver's response to a pedestrian affected by the driver's racial attitudes? Second, is the speed of a driver's response to a pedestrian affected by the contrast between the pedestrian's skin colour and the background?

5.1. Summary of results

The stimulus × stimulus colour interaction was not significant in Experiments 1, 2, or 3. The answer to our first question is "no". Experiments 1 and 2 showed that participants responded faster to high-contrast stimuli compared with lower-contrast stimuli when the stimulus was either subliminal or supraliminal. Experiment 3 showed that participants responded faster to low-contrast stimuli compared to higher contrast stimuli when the stimulus was relatively longer in duration. The answer to our second question is "yes". Moreover, Experiment 1 showed that the visual contrast of subliminally-presented squares affected response time, suggesting that visual information that characterizes a *subliminal* stimulus can influence response time to an obstacle during a simulated driving scene.

5.2. Implications for traffic safety

Our results have important implications for design. Overrepresentation of ethnic minorities in pedestrian-vehicle collisions may be partly due to visual factors such as contrast rather than to racial attitudes. This is important because pedestrians can control their contrast with safety aids but cannot directly control the racial attitudes of drivers. Aids such as reflector vests may require different designs for different skin tones and may need to vary based on time of day. This is consistent with the accident data showing that the rate of fatal pedestrian-vehicle collisions is higher for Whites than Blacks during daylight conditions; the converse is true during nighttime (US Department of Transportation, 2004).

Finally, we note that the current experiments were not designed to tease apart luminescence from semantic information that goes with skin colour. This would require a manipulation of the colour of the pedestrian's shirt. Instead, we held this constant because we wished to use the exact stimuli shown to activate racial attitudes by Greenwald et al. (2003). Future studies should manipulate the colour of the pedestrian's shirt to tease apart luminescence from semantic information that goes with skin colour.

5.3. Implications for methodology

These results also have implications for experimental design. Our finding that racial attitudes did not affect responses to pedestrians during simulated driving raises questions about prior reports that racial attitudes affected performance in other contexts (e.g., Greenwald et al., 2003). Since visual contrast contributed to response times in our driving simulation, visual contrast may also have played a role in the responses to stimuli in prior studies of racial attitudes. Few studies of racial attitudes considered effects of visual information (Eberhardt, Goff, Purdie, & Davies, 2004; Payne, Shimizu, & Jacoby, 2005). Although some studies of visual search for faces have controlled for luminance and contrast (e.g., Chiao, Heck, Nakayama, & Ambady, 2006), we believe that the current experiments represent the first study of racial attitudes that systematically manipulates contrast. Results indicated that visual contrast should be held constant in future studies of racial attitudes that use pictures.

5.4. Limitations and future directions

There are several limitations of the present study. First, although we obtained statistically significant effects, effect sizes were very small. This could be due to the use of a large experimental design which reduces the variance explained by each factor. Nevertheless, the largest significant difference between mean response times translates into .56 m (1.82 ft) travelled at 96.54 km/h (60 miles/h). This is important because faster reaction times translate into earlier detections of pedestrians. Future research should identify other factors that account for more variance in response times.

Second, our suggestion that the speed of a driver's response to a pedestrian is not affected by the driver's racial attitudes is based on a negative (i.e., nonsignificant) result. We cannot rule out that such an effect would be significant with a more powerful design. However, we note that the stimulus × stimulus colour interaction was not significant in Experiments 1, 2, or 3. Moreover, to increase statistical power, we conducted an ANOVA on the combined results of Experiments 1, 2, and 3. The same pattern of results regarding racial attitudes was obtained. The stimulus × stimulus colour interaction was not significant, and the stimulus × stimulus colour × sky colour interaction was significant. Moreover, using "experiment" as a factor, an ANOVA on the combined results indicated no differences among experiments.

Third, our driving scenes contained very simple backgrounds, which may limit the generalizability of our results. In real-world conditions, scenes can be more complex. For example, a driver may encounter a pedestrian against a more cluttered background of objects which camouflage the pedestrians. Hence our stimuli may have enhanced the effects of visual contrast compared with natural scenes. Future research should measure effects of racial attitudes on driver performance in more realistic (but safe) contexts (e.g., Wood et al., 2005). Similarly, it would be useful to quantify differences in the conspicuity of the pedestrians across the different conditions (e.g., Carmi & Itti, 2006).

Fourth, the finding that ethnic minorities are overrepresented in pedestrian-vehicle collisions was based on data collected in the United States and the participants in the current experiments were drawn from a university in the United States. Thus, it is possible that the overrepresentation of ethnic minorities in pedestrian-vehicle collisions does not generalize to other countries. However, Lepore and Brown (1997) demonstrated that negative attitude-consistent behaviour can occur in a British sample in response to subliminal Black primes. If ethnic minorities are overrepresented in pedestrian-vehicle collisions in the United Kingdom, our results would be applicable in that country as well.

Fifth, we did not measure the participants' implicit racial attitudes, which would be useful to do in future studies. Specifically, with larger samples, it would be useful to determine whether negative implicit attitudes toward Blacks are correlated with performance on our driving task.

Finally, our experiments do not examine the role of socioeconomic factors in the overrepresentation of ethnic minorities in pedestrian-vehicle collisions. For example, Blacks and Whites in the United States may tend to live in areas that differ in the amount of money spent on road safety measures, road maintenance, and street lights. Such structural inequalities in the conditions under which Americans of different ethnicities use public roads may play a role in the overrepresentation of ethnic minorities in pedestrian-vehicle collisions. Such factors should be investigated in future research. We did, however, consider the potential role of socioeconomic factors that may put certain pedestrians at greater risk for pedestrian-vehicle collisions. Specifically, ethnic minorities may comprise a greater percentage of pedestrians and thus have more opportunity to be hit by a vehicle. However, this explanation is not supported by analyses of *fatality* rates for pedestrian-vehicle collisions. Specifically, when urban settings are considered alone, fatality *rates* are higher for Blacks than Whites (US Department of Transportation, 2004). Similarly, non-occupant fatalities account for a larger percentage of traffic fatalities for Black children than White children in both rural and urban settings (Hilton, 2006). Our current results suggest that visual contrast is the most parsimonious and empirically supported explanation for the finding that the rate of fatal pedestrian-vehicle collisions is higher for Whites than Blacks during the day, and is higher for Blacks than Whites at night (US Department of Transportation, 2004).

In conclusion, visual information, but not racial attitudes, affected the time for observers to respond to stimuli in driving scenes. Results have implications for traffic safety and for methodologies used to study racial attitudes.

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