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The effects of taboo-related distraction on driving performance

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ABSTRACT

Roadside billboards containing negative and positive emotional content have been shown to influence driving performance, however, the impact of highly arousing taboo information is unknown. Taboo information more reliably evokes emotional arousal and can lead to greater attentional capture due to its inherent 'shock value.' The objective of the present study was to examine driver distraction associated with four types of information presented on roadside billboards: highly arousing taboo words, moderately arousing positive and negative words, and non-arousing neutral words. Participants viewed blocks of taboo, positive, negative and neutral words presented on roadside billboards while operating a driving simulator. They also responded to target (household-related) words by pressing a button on the steering wheel. At the end of the session, a surprise recall task was completed for all the words they saw while driving. Results showed that taboo words captured the most attention as revealed by better memory recall compared to all the other word types. Interestingly, taboo words were associated with better lane control compared to the other word types. We suggest that taboo-related arousal can enhance attentional focus during a complex task like simulated driving. That is, in a highly arousing situation, attention is selectively narrowed to the road ahead, resulting in better lane control.

1. Introduction

According to the National Highway Traffic Safety Administration (NHTSA), driver inattention contributes to over 25% of motor vehicle crashes. Driver distraction, one form of driver inattention, is estimated to be involved in over half of these crashes (Stutts, Reinfurt, Staplin, & Rodgman, 2001). More recent findings place this estimate higher. In 2012, driver distraction accounted for 10% of all fatal crashes and 18% of injury crashes, making it the leading cause of motor vehicle accidents (NHTSA, 2014).

While distraction and inattention are often used interchangeably, NHTSA defines driver distraction as "a specific type of inattention that occurs when drivers divert their attention from the driving task to focus on some other activity instead" (NHTSA, 2014). Secondary task distraction, including cell-phone use, use of in-vehicle information systems (e.g., GPS units), and interactions with passengers, has been estimated to contribute to over 23% of all traffic accidents (Young & Salmon, 2012).

A key element of driver distraction is the voluntary or involuntary diversion of attention toward a competing activity (event, task, object, or person) inside or outside the vehicle. When a cell phone suddenly rings or a baby is screaming in the backseat, the driver is involuntarily compelled to look for the phone or turn to the screaming baby. On the other hand, when a driver reaches for the cup of coffee in his vehicle, he voluntarily chooses to devote his attention to the activity. In general, competing activities that capture attention involuntarily are unpredictable, sudden, and highly salient (Regan, Hallett, & Gordon, 2011); in other words, they are difficult to ignore.

One competing activity that has the potential to compel attention is roadside billboards. The amount of attention that drivers give to billboards and other irrelevant objects is estimated to vary from 30% to 50% (Hughes & Cole, 1986). Studies have found that distraction by foreign objects (including signs) is a significant cause of crashes (Stutts et al., 2001) and that drivers do look and process billboards (Hughes & Cole, 1986). However, little is known about the influences of emotional content on billboards, even though emotional stimuli have been widely reported to capture attention (for review, see Compton, 2003). In a recent study, roadside billboards containing negative and positive emotional content were shown to have differential effects on driving performance (Chan & Singhal, 2013). Drivers drove slower in the presence of negative information, while positive information was associated with faster driving speeds. Moreover, drivers recalled the content of negative billboards better than positive billboards. Another study found that viewing positive images led to better steering performance than negative images (Trick, Brandigampola, & Enns, 2012). Finally, in Jones, Chapman, and Bailey (2014), emotional images were shown to reduce the ability to detect driving-related hazards compared to neutral images. Together, these findings demonstrate that emotionally valenced information can be a significant factor in driving performance, and suggests that emotional distraction can modulate attention.

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Moreover, these effects appear to generalize to other sensory modalities, such as audition. In Chan and Singhal (2015), it was found that negative auditory distractions led to slower driving speeds compared to positive and neutral distractions, suggesting that the processing of emotional stimuli during driving likely reflects the impact on higher-order cognitive process rather than lower level sensory and perceptual processes.

While these results shed some light on the influence of emotional distraction on driving, the impact of taboo information on driving has not been investigated. Taboo (e.g., sexual-related) information have been shown to more reliably evoke emotional arousal than other types of emotional information (Jay, Caldwell-Harris, & King, 2008; Kensinger & Corkin, 2003; LaBar & Phelps, 1998; MacKay et al., 2004; Madan, Caplan, Lau, & Fujiwara, 2012; Madan, Shafer, Chan, & Singhal, in press). Previous studies have found that taboo stimuli can lead to greater attentional capture, presumably due to its inherent 'shock value' (Arnell, Killman, & Fijavz, 2007; Bertels, Kolinsky, & Morais, 2010; Madan et al., in press; Mathewson, Arnell, & Mansfield, 2008). Arnell et al. (2007) showed that in a rapid serial visual presentation (RSVP) task, accuracy was worse when the target was preceded by a sexual word compared to a threat, anxiety, positive, negative, or neutral word, suggesting involuntary attentional capture of arousing sexual words. In another study, Aquino and Arnell (2007) showed that sexually explicit words presented between two digits increased reaction times on a digit-parity task, compared to emotionally neutral and negative words. Additionally, it was revealed that more sexual words were later encoded into memory for recall compared to the other word types.

The effects of taboo distraction on driving have ecological relevance as many North American roadways are lined with billboard advertisements that contain highly arousing and/or sexual content (e.g., an anti-smoking billboard depicting mouth cancer or an advertisement with a woman in a bikini). In the present study, we examined driver distraction associated with four different types of information presented on roadside billboards. The five conditions were driving with: (1) highly arousing taboo words, (2) moderately arousing positive words, (3) moderately arousing negative words, (4) non-arousing neutral words, and (5) no billboard distraction. At the same time, participants responded to target words (household-related items) presented in the context of the four types of words. At the end of the study, participants were given a surprise free recall test in which they were asked to recall as many as words as possible from all conditions.

We hypothesized that driving performance would be most impaired by taboo words compared to all the other word types, as attention would be most involuntarily captured by the taboo distraction. As a result, less attention would be devoted to the driving task, which would impair driving performance. Alternatively, there is evidence that arousal can enhance focus. The narrowing of attention under highly arousing situations has been demonstrated in several studies (Agnew & Agnew, 1963; Bacon, 1974; Easterbrook, 1959; Eysenck & Willett, 1962; Hancock & Dirkin, 1982). It is suggested that as the level of arousal increases, observers tend to become more selective in their patterns of attending, a process known as "cognitive tunneling" (Dirkin & Hancock, 1985). As observers focus their attention on one specific aspect of the environment, information outside this highly attend area is excluded (Dirkin, 1983; Thomas & Wickens, 2001). Thus, it is possible that in the presence of highly arousing taboo words, driving performance would show no decrements as attentional focus would be enhanced towards the road ahead.

2. Methods

2.1. Participants

39 introductory psychology students from the University of Alberta participated for partial course credit. Data were excluded from nine participants because they did not drive to criterion (see Procedure) or due to technical issues, resulting in a final sample of 30 participants (13 males; $M = 19.5$, $SD = 3.3$). All participants had a valid driver's license, normal to corrected-to-normal vision, and were in the age range of 18 to 35 years old. The study was approved by the University of Alberta Ethical Review Board.

2.2. Materials

2.2.1. Word lists

Five 16-word lists were used in the study: one list of highly arousing taboo words; one list of moderately arousing, positive words; one list of moderately arousing, negative words; one list of non-arousing, neutral words; and one list of household-related ("target") words that participants were asked to respond to.

All of the words were selected from the Janschewitz (2008) normative word database. In the database, several subjective ratings were used for each word, including: arousal, valence, tabooness (the extent to which the rater found the word offensive to people in general), offensiveness (the extent to which the rater found the word personally offensive), familiarity (how often the rater encountered the word in any setting), personal use (how often the rater used the word on him or herself), and imageability (conduciveness to mental imagery), as well as number of letters and syllables.

Words were additionally selected based to match within-list similarity between the word lists using the latent semantic analysis method (LSA; Landauer & Dumais, 1997), and were matched for word frequency (occurrences in the English language, per million words), number of orthographic neighbors (number of words of the same length that differ in only one letter), and average word frequency of orthographic neighbors (per million words) were calculated with MCWord (Medler & Binder, 2005) based on the CELEX Lexical Database (Baayen, Piepenbrock, & Gulikers, 1995). See Table 1 for the word property statistics and the appendix for the specific words used. See Madan et al. (in press) for similarly constructed lists of taboo, positive, negative, and neutral words.

2.2.2. Driving simulator

Participants drove a STISIM Drive™ fixed-based driving simulator (Systems Technology Inc., Hawthorne, CA, USA), modeled as a small automatic transmission passenger vehicle. The simulator included a steering wheel, gas and brake pedals, and a projected display of approximately 60° horizontal and 40° vertical on a 22″ widescreen computer monitor. The simulated display included a dashboard, speedometer, and rear-view mirror.

2.3. Design

The driving scenario was 4.4 km in length and consisted of a two-lane (one in each direction) rural road that was mostly straight, with some winding turns. Road events included pedestrians crossing the road, stop signs, and traffic lights. Pedestrians were programmed to cross the road when the participant's vehicle was within 200 m of the pedestrian. Traffic lights were programmed to turn red when the participant's vehicle was within 200 m of the traffic light. Other features included buildings, trees, and other vehicles approaching in the opposite lane.

Participants completed five different driving conditions that each took approximately 5 min: (1) In *Control*, participants drove without billboard distraction. (2) In *Taboo*, participants drove with 16 taboo words and four target words on billboards. (3) In *Positive*, participants drove with 16 positive words and four target words on billboards. (4) In *Negative*, participants drove with 16 negative words and four target words on billboards. (5) In *Neutral*, participants drove with 16 neutral words and four target words on billboards. The order of conditions was counterbalanced across participants using a Latin-square procedure. Fig. 1 shows a screenshot from the taboo condition.

Similar to Chan and Singhal (2013), billboards were placed on the right-hand side of the road every 200 m. The words on the billboards were legible to the driver when the vehicle was approximately 70 m

Table 1
Word property statistics for each list used in the experiment.

	Taboo	Positive	Negative	Neutral	Target
Emotional word properties					
Arousal	5.01 (0.66)[a]	2.84 (0.56)[b]	2.85 (0.56)[b]	1.49 (0.14)[c]	1.46 (0.10)[c]
Valence	3.76 (1.31)[a]	6.50 (0.61)[b]	3.48 (0.39)[a]	5.03 (0.07)[c]	5.05 (0.07)[c]
Tabooness	5.40 (1.05)[a]	1.10 (0.14)[b]	1.38 (0.17)[c]	1.03 (0.03)[b]	1.02 (0.04)[b]
Offensiveness	2.82 (1.10)[a]	1.04 (0.05)[b]	1.23 (0.13)[c]	1.02 (0.01)[b]	1.01 (0.01)[b]
Non-emotional word properties					
Imageability	5.50 (1.83)[a]	5.03 (2.25)[a]	4.82 (1.92)[b]	6.34 (2.22)[a]	7.67 (0.53)[a]
Familiarity	5.35 (1.10)[a]	5.18 (0.81)[b]	4.96 (0.89)[b]	4.61 (0.85)[b]	5.20 (0.90)[b]
Personal use	3.98 (1.09)[a]	4.48 (0.88)[a]	4.15 (0.92)[a]	3.94 (0.88)[a]	4.85 (1.11)[b]
Letters	5.50 (1.10)[a]	6.00 (0.89)[a]	5.69 (1.01)[a]	5.69 (1.14)[a]	5.75 (1.18)[a]
Syllables	1.94 (0.57)[a]	2.00 (0.73)[a]	1.56 (0.51)[a]	1.69 (0.48)[a]	1.81 (0.66)[a]
Semantic similarity	0.09 (0.16)[a]	0.19 (0.14)[a]	0.19 (0.16)[a]	0.12 (0.16)[a]	0.15 (0.16)[a]
Word frequency	7.19 (9.24)[a]	16.07 (17.39)[b]	12.45 (8.57)[a]	22.81 (17.94)[b]	39.47 (55.85)[b]
ON number	3.25 (3.70)[a]	2.12 (2.25)[a]	2.50 (2.00)[a]	2.56 (3.33)[a]	2.62 (2.55)[a]
ON mean frequency	6.27 (14.63)[a]	5.40 (13.77)[a]	6.53 (10.04)[a]	9.02 (13.43)[a]	16.56 (20.18)[a]

Note. Mean ratings are shown with standard deviation in parentheses. Means in a row with the same superscript are not significantly different at $p < .05$. See text for further details about each measure.
ON = Orthographic Neighbors.

away from the billboard location. The order of the words for each condition was randomized for each participant.

2.4. Procedure

Participants were first familiarized with the driving simulator by completing a practice drive that was 6.4 km in length and similar to the control scenario. The practice drive took approximately 8 min. Using the same criterion in Chan and Singhal (2013, 2015), participants were instructed to drive their vehicle in the center of their lane, maintain a speed of 40–80 km/h, and attend to pedestrians, stop signs, and traffic lights.

In the experimental session, each participant completed all five driving conditions (control, taboo, positive, negative, neutral) with a 1-min break between conditions. They were instructed to press a button on the steering wheel with their left hand as quickly as possible when a target (household-related) word came into view. Participants were told that house-related words were "words commonly associated with the house/home" and were given a list of examples. These example words were not used in the actual experiment. Target words were used to ensure that participants were attending to the words.

Upon completion of all driving conditions, participants were given a surprise free recall test, in which they were given 5 min to recall and type all of the words they could remember from the study, in any order. The entire study was completed in 1 h.

Fig. 1. Screenshot of a scenario from the taboo condition.

3. Results

All effects were considered statistically significant based on the alpha level of 0.05. Greenhouse-Geisser corrections were applied to account for violations of sphericity.

All of the driving performance data were analysed with separate one-way repeated measures analysis of variance (ANOVA) with five levels (driving condition: control, taboo, positive, negative, neutral). The target response time data were analysed with a one-way repeated measures ANOVA with four levels (driving condition: taboo, positive, negative, neutral). The target error rate data were analysed with a 2 (error type: miss, false alarm) × 4 (driving condition: taboo, positive, negative, neutral) repeated measures ANOVA. The recall data were analysed with a one-way repeated measures ANOVA with five levels (word type: target, taboo, positive, negative, neutral).

3.1. Driving performance data

To assess driving performance, three measures were collected from the simulator: mean driving speed, lane maintenance (assessed as the root-mean-square error [RMSE] of the driver's lateral lane position with respect to the roadway dividing line), and steering wheel rate (assessed as the RMSE of how fast the driver is turning the steering wheel while doing steering maneuvers) (Rosenthal, 1999). Each measure was aggregated over the entire driving scenario.

We observed a significant effect of driving condition on mean driving speed, $F(4, 116) = 2.80$, $p = 0.037$, $\eta_p^2 = 0.088$. As shown in Fig. 2A, planned contrasts indicated that driving speed was faster in the positive condition compared to the taboo ($p = 0.019$), negative ($p = 0.020$), and neutral ($p = 0.001$) conditions, similar to the results of Chan and Singhal (2013). No other comparisons were significant (all $ps > 0.05$).

Driving condition also had a significant effect on RMSE lane position, $F(4, 116) = 3.57$, $p = 0.013$, $\eta_p^2 = 0.110$. As shown in Fig. 2B, planned contrasts indicated that RMSE lane position was lower in the taboo condition compared to the control ($p = 0.002$), positive ($p = 0.002$), and neutral ($p = 0.022$) conditions. A trend effect was observed suggesting lower RMSE lane position in the taboo condition compared to the negative condition ($p = 0.084$). The other word types did not differ significantly (all $ps > 0.05$).

RMSE steering wheel rates did not significantly differ between conditions, $F(4, 116) = 1.87$, $p = 0.151$, $\eta_p^2 = 0.060$.

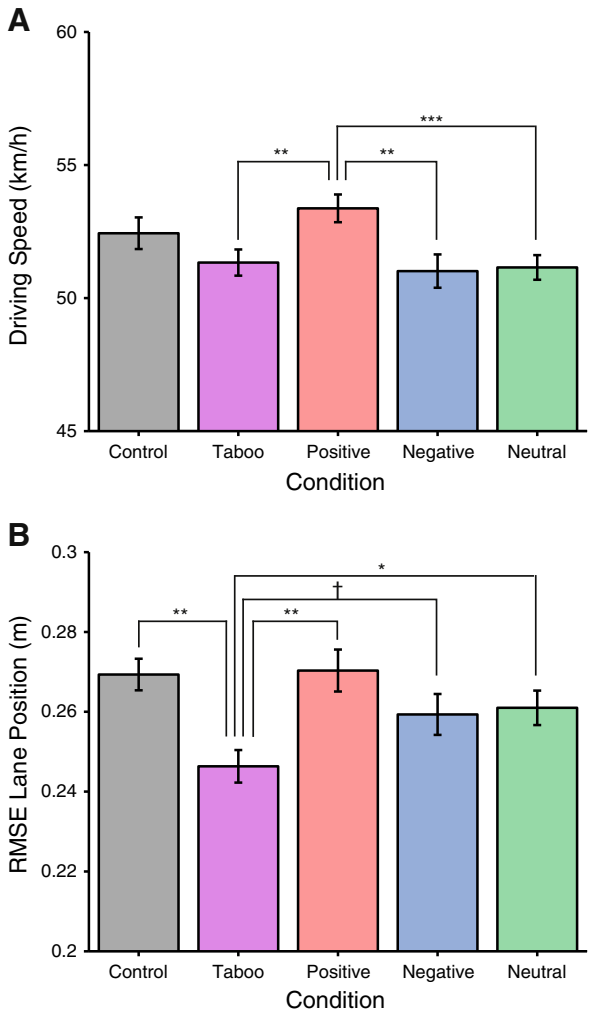

Fig. 2. Driving performance measures for each driving condition. (A) Driving speed. (B) Root mean square error (RMSE) lane position. Error bars denote within-subject standard error of the mean. †$p < 0.1$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

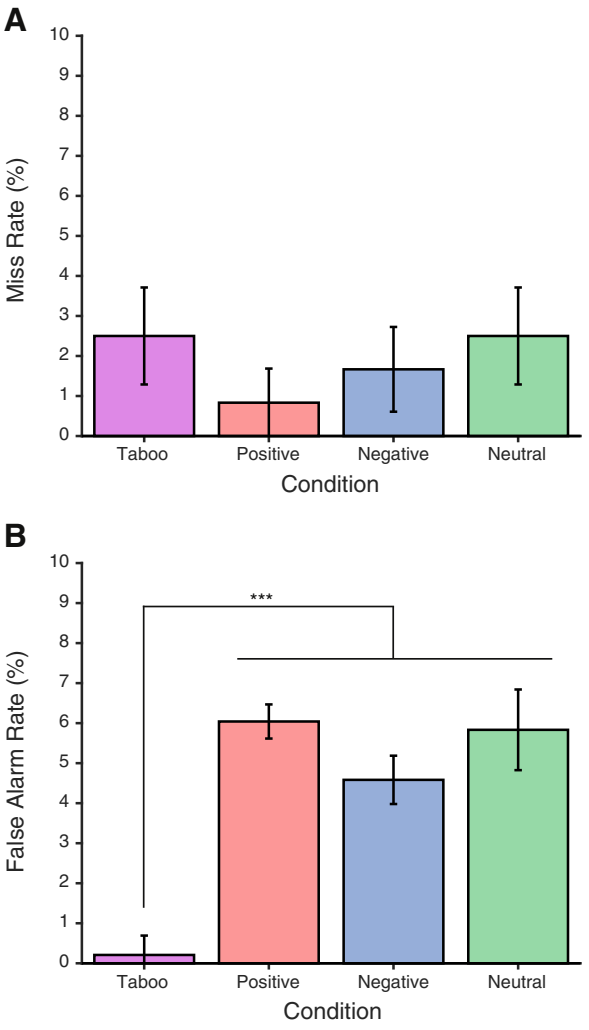

Fig. 3. Error rates of target words for each driving condition. (A) Misses. (B) False alarms. Error bars denote within-subject standard error of the mean. ***$p < 0.001$.

3.2. Target response data

Driving condition may influence participants' speed at responding to the targets. Response time (RT) for each target word was calculated as the time from when the target billboard could be read to when the participant pressed the button. Only correct responses were included for analysis. RTs more than three standard deviations from the mean were excluded. The main effect of condition on RT was not significant, $F(3, 87) = 0.432$, $p = 0.705$, $\eta_p^2 = 0.015$.

As driving condition may also influence participants' ability to accurately detect the household-related target words, we conducted an error analysis on target responses. Miss (i.e., no response to a target) rate was defined as the number of misses, divided by the total number of targets in each condition (i.e., 4 targets per condition). False alarm (i.e., responses to a non-target word) rate was defined as the number of false alarms, divided by the total number of non-targets in each condition (i.e., 16 non-targets per condition). The mean miss rate and false alarm rate for each driving condition are shown in Fig. 3.

Results revealed a significant main effect of error type, $F(1, 29) = 8.85$, $p = .006$, $\eta_p^2 = 0.234$. The false alarm rate was higher than miss rate across all driving conditions. There was also a significant main effect of driving condition, $F(3, 87) = 3.41$, $p = 0.029$, $\eta_p^2 = 0.105$. Planned contrasts indicated that the error rate (misses and false alarms) was lower in the taboo condition compared to the positive ($p = 0.038$) and neutral ($p = 0.034$) conditions. The ANOVA also revealed a significant interaction between error type and driving condition, $F(3, 87) = 3.81$, $p = 0.019$, $\eta_p^2 = 0.116$. As shown in Fig. 3B, planned contrasts indicated that the false alarm rate was lower in the taboo condition compared to the positive ($p = 0.001$), negative ($p = 0.001$), and neutral ($p = 0.001$) conditions.

Further inspection of the data indicated that the false alarms were to random non-target words, and not to any specific word(s) in each condition that had a tendency to cause participants to mistakenly confuse it for a target.

3.3. Relationship between driving performance and target false alarm rates

Pearson correlations were conducted to assess the relationship between RMSE lane position and false alarm rates for each driving condition. There were no significant correlations (all $ps > 0.05$). Pearson correlations were also conducted between driving speed and false alarm rates for each driving condition. No significant correlations emerged (all $ps > 0.05$). These analyses suggests that performance of the driving task and target response task are unrelated and do not influence each other directly.

3.4. Memory recall data

As the billboard words competed for attention with the driving task and were the main manipulation of interest, we additionally analysed

the recall data for differences in memory for the different word types. Proportion of words recalled was defined as the mean number of correct words recalled of each word type, divided by the total number of words presented of each type.

Results revealed a significant main effect of word type, $F(4, 116) = 40.19$, $p = 0.001$, $\eta_p^2 = 0.581$. As shown in Fig. 4, planned contrasts revealed that taboo words were recalled more so than any other word type (all $ps < 0.001$). Target words were recalled more than positive, negative, and neutral words (all $ps < 0.001$). The proportion of words recalled for positive, negative, and neutral words did not differ significantly (all $ps > 0.05$).

4. Discussion

In the present study, we examined the effects of driving performance associated with four types of information presented on roadside billboards: highly arousing taboo words, moderately arousing positive words, moderately arousing negative words, and non-arousing neutral words. The results showed that positive words were associated with faster driving speeds compared to all the other word types. On the other hand, taboo words were associated with better lane control, better memory recall, and better target response accuracy compared to the other word types. These findings suggest that driving performance and attention are differentially affected by the arousal level of the billboard content.

Emotional arousal is an important factor in guiding selective attention as it has been shown that stimuli appraised as emotional are often motivationally relevant and adaptive (Compton, 2003). For example, a threatening stimulus prepares the individual for avoidance-related behaviors (e.g., escape). On the other hand, a positive stimulus that signals reward activates approach-related behaviors (e.g., ingestion of food). As human attention has a limited capacity, only certain stimuli can be attended to at the same time; accordingly it is adaptive that stimuli with high emotional arousal be prioritized for processing (Compton, 2003). Our findings showed that memory performance was highest for taboo words compared to the other word types in the surprise recall task (see also Buchanan, Etzel, Adolphs, & Tranel, 2006; Madan et al., 2012, in press), suggesting that attention was most captured by taboo words despite no instructions to attend to those words. Prior studies have also found preferential processing of sexual or taboo information compared to other emotional information (Arnell et al., 2007; Bertels et al., 2010; Mathewson et al., 2008). For example, Schimmack (2005) showed that highly arousing pictures (e.g., scantily clad opposite-sex models) involuntarily captured more attention than pictures of mildly arousing pictures.

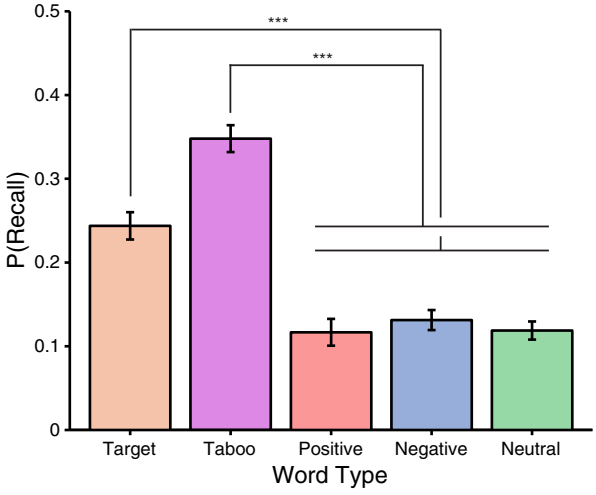

Fig. 4. Proportion of each word type recalled in the free recall task. Error bars denote within-subject standard error of the mean. ***$p < 0.001$.

Together, these findings suggest that arousal level modulates the amount of attention that is given to information, with highly arousing stimuli receiving the most attention.

The driving performance results showed that positive words were associated with faster driving speeds compared to all the other word types. This is consistent with prior findings that positive states can lead to enhanced physical performance, such as the ability to run faster or jump higher, compared to negative and neutral emotions (McCarthy, 2011; Ruiz, 2008). It is possible that this same type of faster behavior seen in human performance may also be present in a driving task.

Interestingly, we found that drivers had better lane control in the presence of taboo words. It is possible that drivers may have allocated more attention to the road ahead when in a highly arousing situation. "Cognitive tunneling" is a phenomenon that occurs when observers focus their attention on one aspect of the environment to the exclusion of information outside this highly attended area (Dirkin, 1983; Thomas & Wickens, 2001). In other words, observers become more selective in their patterns of attending. The hypothesis that attention is narrowed as levels of arousal increase has been demonstrated in several studies (Easterbrook, 1959; Agnew & Agnew, 1963; Bacon, 1974; Eysenck & Willett, 1962; Hancock & Dirkin, 1982). For example, it has been found that attention towards salient cues is "narrowed" under heightened arousal, regardless if the cues are located in the central or peripheral field of vision (e.g., Reeves & Bergum, 1972). As previous findings confirm that arousal can enhance attentional focus, it is possible that drivers may have narrowed their attention to the road ahead in the presence of taboo stimuli. This would also limit the processing of other sensory information in the driving environment (e.g., trees, buildings, oncoming traffic), resulting in better lane control.

On the other hand, positive emotional states have been shown to broaden the scope of attention (Fredrickson, 1998, 2001). Several studies have found that positive emotions can lead to greater global perceptual processing in global-local focus tests, whereas negative affect leads to greater local processing (Basso, Schefft, Ris, & Dember, 1996; Fredrickson & Branigan, 2005; Gasper & Clore, 2002). The impact of positive emotion on visual attention has also been measured using eye tracking in response to emotional pictures (Wadlinger & Isaacowitz, 2006). Using a mood induction task, it was found that participants who experienced positive emotional states had a broader area of visual attention. In a driving task, positive arousal may increase attention to peripheral information, due to a broadening of attention to global aspects of the driving environment, which may reduce the drivers' ability to maintain lane control, compared to the presence of taboo stimuli.

The target response results showed that drivers made fewer false alarms in the taboo condition compared to the other word conditions. One possible explanation is that drivers were more vigilant and attentive in the presence of taboo words, resulting in better accuracy (i.e., lower false alarm rates). Providing some support for this idea, prior studies have also found that participants showed more attentional vigilance (i.e., attentional capture) to taboo words compared to other word types (Arnell et al., 2007; Bertels et al., 2010; Mathewson et al., 2008).

Research has also shown that taboo and threatening stimuli (e.g., pictures of mutilated bodies) can elicit a motor response suppression in humans that is similar to the freezing response exhibited in animals when faced with a potential threat (Azevedo et al., 2005; Fox, Russo, Bowles, & Dutton, 2001; Wilkowski & Robinson, 2006). Evidence of this can be found in a study by Azevedo et al. (2005). Here, participants viewed images that were threatening (mutilation), pleasant (sports), and neutral (objects) while standing on a platform. Posturographic recordings showed that during pictures of mutilation, participants exhibited a more immobile posture (i.e., reduced body sway and increased muscle stiffness) compared to the other pictures. Thus, the presence of threatening stimuli reduced motor activities. In the present study, it is possible that the viewing of taboo words (which are similar to threat-related words; Schmidt & Saari, 2007)

induced a similar response suppression during the target response task, so that participants were less prone to making incorrect responses (i.e., false alarms).

While we interpret these results as being due to the taboo words eliciting an enhancement in vigilance or a motor response suppression, a third alternative account could be that the taboo words and target words were more different from each other than the neutral, negative, and positive words were from the target words. Specifically, the taboo words were greater in tabooness, offensiveness, arousal, as well as familiarity; these differences could have made the target words more distinct and easier to detect, as well as better recalled. However, while this alternative account could partially explain the differences in error rates, they do not account for any of the differences found in driving performance in the taboo condition, which was the main goal of the current study.

Chan and Singhal (2013) observed faster RTs when target words were embedded in the context of positive words compared to negative and neutral words. However, in the present study, we found no effect on target RT across driving conditions. Chan and Singhal (2013) used animal words as target words, while household-related items were used here. It is likely that since we intentionally matched the word properties of the target (household-related) items to the other word pools [in contrast to Chan and Singhal (2013)], the target words here were less distinct from the non-target words and thus, not as readily detectable.

While we suggest that cognitive tunneling may have occurred in the presence of taboo words, resulting in better lane control, it is likely not the only mechanism that may have contributed to this finding. For instance, our effects may have been mediated by linguistic properties that may not generalize to non-verbal (i.e., pictorial) taboo stimuli, such as pictures of scantily clad models. Some researchers have proposed that emotional information in pictures and words are processed differently, and that emotional pictures induce higher levels of arousal than emotional words (Carretié et al., 2008; Hinojosa, Carretié, Valcárcel, Méndez-Bertolo, & Pozo, 2009; Keil, 2006; Kissler, Assadollahi, & Herbert, 2006). Evidence for this can be found in a functional magnetic resonance imaging (fMRI) study by Kensinger and Schacter (2006), where participants were presented with positive, negative, and neutral pictures and words. Both emotional pictures and words were associated with increased activity in the amygdala, regions of the prefrontal cortex, and the anterior temporal cortex; however, the effects were stronger and more bilateral for pictures. In Hinojosa et al. (2009), event-related potentials (ERP) were recorded as participants viewed pictures and words that were emotional and neutral. The authors found that emotion-related ERP modulations were more pronounced for emotional pictures than for emotional words. Future research will be necessary to determine whether driving performance will differ with emotionally arousing pictures on billboards compared to words. Based on prior findings that emotional pictures are more arousing than emotional verbal stimuli (e.g., Hinojosa et al., 2009), it is predicted that emotional images on billboards will impact driving performance and target detection in a similar pattern as words but to a greater extent (i.e., taboo pictures will be associated with better lane control, better memory recall, and lower false alarm rates compared to taboo words). Taboo words are also relatively rare and unusual, and thus, more distinctive compared to other word types (Kensinger & Corkin, 2003; Schmidt & Saari, 2007). The effects of distinctive non-taboo words (e.g., names of animals, diseases, or germs) should also be compared with taboo words in future studies.

Driving simulators provide a safe and objective method to assess driving performance in dangerous situations, however there are limitations in the generalizability of our findings to real-world driving. For instance, our simulator has a limited projected field of view of 60° horizontal and 40° vertical. As a result, there is no rotation of the head to view the billboards or other visual information in the environment when these objects become located in the periphery, unlike actual driving. Additionally, the simulator is static and provides no vestibular and proprioceptive information to simulate motion. Nonetheless, despite these limitations, a large body of evidence suggests that simulators can provide a valid tool to assess driving performance (e.g. Kaptein, Theeuwes, & van der Horst, 1996; Mullen, Charlton, Devlin, & Bedard, 2011).

5. Conclusion

Our results showed that highly arousing taboo words captured the most attention and were associated with better lane control compared to moderately arousing and non-arousing words. One possible explanation is that cognitive tunneling may have occurred under high arousal; in other words, attention was selectively narrowed to the road ahead, resulting in better lane control. Additionally, as 'shock value' is an intrinsic attribute specific to taboo words (distinct from arousal and valence alone; Madan et al., 2012, in press), it is possible that this additional property may have contributed to the differential effects on driving performance.

Overall, our findings demonstrate that attention and arousal are linked, and can impact driving performance in the laboratory. Our results suggest that the effects of emotional distraction may be more complicated than previously thought: Highly arousing stimuli can influence performance in different ways than moderately arousing stimuli.

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Appendix A. Experiment word pools

Taboo words	Positive words	Negative words	Neutral words	Target words
ANUS	ADMIRED	BLISTER	BANNER	ARMCHAIR
ASSHOLE	ANGEL	CHAOS	CIRCLE	BENCH
BASTARD	BEAUTY	CRASH	CONTEXT	CABINET
BITCH	BRAVE	GLOOM	ENGINE	CHAIR
BONER	BREEZE	HEADACHE	ERRAND	CLOSET
BREASTS	BUNNY	HORROR	GLACIER	DESK
DILDO	CHAMP	PANIC	PHASE	DRESSER
FUCK	ELATED	QUARREL	PRAIRIE	DRYER
HOOKER	LIBERTY	RESENT	QUART	FREEZER
ORGASM	LUSCIOUS	SCREAM	SHIP	FURNACE
PENIS	MELODY	SNAKE	SPRAY	KETTLE
PUSSY	PILLOW	STENCH	TAXI	MIRROR
SCROTUM	PROFIT	TOMB	TOWER	PATIO
SEMEN	QUEEN	TOXIC	TRUCK	ROOF
SLUT	SNUGGLE	TRASH	WAGON	STOVE
VAGINA	SUNSET	TRAUMA	WINDMILL	TABLE

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