LEARNING TO AVOID ONCOMING MOTORCYCLES AT INTERSECTIONS

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ABSTRACT

Crashes involving drivers turning right across the path of oncoming motorcycles are an ongoing problem for rider safety. This study demonstrated the acquisition of avoidance learning in a decision task similar to that made by drivers when turning across oncoming traffic at an intersection. A sample of 48 participants was divided randomly into two groups – a Learning Group and a Control Group. In the first phase of the study, participants responded to 200 digital photographs of oncoming traffic at intersections, presented on a computer monitor, by indicating whether they would turn across the traffic in each situation or would choose to wait. Half the photographs included one or more motorcycles in the oncoming traffic, and a long inter-trial interval was used as a negative consequence if the participant's decision to GO was deemed to be unsafe by the software. The Learning Group was subjected to a contingency between motorcycles and crash risk such that the computer-determined crash risk for a GO decision was higher when a motorcycle was present than when there were no motorcycles. The Control Group's crash risk was unrelated to the presence or absence of motorcycles, and the average crash risk across all trials was the same for the two groups. The result was consistent with the acquisition of avoidance learning, with Learning Group participants becoming more cautious as the first phase continued – but only when the image included a motorcycle. A second phase conducted four weeks later demonstrated that the avoidance learning had not decayed, and showed the effect of prior learning in the avoidance learning paradigm. The implications of this demonstration of avoidance learning for the development of training programs are discussed.

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INTRODUCTION

There has been increasing interest in the role of associative learning mechanisms in real-world behaviour (eg. Domjan, 2005; Domjan, Cusato, & Villareal, 2000; Hollis, 1997) where it is argued that it serves to alert animals to important events in their environment. Domjan (2005) argues that Pavlovian conditioning – one form of associative learning – is an adaptive trait that detects relationships between natural precursors to significant events and the events themselves, allowing the organism to respond to the signal or cue as if it expects the event to occur.

This view of associative learning leads to an expectation that the learning mechanism should influence driving behaviours. One effect of driving experience should be the accumulation of associative learning about the contingencies between cues and potential hazards, with the consequence that drivers should be able to react to these cues as if they expect the potential hazard to occur. Learning mechanisms should therefore assist drivers to avoid hazards, and Parsons (1976) and subsequently Fuller (1984, 1988, 1992) discussed this avoidance learning (eg. Seligman and Johnson, 1973) and its application to driver behaviour.

Taking this approach to hazard-related behaviours leads to some interesting hypotheses. The most important of these is that it should be possible to demonstrate the development of avoidance learning in a driving context. The study reported here was conducted specifically to test this prediction. It was undertaken using a computer-based decision-making task that was designed to represent a common hazard when driving. Participants observed digital still photographs of oncoming traffic at an intersection and were required to make a GO or WAIT decision for each one to indicate if they felt it was safe to turn across the oncoming traffic. This situation is particularly risky for motorcycles, and for this reason the study focused on turning decisions across oncoming motorcycles. Half the images included one or more motorcycles.

Unsafe decisions were punished with a time penalty and a message that the participant had crashed on that trial. In the first phase of the study, a control group was exposed to consequences that were random and an experimental group was exposed to a contingency between the presence of one or more motorcycles in the photograph and a higher risk of a "crash" outcome, with the aim of demonstrating the development of avoidance learning (a decision to WAIT) whenever a motorcycle was present in the photographs.

In addition to this, the study was planned to test some specific predictions derived from an associative learning perspective. The study included a follow-up phase conducted four weeks after the first phase where it was predicted that any avoidance learning from the first phase would still be apparent at the beginning of the second phase because associative learning is considered to be long-lasting (Kehoe & Macrae, 2002)).

The study was also planned to assess the effect of learned irrelevance (Bonardi & Ong, 2003) – where the associative learning mechanism appears to be sensitive to random relationships between events. Exposure to a non-contingent relationship between events is known to interfere with subsequent learning about a new relationship between the events. In the current study it was expected that the control group, which was exposed to a random relationship between motorcycles and crash outcomes in the first phase of the study, would not develop an avoidance response when exposed to a contingency between them in the second phase of the study. It was also expected that drivers with larger amounts of driving experience would be less likely to develop an avoidance response because their exposure to motorcycles at intersections will have resulted in the development of learned irrelevance.

METHOD

Participants

The method is described fully in Harrison (2005).

There were 48 participants. Sixteen (eight male and eight female) formed the Inexperienced Driver group - with either no driving experience or having only-recently obtained a learner permit. The average age of participants in this group was 16.25 years, with a range from 15 to 17 years. Sixteen participants (eight male and eight female) formed the Novice Driver group. These participants were required to hold probationary licences and to be towards the end of their three-year probationary period. The average age of participants in this group was 20.4 years, ranging from 19 to 21 years. Sixteen participants (eight male and eight female) formed an Experienced Driver group. These participants were required to hold full licences and were not involved in road safety research or practice. The average age of participants in this group was 42.9 years, ranging from 34 to 64 years.

Participants were allocated to one of two groups randomly – a Learning Group (the experimental group) and a Control Group – with the additional requirement that each group had to include an equal number of each of the three experience groups, and within this an equal number of male and female participants. Participants were paid a small amount to compensate them for their time. All participants were provided with general information about the project, instructions, a CD-ROM that included the software and digital images, and at the end of the project a short summary of the purpose of the study. Participants completed the study on their own personal computers and emailed their data files to the author.

The Task

The study involved repeated exposure to "learning" trials in which participants were shown digital photographs on a computer monitor taken from the position of a vehicle waiting to turn right at an intersection across oncoming traffic. The photographs showed the oncoming traffic from about the driver's position. There were 300 photographs in the set - half included one or more motorcycles in the oncoming traffic, and half did not. In all photographs, the closest vehicle in the image was between 50m and 100m from the camera at the time of the photograph. The locations were divided, multilane roads with speed limits of 80 km/h.

Participants were required to make a decision about whether they would turn across the oncoming traffic in each photograph. They indicated their decision by clicking one of two buttons that were displayed below the photograph – a "GO" button and a "WAIT" button. The participants had five seconds to make each decision.

Each trial concluded with a variable time delay and message that were used to deliver a negative consequence. The longest delay between learning trials occurred if participants failed to make any response to a photograph ("NO RESPONSE DETECTED" and a total of 9-seconds delay before the next item). The next longest delay accompanied a decision that the software determined to be unsafe – thus delivering a negative consequence for "unsafe" GO decisions ("YOU CRASHED", and a total of 7 seconds before the next trial). The shortest delay occurred for a safe GO decision ("YOU TURNED SAFELY", and 1-second delay), and a delay was incorporated for WAIT decisions (4 seconds) to encourage participants to make a decision to GO as often as possible.

The software determined the consequences of making a GO decision in each learning trial randomly, with the additional condition that the average risk of a "crash" was set to a higher figure for some participants in some conditions (see below). This manipulation of the crash risk made it possible to increase the frequency of negative consequences of a GO decision in some circumstances, with the expectation that the participants would learn this relationship and adjust their decision making accordingly.

Procedure

All participants completed two experimental phases, separated by about four weeks. The first phase involved responding to 200 learning trials presented in ten blocks of 20 trials with an opportunity for a short break between each block. The second phase involved responding to 100 learning trials presented in five blocks of 20 trials. In both phases, half the photographs included one or more motorcycles in the oncoming traffic, and half did not. The order of photographs was randomised for all participants within the first phase and the second phase.

The only difference between the two groups in the first phase was that members of the Learning Group had their negative consequences arranged such that there was a contingency between the presence of a motorcycle in the oncoming traffic and the likelihood of a "crash" consequence if they decided to GO. The average risk of crashing for GO decisions across all trials for both groups of participants and for both types of photographs was 0.4. Thus, 40 percent of all GO decisions resulted in a crash. In the first phase of the study, members of the Learning Group were exposed to a contingency between the photograph type and crash risk such that the risk of a crash was 0.6 when one or more motorcycles were present, and 0.2 when no motorcycle was present. The risk of crashing in the first phased of the study for all photographs was 0.4 for members of the Control Group. In the second phase of the study, all participants were subjected to the Learning Group contingency between photograph content and crash risk.

RESULTS

Participants' responses to each trial were collected. The data were summarised into blocks of twenty learning trials and the outcome variable used in the analysis was the proportion of responses in each block of twenty trials that were WAIT responses, separately for images that included and did not include motorcycles.

As the purpose of this study was to demonstrate the acquisition of a learned avoidance response in the Learning Group, data analysis involved a relatively conservative approach that focused on testing specific hypotheses. Data were analysed using repeated-measures ANOVA to reflect the within-subjects design, with group membership, experience, and sex as between-subject factors. The analysis involved testing planned contrasts or comparisons based on hypothesised effects. Assessing the presence of learning involved applying contrast coefficients that were consistent with the expected change in behaviour over blocks of trials. Discussions of this approach can be found in Lindman (1974) and Hays (1981).

First Phase

As the key hypothesis related to the development of associative learning, the planned contrasts including "learning block" as a factor were based on the expected learning curve or power function predicted under the mathematical model of learning proposed by Rescorla and Wagner (1972). Information about the statistical tests used is in Harrison (2005).

The data were consistent with the hypothesis that avoidance learning would occur (C1 = -39.0, t = -2.53, p < .05), with the probability of a WAIT response changed over Learning Blocks consistent with the Rescorla-Wagner learning curve, but depending on group membership and image content. The probability of a WAIT response in the two phases of the study is shown in Figure 1, disaggregated by group membership and image content.

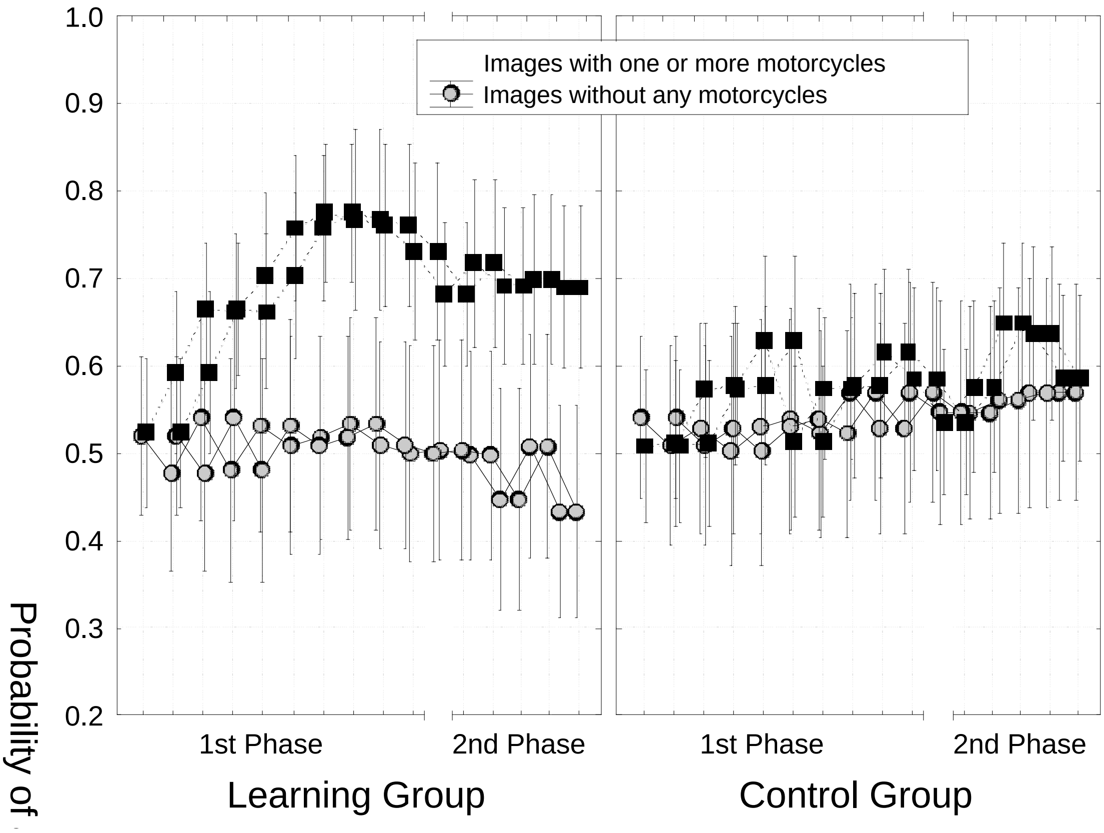

Figure 1: WAIT responses disaggregated by group, image content, and block

As the learning trials in the first phase progressed, members of the Learning Group became more likely to respond with a WAIT response when motorcycles were present in the image. The likelihood of a WAIT response did not appear to change when no motorcycles were present in the photograph, and members of the Control Group did not appear to change their responses over the learning trials to either type of image. This result is consistent with the expectation that avoidance learning would be demonstrated – there was an increase in proportion of WAIT responses to the stimulus that signalled a negative consequence for GO responses.

The pattern of results in Figure 1 was stronger for Inexperienced Drivers than for Experienced Drivers ($C2 = -32.3$, $t = -2.60$, $p < .05$), and there was no difference in this pattern between Inexperienced and Novice drivers ($C3 = -21.2$, $t = -1.68$, $p > .05$). This is consistent with the known effects of pre-exposure to learning and is discussed later as it suggests that the benefits of a program using learning mechanisms may be realised more successfully with less-experienced drivers.

There were no statistically significant differences between male and female participants ($C4 = 9.4$, $t = 0.61$, $p > .05$).

<u>Second Phase</u>

The second phase of the study involved exposure to the learning trials (under the Learning Group conditions) for all participants. This provided the opportunity to investigate some specific issues.

The difference between the Learning Group at the end of the first phase of the study and the first block of learning trials in the second phase would reflect the level of “forgetting” or extinction of the learned WAIT response over the four-week period between phases. This was assessed by comparing change in WAIT responses to photographs with motorcycles between the last five blocks of the first phase and the first block of the second phase in the Learning Group, with the change in responses to photographs without motorcycles over the same time period for the same group of participants. This contrast was not statistically significant ($C = -1.9$, $t = -1.8$, $p > .05$), indicating that it was not possible to detect any extinction of the learned WAIT response. This can be seen in Figure 1, where it is clear that responses to images that included one or more motorcycles were more cautious than responses to car images at the start of the second phase of the study.

Exposing the Control Group in the second phase of the study to the Learning-Group contingency between motorcycles and increased risk was designed to provide an additional assessment of the effect of learned irrelevance (see Bonardi & Ong, 2003). Pre-existing learning of this type is known to interfere with subsequent learning when a relationship is instated – leading to a prediction that the Control Group in the second phase, when exposed to learning trials where there is a contingency between the presence of a motorcycle and increased crash risk, will not learn about the new relationship.

There was no statistically significant evidence of associative learning in the Control Group in the second phase of the study when participants were exposed to the contingency between motorcycles and crash risk ($C = 0.67$, $t = 0.1$, $p > .05$). This outcome can also be seen in Figure 1.

An additional issue arises from Figure 1. While the Control Group showed no sign of the learning specific to the content of the images that was apparent in the Learning Group, there was an apparent gradual increase in the likelihood of a WAIT response amongst control group members across the whole of the study. Although this apparent increase in cautious responses was not statistically significant (the difference between the probability of a WAIT response in the first block (in phase 1) and the last block (in phase 2) of learning trials was borderline ($C = 1.8$, $t = 1.9$, $p = .07$)), it is consistent enough across the two phases of the study to suggest that Control Group participants were becoming more cautious – perhaps because they were unable to predict the risk of crashing based on any features of the images. It may be of some interest to investigate this issue in future studies.

DISCUSSION

The results of this study are consistent with the acquisition of avoidance learning in a driving-related behaviour. Participants exposed to an avoidance-learning paradigm in which they could avoid the negative consequences of a “crash” by responding more cautiously in the presence of oncoming motorcycles did so, and the time course of the development of this response was consistent with the development of associative learning.

In the first phase of the study, the Control Group experienced conditions similar to those experienced in the Learning Group. They were exposed to the same photographic images and the average risk of a crash was the same (0.4) in both groups – meaning that the number of crashes experienced in the two groups would have been equal had participants given GO responses the same number of times. The key difference between the two groups was the relationship between the image content and crash risk. In the Control Group, the risk of a crash outcome to a GO response was random – there were no experimenter-determined contingencies between image content and crash risk. In the learning group, the average crash risk was higher when one or more motorcycles were present in the oncoming traffic.

If the only difference between the Control Group and the Learning Group was this contingency between crash risk and image content, then the differences in decision-making outcomes shown in Figure 1 must relate to that contingency. It is therefore reasonable to conclude that the long-lasting, significant change in behavioural decision making that occurred for Learning Group members is the result of avoidance learning based on detecting and using this contingency.

The learned avoidance response was still present after four weeks had elapsed. This longevity was also consistent with expectations about learnt responses, further supporting the suggestion that the change in behaviour in the Learning Group is a consequence of associative learning.

It was predicted that avoidance learning would fail to develop in two situations in the current study – in both cases because prior learning that there is no relationship between two events weakens any new learning that there is a relationship between them. It was predicted that any avoidance learning would be weaker for experienced drivers because their real-world learning would inhibit learning about a heightened risk of crashing in the presence of motorcycles. It was also predicted that the Control Group (which had been exposed to a non-contingent relationship) would fail to develop an avoidance-learning response when exposed to the contingency used in the Learning Group.

Both predictions were supported by the data. This adds further support to the conclusion that the current study has demonstrated the development of avoidance learning in the intersection decision-making task.

The implications of the results for understanding the development of safe and unsafe driver behaviour are interesting. If it is possible to modify a driving-related decision-making process using an associative learning paradigm, and if the results appear to be consistent with other research in the associative learning area, then it is possible that associative learning mechanisms play a role in some aspects of driving behaviour. The results are consistent with earlier suggestions (Parsons, 1976; Fuller, 1984, 1988, 1992) that avoidance learning plays a role in the development and maintenance of safe driving behaviours.

The results might also support the potential value of using an associative-learning paradigm to modify driver behaviours in safety-related areas. This is speculative, however, and it is important to move slowly in attempting to apply this approach to the development of a training program. While there is evidence in the current study of an increase in caution on the part of participants when exposed to the avoidance learning paradigm, application to the real world requires some additional research.

The first issue here is that decision-making when driving takes place in a dynamic environment and the study made use of still images as cues. This is an important difference and needs to be addressed, perhaps through a study involving decision making with video stimuli or in a simulator with a similar task. Although there is no reason to believe that avoidance learning will not occur in a more-complex situation, it would be necessary to demonstrate that this is so before assuming that a program could influence drivers in the real world.

This issue is one of ecological validity – it may be a reasonable criticism of the current study that the use of still images with minimal information about the speed of oncoming traffic, a computer-mouse based decision task, and seemingly-high probabilities of a crash occurring on a GO decision (an average of 0.4) limits the generalisability of the results to real-world driving decisions and training programs. This is true in relation to the use of still images and the use of a computer mouse, but it is a common failing of studies that are laboratory-based and underscores the need for further work using an experimental paradigm that more-closely matches the characteristics of the driving task.

The ecological validity issue is less of a problem, however, in relation to the probabilities of a crash occurring after a decision to GO. These probabilities were selected to reflect the likelihood of a crash if a decision to turn were to be made in the situations depicted in the photographs. The closest oncoming vehicle or motorcycle was between 50m and 100m from the camera, which means that a decision to turn across the traffic in an 80 km/h speed zone would be associated with a non-trivial probability of a crash.

It is not possible, however, to answer the broader concerns about the generalisability of the results of this study to real-world driving. The study appears to demonstrate that avoidance learning can occur in a task that includes elements likely to be present in driver decision-making, but there is a clear need for additional research using closer approximations to the driving task. The use of dynamic stimuli such as video would be one important step, and conducting a similar study in a driving simulator would provide more-convincing results.

The second issue concerning the application of these results to program development is one that applies to any training or educational program. If it is true that associative learning processes play an important role in driving-related behaviours, then new learning will be occurring whenever driving takes place. This means that any learning that occurs in a training program is likely to be counteracted by the learning that occurs in day-to-day driving. A possible criticism of the learning approach suggested here is that attempting to teach drivers that there is a high risk of collision associated with turning in front of motorcycles will be ineffective when drivers' experiences after the program expose them to the real risk, which is much lower.

Avoidance learning differs from other types of associative learning, however, in that it can be self-reinforcing. When a learnt avoidance behaviour occurs in response to something that has been paired with a negative consequence and the negative consequence does not occur, the behaviour is more likely to occur again in the same situation because it has produced a positive consequence – the absence of an anticipated negative event. It does not matter that the negative event may have been unlikely to occur – its absence is paired with the behaviour and this reinforces the behaviour.

In the case of drivers turning across oncoming traffic, a learned avoidance behaviour (WAITING) when a motorcycle is coming results in the absence of an anticipated negative consequence – a crash or near miss. This occurs even though the crash itself is a very rare event – as long as the oncoming motorcycle signals a potential crash through the driver's learning history, the avoidance response will be self reinforcing.

This means that an avoidance learning approach should have a long-lasting effect despite the low frequency of crashes with motorcycles – assuming that the learning occurs early in the driver's career and assuming that other factors do not result in the driver taking risks at intersections so that the original learning about motorcycles and crash risk is extinguished.

The most challenging problem, however, is the need to transfer any learning from the learning environment (whether it is in front of a computer or in a simulator) to the real world. The learning mechanism is strongly dependent on the context in which learning occurs – a learned response from one context may not occur in another context because the contextual cues from the learning situation are included in the learning (Kehoe & Macrae, 2002). This means that the most pressing problem before attempting to implement any training program will be the need to demonstrate that a change in decision making behaviour based on avoidance learning in an artificial learning environment transfers to a long-lasting behaviour change in day-to-day driving. If this transfer of learning cannot be demonstrated, proceeding to implementation of a training program would not be justified.

Two aspects of the results of the current study were unexpected. The first was that the proportion of WAIT responses to images with one or more motorcycles was similar to the proportion of WAIT responses to images without any motorcycles at the start of the learning trials. If associative learning processes do play a role in the development of caution-related behaviour at intersections, it might be expected that the relatively small amount of experience of motorcycles at intersections in day-to-day driving would lead to a reduced incidence of cautious decisions in this study. This would certainly be consistent with the nature of motorcycle crash problems at intersections. It is possible that participants in this study reacted to the uncertainty of the task by responding largely randomly to the images. This might explain why the initial WAIT response rates were about 50% (see Figure 1), but future research in this area might need to investigate the initial response rates more closely.

The second unexpected finding was that although responses to images with motorcycles changed in the Learning Group, responses to images without motorcycles did not. This change might have been expected because images without motorcycles were associated with a lower crash rate, with a consequent expectation that participants in the Learning Group might have become less cautious with these images while they became more cautious with the motorcycle images. The most likely explanation for this result is that a low risk of crashing may be less salient and therefore less able to support associative learning than a high risk of crashing. The effect of salience on associative learning is well known (Kehoe & Macrae, 2002), and it is possible that a longer period of exposure to the learning contingency used for the Learning Group might have generated a change in decision-making behaviour. This may be of interest in future research, but it is not critical to the development of a training program based on associative learning.

REFERENCES

Bonardi, C., & Ong, S.Y. (2003) Learned irrelevance: A contemporary overview. *The Quarterly Journal of Experimental Psychology, 56B*, 80–89.

Domjan, M. (2005) Pavlovian Conditioning: A Functional Perspective. *Annual Review of Psychology, 56*, 179-206

Domjan M, Cusato B, & Villarreal R. (2000). Pavlovian feed-forward mechanisms in the control of social behavior. *Behavioral and Brain Sciences,* 23, 235–49.

Fuller, R. (1984) A conceptualisation of driving behaviour as threat avoidance. *Ergonomics, 27*, 1139-1155

Fuller, R. (1988) On learning to make risky decisions. *Ergonomics, 31*, 519-526

Fuller, R. (1992) Learned riskiness. *Irish Journal of Psychology, 13,* 250-257.

Hays, W.L. (1981) *Statistics* (3rd Edition). New York: Holt, Rinehar, & Winston.

Hollis K.L. (1997). Contemporary research on Pavlovian conditioning: a "new" functional analysis. *American Psychologist, 52*, 956–65.

Kehoe, E.J., & Macrae, M. (2002). Fundamental behavioral methods and findings in classical conditioning. In J.W.Moore (Ed.), *A Neuroscientist's Guide to Classical Conditioning*. New York: Springer.

Lindman, H.R. (1974) *Analysis of Variance in Complex Experimental Designs*. San Franciso: W.H. Freeman and Company.

Parsons, H.M. (1976) Caution behavior and its conditioning in driving. *Human Factors, 18*, 397-408.

Rescorla, R.A., & Wagner, A.R. (1972) A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and non-reinforcement. In A.H. Black & W.F. Prokasy (Eds) *Classical Conditioning II: Current Research and Theory*. New York: Appleton Century-Crofts.

Seligman, M.E.P., & Johnston, J.C. (1973) A cognitive theory of avoidance learning. In F.J. McGuigan & D.B. Lumsden (Eds.), *Contemporary Approaches to Conditioning and Learning*. Washington D.C.: V.H. Winston and Sons.

Harrison, W.A. (2005) A demonstration of avoidance learning in turning decisions at intersections. *Transportation Research F: Traffic Psychology and Behaviour*, *8*, 341-354.