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# The priming function of road signs

David Crundall \*, Geoffrey Underwood

*School of Psychology, University of Nottingham, University Park, Nottingham NG7 2RD, UK*

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## Abstract

What is the true nature of the relationship between road signs and the transmission of information? The current perspective regards the information obtained from road signs to be conscious and explicit. Recent research however suggests that road signs may also have an automatic priming function distinct from the conscious use of information. The current study tested novice and experienced drivers in a repetitive priming condition (road signs priming road signs) and a semantic priming condition (road signs priming road scenes). Strong repetitive priming effects and weaker semantic priming effects were found for the experienced drivers but not the novices. This suggests that not only do road signs have an automatic priming function, but that this process is developed with increased experience in the relevant context. © 2001 Elsevier Science Ltd. All rights reserved.

*Keywords:* Semantic priming; Repetitive priming; Road signs

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## 1. Introduction

### *1.1. Assumptions in the study of road signs*

The role of the warning traffic sign is to prepare the driver for a subsequent behaviour necessitated by the road layout ahead. By giving the driver advanced notice of a left-bend, a hidden dip or an adverse camber, it is hoped that the motor response required for the appropriate action is facilitated (Traffic Signs Manual, 1986, Chapter 4). Without advanced notice of road conditions the driver would have to initiate the appropriate behaviour when they first perceive the focus of the hazard, such as a sharp left-bend. This increases the risk of accidents in those situations where the amount of time required to first assess the road conditions and then take appropriate action is

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\* Corresponding author. Tel.: +44-115-951-5297; fax: +44-115-951-5324.  
*E-mail address:* david.crundall@nottingham.ac.uk (D. Crundall).

greater than the time available before reaching the hazard. For instance, on a high speed rural lane, the braking distance may be too great to affect a safe speed before turning into a left-bend that suddenly appears without warning.

The nature of the relationship between warning road signs and the subsequent road way is assumed to be a conscious transmission of information which allows behaviour to be modified. This has led to the further assumption that the sooner one sees a traffic sign, the longer one has to act on that conscious information, hence the decreased likelihood of an accident. The majority of research conducted upon traffic signs usually reflects these assumptions. For instance Zwahlen (1994) and Zwahlen and Schnell (1998) have published research calculating the mean required legibility distance (MRLD) for signs under different driving conditions, while other researchers have investigated how the reflectivity and size of traffic signs affect salience (Cole & Hughes, 1984; Hughes & Cole, 1986; Paniati & Mace, 1993). However there is evidence that these assumptions could be flawed.

Research attempts to identify the conscious use of warning sign information have had mixed results. The *roadblock paradigm* involves stopping cars and interviewing the drivers about the road signs they have previously passed (e.g. Johansson & Backlund, 1970; Milosevic & Gajic, 1986). Several of these studies have demonstrated poor recall rates for road signs which has led to the suggestion that signs are a poor medium of information transmission. Recent research has confirmed the suspicion that experienced drivers may fixate traffic signs less frequently than expected (Sprenger, Schneider, & Derkum, 1999). Despite the inherent problem of memory decay in the roadblock paradigm (cf. Fisher, 1992), the research suggests that the conscious use of road sign information may not be straightforward. A number of studies have even noted that drivers may modify their driving behaviour (such as a decrease in speed) without being able to consciously recall doing so on the basis of a traffic sign (e.g. Häkkinen, 1965; Summala & Hietamäki, 1984). On this basis one may not only question whether or not road signs achieve their primary function of conveying conscious information, but also whether unconscious or automatic responses to road signs may also occur.

This study is concerned with the latter question of whether the perception of a road sign can instigate an automatic, or procedural, response. The possibility of such an effect has been likened by some to the research conducted upon semantic and repetitive priming (Avant, Thieman, Zang, & Hsu, 1996; Castro, Horberry, & Gale, 1999) as the road sign can be considered to prime a response to the subsequent hazard. The standard priming experiment displays two stimuli in brief succession. The participant's task is to respond to the second item and ignore the first. Previous findings have noted that response times to the second item (often termed the *probe*) are faster when preceded by an identical first item (often called the *prime*). This is an example of repetitive priming; a brief identical presentation of a prime stimulus reduces response times to the same word or picture when it is presented as the probe. Further experiments have noted a consistent facilitatory effect for primes that are semantically related. Though the repetitive prime (*butter* followed by *butter*) produces the greatest benefit, the semantic prime (*bread* followed by *butter*) also produces a reduction in response times compared to an unrelated prime (e.g. Meyer & Schvaneveldt, 1971).

The current study aims to investigate the warning potential of simple, symbol-based traffic signs through the application of the priming paradigm. Furthermore, the suggestion is made in the following sections that the ability to extract information to act as a cue for subsequent behaviour

is, according to current theories of priming, dependent on experience of the context. If this is the case then experienced drivers should receive greater benefit from road sign priming compared to novice drivers.

### *1.2. The priming function of road signs*

If any benefit is gained from the hypothesised priming function of a road sign it is because the sign (either symbolically or via written words) represents the danger ahead. This reduces reaction time to the subsequent hazard as the particular response has already been activated to some extent by the warning sign. One might argue that the ultimate prime for a driver advancing toward a hazard would be an actual picture of that hazard. However a picture of an actual road scene contains a lot of redundant information that is not pertinent to the hazard. This unwanted information would act as a distracting background. The driver would then have to extract the hazard from the scene in order to process the relevant parts of the prime. This would be a difficult task for two main reasons. First, the ability to detect embedded targets varies according to other skills such as field dependence (e.g. Loo, 1978), and secondly, novel hazards (or novel exemplars of a common hazard type) will take longer to process. The benefit of symbolic warning signs is that they provide only the information the driver needs without surplus distracters, and they present that information in a standardised fashion that should encourage the same levels of anticipation regardless of the physical nuances of the hazard ahead. Written signs attempt to do the same, though where possible symbolic signs are favoured (or are used in conjunction). This emphasis on symbolic signs fits with the psychological literature which has demonstrated the improvement in discriminative reaction times of pictographs over verbal signs (Potter & Faulconer, 1975; Ells & Dewar, 1979; Sperber, McCauley, Ragain, & Weil, 1979; Whitaker & Stacey, 1981).

The nature of the relationship between a symbolic warning sign and the road ahead is a difficult one to categorise. The connection between simple signs, such as a junction or bend sign, and the road ahead is based upon repetitive priming (i.e. the sign shows the driver what the hazard will look like), though at a more standardised level. Repetitive priming breaks down however when the prime and probe do not have the same surface structure. Warren and Morton (1982) found facilitation for responses to picture targets if the participants were previously presented with the same image, but not if they were previously presented with the word for the target image. Though the connection between the road ahead and a symbolic road sign is closer to a repetitive relationship than a road scene primed by a word, it is likely that both relationships will be mediated by the underlying semantics. This study will therefore refer to the priming of road scenes with traffic signs as semantic rather than repetitive priming.

One particular study that has attempted to explore the role of priming in traffic signs was conducted by Castro et al. (1999). They used words usually found on road signs such as 'caution', 'library' and 'church' as both primes and probes to create a repetitive condition ('church' followed by 'church') and a semantic condition ('cemetery' followed by 'church'). These words were presented within traffic sign frames with an interval of 400 ms between the prime and probe. Their results demonstrated an effect of repetitive priming but not semantic priming. On this basis the priming function of road signs for other road signs is partially supported in regard to repetitive priming (cf. Milosevic & Gajic, 1986; Avant et al., 1996). Any comparison with priming road

scenes was not undertaken, though if the prime words did not benefit semantically related probe words in Castro et al.'s study it is unlikely that any facilitation for classifying a road scene would have occurred.

The present study aims not only to replicate the repetitive priming effect noted in previous studies but to also answer the more direct question of whether warning road signs fulfil the primary implicit function that is attributed to them; can they semantically prime road scenes?

In place of word signs as used by Castro et al. (1999) the experimental primes for the current study were chosen from the most frequent warning road signs: a left bend, a crossroads, and a right bend. All signs were presented in the white triangle with red border typical of UK warning signs. This not only increases the ecological validity of the primes, as symbolic signs are more prevalent on UK roads than single word road signs, but it also avoids the problem of controlling for the frequency of use of the stimuli in two separate contexts. For example Kucera and Francis' (1967) frequency rating for the word 'church' is 348 written words per million, whereas the rating for 'caution' is 19 words per million. However these ratings are based upon the written context. The driving context has a frequency hierarchy of its own in which the use of the word 'caution' is likely to occur a lot more frequently than 'church'. Controlling stimulus frequency in traffic sign priming must be based on use within the driving context. The three symbolic warning signs chosen for this study are all extremely commonplace on UK roads, and will not be affected by frequency of use in other contexts. It should be noted that several other categories of road signs are used in the UK road system such as informational and prohibitive signs. Warning signs were chosen as the relationship between sign and behavioural response is more straightforward than with other classifications. With prohibitive and informational signs the driver may only need and use the information in specific situations. Warning signs are always useful however, and should therefore give the best chance of finding a priming relationship between sign and road scene.

### *1.3. The role of experience*

As a child's intellect and vocabulary develop, so they come to approximate the standard frequency of use accepted in the majority of psycholinguistic studies (Kucera & Francis, 1967). During the formative years of language development the most frequent words encountered and used by young children are unlikely to match the frequency tables accepted for the adult population. This is no doubt the same for new drivers; though they may declaratively learn the finite population of road signs in preparation for the driving test, their performance should not be as stable or as fast as that of the automatised responses to road-signs built up by experienced drivers over many years. The effects of experience on automatisisation were noted in the early studies of Shiffrin and Schneider (1977). They reported that discrimination of letters from digits was an automatic task in normal adults requiring little or no attention. In a later experiment they repeated this result in a discrimination task between the letters from the first half of the alphabet and from the last half. In order to build up the automatic response however participants had to undergo extensive training to discriminate the two halves of the alphabet.

The effect of experience on the identification of road signs has already been noted by Brachacki, Nicholson, and Fawcett (1995). In a comparison of normal and dyslexic drivers they discovered that driving experience correlated with road sign recognition for the control group but not for the dyslexics. In regard to the simple perception of road signs this is a problem in itself, yet these authors

suggest that not only are overall reaction times to traffic signs likely to decrease with experience, but the semantic priming function of the sign should also improve. Repetitive priming however is based on the orthography of the sign so one should not expect a difference between novice and experienced drivers as no understanding of the sign is necessary. A series of experiments conducted by Schwartz and Hashtroudi (1991) attempted to find improvements in repetitive priming due to skill improvement at the primary task. Though they found several tasks where performance improved with practice, none of the tasks showed any improvement in the benefits of priming.

Semantic priming however should be more susceptible to improvements in skill. Whether one discusses priming in terms of spreading activation through a semantic hierarchy of information nodes (e.g. Collins & Loftus, 1975) or on the basis of connection weights between processing units in a distributed memory model (e.g. Masson, 1995) semantic links have to be learned through either experience or practice. Exposure to frequently co-occurring and meaningful stimuli will generate semantic links between them. In regard to driving, though the novice driver may be generally slower at identifying road signs they should also fail to display the priming response that experienced drivers may reveal, as their response to the road sign may still act purely on a conscious level (Neely, 1977).

On this basis the current study attempted to distinguish between novice and experienced drivers not only by their overall response times to driving stimuli, but also by the level of facilitation provided by semantic primes. To summarise, in addition to the initial aim of this study to reveal the potential priming function of road signs, (both upon other road signs supporting the findings of Castro et al. (1999), and more interestingly upon road scenes), exposure to the context within which the prime and probe co-occur will determine the success of the priming, with experienced drivers benefiting more than novices especially in the semantic trials.

## **2. Method**

### *2.1. Participants*

Twenty six participants (aged between 17 and 24) took part in the current study. 13 of these participants had passed their driving test within three months prior to their inclusion in the study, and were considered to be novice drivers. They were recruited through questionnaires that were distributed by the Driving and Vehicle Licensing Agency to drivers who successfully passed their driving test in the Nottingham area. The remaining 13 participants were recruited from the undergraduate population of the University of Nottingham, and had at least 3 years of driving experience, and were considered to be experienced drivers. All participants received remuneration for their time and had either normal or corrected-to-normal vision. The average age difference between the two groups of participants was under 4 years and therefore should not have led to any age-related deficits in visual acuity.

### *2.2. Stimuli and apparatus*

The primes were the same for both the repetitive and semantic priming conditions. There were three primes: a right-hand bend, a left-hand bend, and a crossroads sign. All the primes were

triangular warning signs with a red border and black symbol. They were centrally presented and subtended approximately  $10^\circ \times 8.5^\circ$  on a screen of  $15^\circ \times 11^\circ$ , with the participant at a distance of 60 cm from the screen. In the repetitive and semantic control conditions three Xs subtending roughly the same width as the road signs were presented in place of the primes.

In the semantic condition eighteen target road scenes (the probes) were chosen from digital video footage of roads in Nottinghamshire, UK, filmed from a dashboard-mounted digital video camera. Half of the road scenes were selected from rural roads and half were selected from suburban roads. Of the 18 road scenes, six clearly showed a left-hand bend, another six showed a right-hand bend, with the final six depicting a crossroads junction. If the prime and probe were congruent (e.g. a right bend warning sign followed by a right bend road scene) this was considered a valid trial. Other combinations of prime and probe were considered invalid. There were an equal number of valid and invalid prime-probe pairings and control trials (where the prime was replaced by three Xs).

In the repetitive condition the same three types of road signs that were used as primes were used as the target probes. These probe signs were embedded in the road scenes used as the semantic targets,  $6^\circ$  below centre. Participants responded to the road sign rather than the road scene however. The rationale behind embedding the road sign within the road scene was to provide a more ecologically valid background (as road signs that require a response rarely occur on a blank background) and to maintain a consistent overall level of complexity on the screen between the semantic and repetitive conditions. The repetitive target road sign was always congruent with the background road scene (i.e. a target left bend sign was always embedded in a left bend road scene). As with the semantic condition, congruent prime-probe pairings were considered valid, and incongruent pairings were invalid. There were an equal number of valid, invalid and control trials (where the prime was replaced by three Xs).

In order to measure any effect of embedding the repetitive targets within a road scene upon the response times, a further, overall control condition used road sign targets (again  $6^\circ$  below centre) without the embedded background. The primes were displayed for 350 ms and the SOA to the target was 550 ms. Examples of all the stimuli used in the two experimental conditions and the three control conditions can be viewed in Fig. 1.

The stimuli were displayed on a P3 450 PC. Participants responses were recorded via the keyboard: Z, X, and C, represented the 'left', 'crossroads' and 'right' responses.

### 2.3. Design

The efficacy of both the semantic prime and the repetitive prime was assessed separately in two  $2 \times 3$  mixed designs, with the between groups factor consisting of novice and experienced drivers compared across prime validity (valid, invalid and the related control condition, either semantic or repetitive depending on the prime type). The overall control condition formed the basis of a separate  $2 \times 3$  analysis to compare the semantic and repetitive controls with a baseline level of performance across the factor of experience.

Each of the five blocks were presented to the participants in a counterbalanced order. Each block comprised 36 targets to which the participant had to respond 'left', 'right' or 'straight ahead' via the keyboard (the semantic targets were roads, the repetitive targets were road signs embedded in a congruent scene, and the overall control targets were road signs on a white background). Accuracy and response times were recorded by the computer.

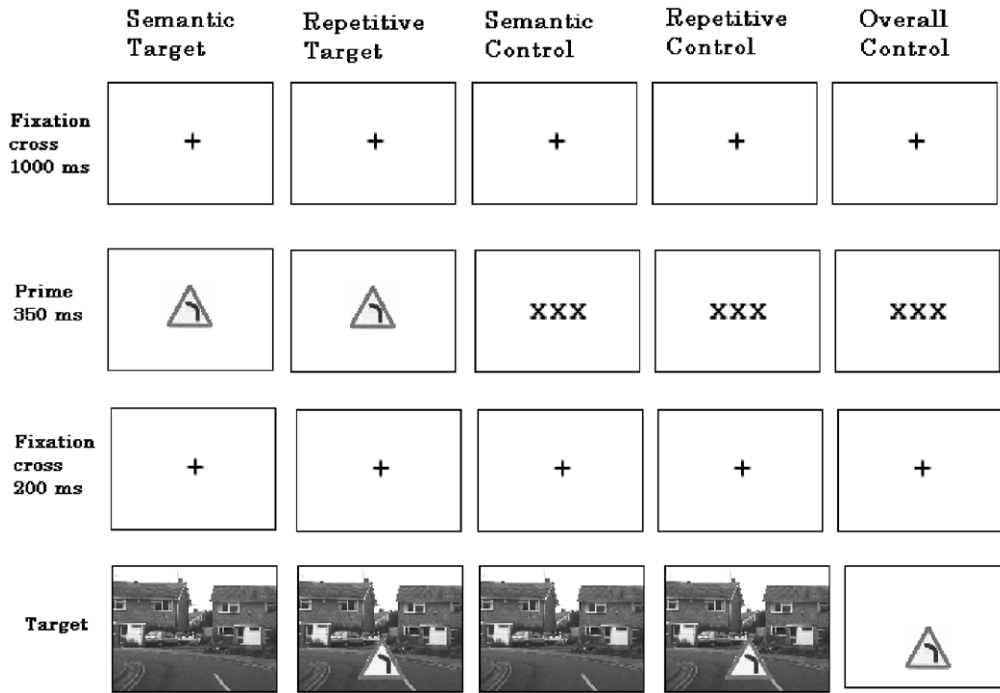


Fig. 1. Time course of the five conditions.

#### 2.4. Procedure

Participants were seated approximately 60 cm from the screen and asked to read a set of standardised instructions on the computer screen. The instructions informed the participants that they were going to see several pairs of pictures appear on the screen, the first picture being followed almost immediately by the second picture. They were told to ignore the first picture and concentrate on the second picture in order to make a correct response. In the repetitive conditions participants were additionally told to ignore the background road scene during the presentation of the probe. Once the participants had asked the experimenter any questions they were given a brief practice at responding to the type of trials that they were about to see in the first block. Each subsequent block was also preceded by a target-specific practice block. Each pair of stimuli were preceded by a fixation cross for one second, and separated by a fixation cross for 200 ms (550 ms SOA). After a response the participant was shown a feedback screen that told them whether the answer had been correct. One second later the cycle would repeat until all stimuli in that block had been displayed.

### 3. Results

The accuracy rates for participant groups were consistently high across the prime and control conditions. The lowest accuracy rates occurred in the semantic prime trials (95% for novices and

96% for experienced drivers). The repetitive trials and the overall control trials all produced an average accuracy rate of 98% for both participant groups. Inaccurate trials were excluded from the subsequent analysis of response times, though as a prelude to these analyses, a comparison of accuracy rates was conducted. In separate analyses of the repetitive prime and the semantic prime, accuracy rates were found to be lower for invalid trials compared to valid trials and the respective control trials ( $F_{\text{Repetitive}(2,48)} = 3.23, p < .05$ ;  $F_{\text{Semantic}(2,48)} = 4.88, p < .05$ ). A further comparison of the three control trials (semantic, repetitive, and overall control) also found a main effect ( $F_{\text{Control}(2,48)} = 4.28, p < .05$ ). Means comparisons revealed that the semantic control trials produced more errors than the repetitive control trials ( $p < .01$ ) and a marginal significant difference was noted between semantic and overall control trials ( $p = .06$ ). The results of these preliminary analyses confirmed the assumptions that the semantic task would be more error prone than the repetitive task, and that invalid priming produces more errors than valid priming. The lack of difference between repetitive and overall control trials suggests that embedding the road sign within a road scene did not significantly increase the error rate.

### 3.1. Response times to repetitive primes

A  $2 \times 3$  analysis of variance was conducted on the reaction times to targets in the repetitive prime condition across the factors of prime type (valid, invalid, and repetitive control) and experience. Experienced drivers responded faster than the novice drivers ( $F_{(1,24)} = 14.13, p < .01$ ) with mean response times of 477 and 614 ms, respectively. Invalid trials were found to slow responses compared to valid and control trials ( $F_{(2,48)} = 10.51, p < .01$ ). The interaction between these two factors was also significant ( $F_{(2,48)} = 10.05, p < .01$ ) and can be viewed in Fig. 2.

The experienced drivers benefited from valid priming with faster responses compared to the control and invalid trials ( $p < .01$ ). Novices were however faster with the repetitive control targets than with either the valid or invalid trials ( $p < .01$ ). This suggests that any prime information given to the novice drivers (beyond the temporal warning given by the three Xs in the control prime) actually hindered performance. The experienced drivers however made use of the valid

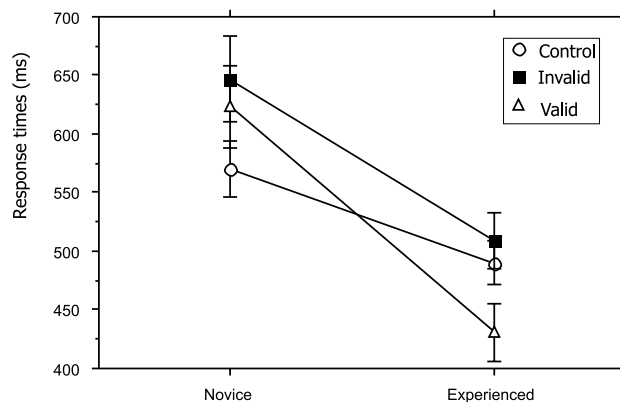


Fig. 2. Mean response time to road sign targets preceded by either a repetitive valid, invalid or control prime across the participant groups (with standard error bars added).

repetitive primes to improve response times, and were unhindered by the presence of invalid primes (when compared to the repetitive prime controls).

### 3.2. Response times to semantic primes

The mean response times for novice and experienced drivers were compared in a further  $2 \times 3$  analysis of variance across the three levels of prime type. Experienced drivers (519 ms) were faster than novice drivers (698 ms;  $F_{(1,24)} = 15.1, p < .01$ ). The main effect of prime validity ( $F_{(2,48)} = 4.3, p < .05$ ) revealed that valid trials were faster than control trials ( $p < .01$ ) while invalid prime response times fell in between. The means can be viewed in Fig. 3. Though this figure is suggestive of an interaction, the effect did not reach significance ( $F_{(2,48)} = 1.9$ ). Despite this, the pre-planned analysis of the prime types within driver groups supported a beneficial effect of valid primes over invalid and control trials for experienced drivers ( $F_{(2,24)} = 12.2, p < .01$ ).

### 3.3. Comparing control conditions

The rationale for the inclusion of an overall condition was that it would allow a comparison of both the semantic and repetitive tasks against a baseline. The overall control condition required participants to respond to a road sign without a corresponding background scene. Experienced drivers responded faster than novices over all three control conditions ( $F_{(1,24)} = 6.8, p < .05$ ). A main effect of control condition showed that responding to picture targets produced longer RTs than responding to road signs regardless of background ( $F_{(2,48)} = 41.9, p < .01$ ). An interaction between experience and control trial ( $F_{(2,48)} = 5.0, p < .05$ ) revealed that though both experienced and novice drivers were slower responding to the semantic targets as expected, the effect was greater for the novice drivers (see Fig. 4).

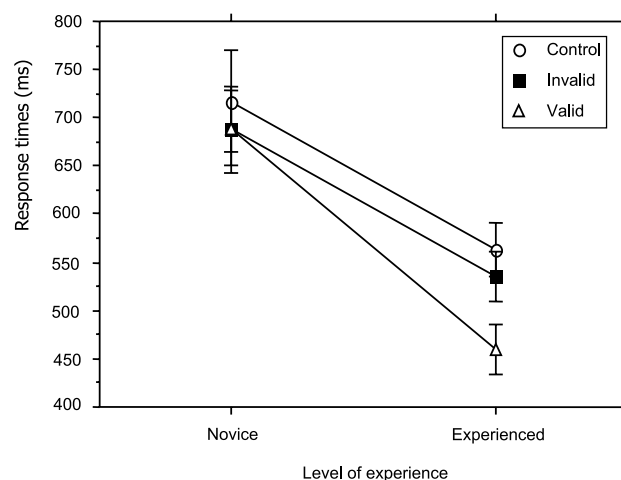


Fig. 3. Mean response time to traffic scenes preceded by either a semantic valid, invalid or control prime across the participant groups (with standard error bars added).

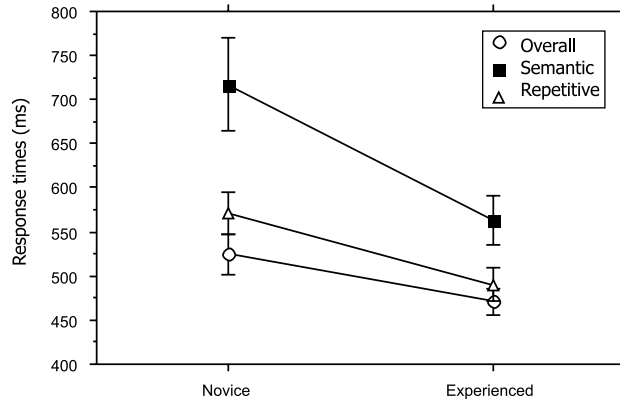


Fig. 4. Mean response time to the three control conditions across the participant groups (with standard error bars added).

#### 4. Discussion

The results revealed clear repetitive priming effects, and a suggestion of semantic priming (on the basis of pre-planned comparisons) for the experienced drivers. Overall the novice drivers performed worse on simple response times to both the traffic sign targets and the road scenes, and the effects of the primes actually seemed to reduce performance, at least for the repetitive primes. The results of the repetitive, semantic and control analyses are discussed separately in the following discussion.

##### 4.1. Do road signs prime road signs?

The analysis of the repetitive prime trials revealed a benefit for experienced drivers when responding to identical traffic sign probes but no cost for an invalid prime. The novices however performed surprisingly better on the control trials than either the valid or invalid prime trials. It was initially predicted that the participant groups would produce the same pattern of benefits for valid priming (as there should be little experiential effect in the direct mapping of two orthographically identical images) though novices would have longer response times overall due to their relative unfamiliarity with the stimuli. Though the overall difference in response times did occur between novice and experienced drivers, the benefits of priming did not occur for the novices. Remarkably, instead the valid trials were found to hinder them as much as the invalid trials.

The main effect of experience on response times is the easier effect to explain. Previous research has noted that novices tend to take longer to process driving related stimuli (which is often reflected in their increased length of fixation durations, e.g. Chapman & Underwood, 1998; Crundall & Underwood, 1998). This may represent the novelty of the stimuli for the novice drivers. Experienced drivers may have developed automatised responses to road signs and other driving stimuli that are perceived on a frequent basis, improving response speed. Other explanations could also be posited such as the reduction of thresholds within a driving-related memory store similar to conceptions of the internal lexicon. Though several mechanisms could potentially

explain the overall response differences between the groups, they cannot however account for the lack of repetitive priming in the novice drivers. In order to explain this intriguing effect one could propose the interference of conscious information (such that the novice drivers actually think about the prime whereas the beneficial effects that experienced drivers receive are automatic responses to the prime), though if this were the case then one would still expect differentiation between valid and invalid trials. One further possibility is that the valid and invalid primes trigger some unnecessary processing in novice participants perhaps through the creation of a sub-vocal phonological code in an attempt to interpret the sign. This time consuming process may not actually be required for the orthographic discrimination and subsequent response, and experienced drivers may have developed an ability to override such unnecessary use of resources. If novice drivers are still obliged to undertake such unnecessary processing this would reduce overall response times and produce an artificial benefit for the neutral condition as no phonological encoding may be instigated by a simple string of Xs.

In answer to the heading at the start of this section, it seems that road signs do prime identical road signs (supporting the basic findings of Castro et al., 1999), but only in experienced drivers. This unexpected experiential effect is hard to explain, and runs contra to the results of Schwartz and Hashtroudi (1991) who found no improvement in repetitive priming. This issue will be returned to later.

#### *4.2. Do road signs prime road scenes?*

The analysis of the semantic prime trials revealed the experienced drivers to be faster at classifying road scenes into the categories left bend, right bend and crossroads than novice drivers by an average difference of 179 ms. A main effect was also noted for prime type with the valid primes producing a benefit compared to the control trials, while invalid trials tended to incur no extra cost. The interaction did not reach significance but this was probably due to the large difference in response times due to experience which will have dampened any smaller differences in the within-group factor. Though one cannot infer any differential effects of priming due to experience from the initial analysis of variance, if the dampening effect of the between-groups factor is removed according to the pre-planned comparisons, then one is left with a definite benefit of semantic priming for experienced drivers and no appreciable cost of an invalid prime compared to a control prime. Novice drivers show no difference between the prime types and the control trials. This provides partial support for the prediction that experienced drivers would gain greater benefit from semantic priming than novices would.

Though the novices' response times are in keeping with the hypotheses, they differ to the repetitive results in that no bias was found for the control condition. If novice drivers are prone to the unnecessary encoding of a phonological code in the repetitive trials, this problem appears to be absent in the semantic trials. It is possible that, as the required response was triggered by a road scene, it was easier for the novice drivers to explicitly ignore the prime (i.e. not begin phonological encoding) because of its different surface structure to targets. This could explain why a benefit for the control trials was noted in the repetitive condition but not in the semantic condition.

If this post hoc argument is correct then one must question the neutrality of the control prime (especially a string of Xs – cf. Rayner & Slowiaczek, 1981). Whether the novices' anomalous results are due to a questionable neutral prime or actually reflect an underlying process is open to

debate. Replication and further investigation of this effect is required before one can start to postulate cognitive reasons for the neutral prime bias in novice drivers. Use of a neutral prime that may still be given a phonological code by novices (such as a warning sign that is irrelevant to the task at hand) may be a better choice.

#### *4.3. Comparison of the control trials*

Though the validity of the string of Xs as a neutral prime may have been called into doubt, the comparison of neutral trials is still informative in comparisons of the processing time required for road signs and road scenes. The comparison of the three control conditions revealed the same advantage noted in earlier analyses for experienced drivers responding to driving. The interaction demonstrated that though both groups were slower responding to the road scenes (semantic targets) compared to the repetitive and overall control conditions, this difference was considerably greater in the novice drivers. This suggests that the repetitive and overall control tasks were comparable, therefore the embedding of repetitive targets within a distracting background had no effect. However the ability to interrogate the visual scene and process the road direction was considerably more difficult for the novice drivers. This effect can be understood in regard to novice drivers' less efficient use of eye movements to extract visual information while driving (e.g. Mourant & Rockwell, 1972; Crundall & Underwood, 1998), and the greater cognitive demands that inexperienced drivers suffer when processing driving stimuli (Crundall, Underwood, & Chapman, 1999). There should be consensus between all participants as to the focus of information in a traffic sign (i.e. in this case within the red triangular border) though the information in a road scene is more dispersed and therefore open to greater variance in the time taken to access the meaning on the basis of the visual input.

### **5. Conclusions**

The findings have confirmed the results reported by Castro et al. (1999) in regard to repetitive priming, but have also demonstrated the possibility of semantic priming between road signs and road scenes.

The repetition priming results are of less generalisable interest than those from the semantic priming conditions, as the latter task seems more relevant to driving. However the results (following the design of Castro et al., 1999) do suggest some interesting experiential effects on repetition priming and extend previous research in this area. In addition, though the semantic task seems better suited to explaining the transmission of information in the real world, it should be noted that the UK road system often employs the repetitive use of road signs on the run up to a single hazardous road feature. This research suggests that this strategy, rather than being a redundant use of resources, could possibly provide some benefit.

Overall the results call into question the purely conscious view of road sign information transmission. The experiential differences suggest that priming is developed with experience of the context (presumably due to the consistent mapping built up over time). In addition the analysis of the control conditions revealed that experienced drivers can abstract information from a road scene faster than novice drivers. Previous research has demonstrated differences in eye movements

between novice and experienced drivers. The results presented here fit with the suggestion that such eye movement differences may affect the speed with which drivers classify road scenes. Future research should integrate eye-tracking technology with the priming paradigm in order to assess this relationship directly, and a wider variety of signs should be tested including prohibitive and informational signs.

The implications of successful road scene and road sign priming will change the basic conception of road sign information, and could feasibly be used as a tool in road sign design and placement. The experiential differences also add another dimension to the automatic processes that are currently recognised as a development of driving experience (such as the increased efficacy of gear changing with increased experience – Groeger & Clegg, 1997). Currently tests upon the use of conscious information are being developed as driving test diagnostics (e.g. the hazard perception test, McKenna & Crick, 1994). Further development of the priming paradigm could lead to a similar diagnostic of the automatic relations that are built up with experience.

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### References

- Avant, L. L., Thieman, A. A., Zang, A. L., & Hsu, S. Y. (1996). Memory codes for traffic sign information: visual verses meaning codes. In A. G. Gale et al. (Eds.), *Vision in vehicles V*. Amsterdam: Elsevier.
- Brachacki, G. W. Z., Nicholson, R. L., & Fawcett, A. J. (1995). Impaired recognition of traffic signs in adults with dyslexia. *Journal of Learning Disabilities*, 28, 297–301.
- Castro, C., Horberry, T., & Gale, A. (1999). *The effects of semantic priming and repetition priming on traffic sign recognition*. Paper presented at Vision in Vehicles VIII, Boston.
- Chapman, P. R., & Underwood, G. (1998). Visual search of dynamic scenes: Event types and the role of experience in viewing driving simulations. In G. Underwood (Ed.), *Eye guidance in reading and scene perception*. North Holland: Elsevier.
- Cole, B. L., & Hughes, P. K. (1984). A field trial of attention and search conspicuity. *Human Factors*, 26, 229–313.
- Collins, A. M., & Loftus, E. F. (1975). A spreading activation theory of semantic processing. *Psychological Review*, 82, 407–428.
- Crundall, D., Underwood, G., & Chapman, P. (1999). Driving experience and the functional field of view. *Perception*, 28, 1075–1087.
- Crundall, D., & Underwood, G. (1998). The effects of experience and processing demands on visual information acquisition in drivers. *Ergonomics*, 41, 448–458.
- Ells, J. G., & Dewar, R. E. (1979). Rapid comprehension of verbal and symbolic traffic sign messages. *Human Factors*, 21, 161–168.
- Fisher, J. (1992). Testing the effect of road traffic signs' informational value on driver behaviour. *Human Factors*, 34(2), 231–237.
- Groeger, J. A., & Clegg, B. A. (1997). Automaticity and driving: Time to change gear. In T. Rothengatter, & E. Carbonell Vaya (Eds.), *Traffic and transport psychology: Theory and application* (pp. 137–146). Oxford: Pergamon Press.

- Häkkinen, S. (1965). *Perception of highway traffic signs*. Helsinki: TALJA.
- Hughes, P. K., & Cole, B. L. (1986). Can the conspicuity of objects be predicted from laboratory experiments? *Ergonomics*, 29(9), 1097–1111.
- Johansson, G., & Backlund, F. (1970). Drivers and road signs. *Ergonomics*, 13, 749–756.
- Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence: Brown University Press.
- Loo, R. (1978). Individual differences and the perception of traffic signs. *Human Factors*, 20, 65–74.
- Masson, M. E. J. (1995). A distributed memory model of semantic priming. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 21, 3–23.
- McKenna, F. P., & Crick, J. L. (1994). *Hazard perception in drivers: A methodology for testing and training*. Transport Research Laboratory Report, 313. Transport Research Laboratory, Crowthorne.
- Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognising pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, 90, 227–234.
- Milosevic, S., & Gajic, R. (1986). Presentation factors and driver characteristics affecting road sign registration. *Ergonomics*, 29, 807–815.
- Mourant, R. R., & Rockwell, T. H. (1972). Strategies of visual search by novice and experienced drivers. *Human Factors*, 14(4), 325–335.
- Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited capacity attention. *Journal of Experimental Psychology*, 106, 226–254.
- Paniati, J. F., & Mace, D. J. (1993). *Minimum retroreflectivity requirements for traffic signs*. Report No. FHWA-RD-93-077, US Department of Transportation.
- Rayner, K., & Slowiaczek, M. L. (1981). Expectations and parafoveal information in reading: Comments on McClelland and O'Regan. *Journal of Experimental Psychology: Human Perception and Performance*, 7, 645–651.
- Potter, M. C., & Faulconer, B. A. (1975). Time to understand pictures. *Nature*, 253, 437–438.
- Schwartz, B. L., & Hashtroudi, S. (1991). Priming is independent of skill learning. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 17, 1177–1187.
- Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic processing: II. Perception, learning, and automatic attending and a general theory. *Psychological Review*, 83, 127–190.
- Sperber, R. D., McCauley, C., Ragain, R. D., & Weil, C. M. (1979). Semantic priming effects on picture and word processing. *Memory and Cognition*, 7, 339–345.
- Sprenger, A., Schneider, W., & Derkum, H. (1999). Traffic signs, visibility and recognition. In A. G. Gale et al. (Eds.), *Vision in Vehicles VII*. Amsterdam: Elsevier.
- Summala, H., & Hietamäki, J. (1984). Drivers' immediate responses to traffic signs. *Ergonomics*, 27, 205–216.
- Traffic Signs Manual (1986). *Warning Signs*. The Stationary Office, London.
- Warren, C. E. J., & Morton, J. (1982). The effects of priming on picture recognition. *British Journal of Psychology*, 13, 117–130.
- Whitaker, L. A., & Stacey, S. (1981). Response times to left and right directional signs. *Human Factors*, 23, 447–452.
- Zwahlen, H. T. (1994). *Traffic sign reading distances and sign reading times when driving at night*. Paper presented at the 12th Biennial Symposium on Improving Visibility for the Night Traveller. National Academy of Sciences, Washington, DC.
- Zwahlen, H. T., & Schnell, T. (1998). Driver eye scanning behaviour when reading symbolic warning signs. In A. G. Gale et al. (Eds.), *Vision in Vehicles VI*. Amsterdam: Elsevier.