**Understanding how drivers learn to anticipate risk on the road: A laboratory experiment of affective anticipation of road hazards**

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**Abstract**

This study examines whether there is evidence that converging theories from the domains of risk and decision making, neuroscience, and psychology can improve our understanding of how drivers learn to appraise on-the-road hazards. Within the domain of decision making it is suggested that there are two distinct ways in which humans appraise risk: risk as feelings and risk as analysis. Meanwhile, current neurological theory, in the form of the Somatic Marker Hypothesis, supports the role of feelings and emotion as an evolved automated system of human risk appraisal that biases judgment and decision making. This study used Skin Conductance Responses (SCR) to measure learner, novice and experienced drivers’ psycho-physiological responses to the development of driving hazards. Experienced drivers were twice as likely to produce an SCR to developing hazards as novice drivers and three times as likely when compared with learner drivers. These differences maintained significance when age, gender and exposure were controlled for. Further analysis revealed that novice drivers who had less than 1,000 miles driving experience had anticipatory physiological responses similar to learner drivers, whereas novices who had driven more than 1,000 miles had scores approaching those of experienced drivers. This demonstrated a learning curve mediated by driving experience supporting experiential learning as proposed within the Somatic Marker Hypothesis. A differentiation between cognitive and psycho-physiological responses was also found supporting theory that distinguishes between conscious and non-conscious risk appraisal.

Keywords: Driving, Novice drivers, Hazard perception, Risk, Somatic Marker Hypothesis, Skin conductance

# Introduction

Crash risk negatively correlates with driving experience with a large reduction in risk occurring in the first few months of post-test driving (Drummond, 2000; Mayhew et al., 2003; Groeger, 2006). A more direct measure of driving experience (cumulative miles driven after licensure) shows crash risk levelling after 1,000 miles (McCartt et al., 2003) for both male and female novices and further decreasing between 2,500 and 3,000 miles though this decrement may not be uniform across crash type. There is some evidence that the likelihood of certain crash types decreases more quickly than others possibly because avoidance of these types rely on a more easily acquired skill set (Sagberg, 1998).

One of the higher-order skills that improves with continued experience and may partly underlie decreasing crash risk is hazard perception (McKenna and Crick, 1994). Hazard perception skill has been shown to increase with driving experience (e.g. Deery, 1999; Grayson and Sexton, 2002; McKenna and Crick, 1991; Quimby, et al., 1986) and is related to the likelihood of being involved in a road traffic accident (Quimby et al., 1986; Horswill and McKenna, 2004). The precise mechanisms underlying hazard perception remain unknown although there is evidence for both cognitive and visual search components. Crundall and Underwood (1998) found that experienced drivers developed a flexible search strategy when viewing different driving scenarios whereas novice drivers maintained the same pattern of search across all road types. Inexperienced drivers also show a tendency to foveate on an area close to the front of the vehicle (Falkmer and Gregersen, 2001), with poor attention to the sides of the road (McKnight and McKnight, 2003). In addition to poorer visual search for hazards, novice drivers also demonstrate considerably worse anticipation of other road users’ behavior (e.g. Sagberg and Bjornskau, 2005). Efforts to train novice drivers with hazard perception skills have had some success (e.g. Crick and McKenna, 1991; McKenna and Crick, 1993; McKenna et al., 2006; Sexton, 2000) although there is no evidence that training hazard perception skill using video and other stimuli can fully substitute for on-road experience.

The evidence for hazard perception, visual search and anticipation as skills that can distinguish between the relative crash risk between inexperienced and experienced drivers is strong. Nevertheless, scope remains for further elucidation of skill subcomponents and in particular those relevant to appraisal and decision-making. This study focuses on a potential contributory mechanism for rapid and accurate assessment of driving risk involving affect based information, which may be underdeveloped in novice drivers and requires experience across a range of driving situations to become established.

## Risk appraisal

Slovic and Peters (2006) suggest that risk is processed in two fundamental ways: risk as analysis and risk as feelings. Much of the recent decision-making literature has seen a shift in interest from the former to the latter (Peters et al., 2006) with feelings having become more precisely defined as 'affect'. Affect refers to a specific quality of "goodness" or "badness" associated with either positive or negative stimulus valence and which may be available to conscious awareness or may not (Slovic et al., 2002). A simple demonstration of the ‘effect of affect’ was shown by Denes-Raj and Epstein (1994) where participants elected to choose a winning red jelly bean from an urn which contained a greater absolute number but smaller proportion of red beans rather than the rationally more correct choice of an urn with fewer red beans but a proportionately better chance of winning. These participants reported that although they knew this choice was a poorer one probabilistically, they felt that they had a better chance when there were visually more red beans. This influence on decision-making has been labeled 'the affect heuristic' (Finucane et al., 2000).

Dual-process theories (e.g. Chaiken and Trope, 1999; Kahneman and Frederick, 2002) of information processing assume affect is processed in a separate underlying system from analytic processing with each system displaying qualitative differences from the other. The analytic system is conceptualized as logical, conscious, capable of utilizing abstract representations and slow whereas the ‘experiential’ system relies upon concrete representations, affective signals determined by past experience and more rapid processing oriented toward immediate action (e.g. Epstein, 1994). The utility of a non-analytic system is exemplified by the following quote from Slovic et al. (2004, p311):

“The ‘experiential system’ is intuitive, fast, mostly automatic, and not very accessible to conscious awareness. The experiential system enabled human beings to survive during their long period of evolution and remains today the most natural and most common way to respond to risk. It relies on images and associations, linked by experience to emotion and affect (a feeling that something is good or bad). This system represents risk as a feeling that tells us whether it is safe to walk down a dark street.”

Epstein (1994) suggests that these two systems work in parallel – a position also adopted by LeDoux (1996) and Zajonc (1980) and further embedded in a neurological theory of risk appraisal and decision making proposed by Damasio (1994, 2003) in the form of the Somatic Marker Hypothesis (SMH). Damasio argued that a completely rational system operating in isolation, would take too long to reach complex decisions or any such decision would be incomplete due to working memory limitations. However, decision speed and accuracy could be ecologically viable if facilitated using feedback from the autonomic and the somatic nervous systems via the emotion circuitry in the brain, and in particular, the amygdala and ventromedial prefrontal cortex (Bechara and Damasio, 2005). Damasio suggested that prior valenced experience results in the formation of a gut feeling or 'somatic marker’ which in turn biases the options available to a rational decision-making system. Experimental support for the Somatic Marker Hypothesis has relied mainly on the Iowa Gambling Task (IGT; Bechara et al., 1997, 1999, 2005) which affords learning of higher-order choice-outcome contingencies in the context of a complex environment. Participants are required to choose cards from four decks that are unknowingly advantageous or disadvantageous with different reward and punishment ratios. Participants can learn that some decks are advantageous or disadvantageous over the longer term and alter their behaviour to choose from the advantageous decks only. The SMH suggests that this learning, at least initially, does not derive from increased explicit knowledge of the reward/punishment schedule but rather from these emotion-based somatic signals. Crucially, normal participants begin to show anticipatory Skin Conductance Responses (SCRs) in the five second time period prior to physically choosing a deck and these responses are more pronounced for the ‘bad’ decks than the ‘good’ decks (Bechara et al., 1997). The task has often been used to compare groups of patients with brain lesions with a control group and shows that frontal and amygdala damage patients fail to produce anticipatory SCRs and record poor behavioural performance on the task (Bechara et al, 1999). Repeated experiments now offer substantial evidence for the existence and development of somatic markers in normal participants demonstrated by SCRs prior to the selection of a card (see Bechara et al., 1997)[[1]](#footnote-1).

## Somatic markers and driving

The relevance of the Somatic Marker Hypothesis to driving can be seen in recent models of driver behaviour such as Vaa’s (2007) Monitor Model, Fuller’s (2011) Risk Allostasis Theory and Kinnear’s (2008) Feelings of Risk Homeostasis model. These models share a common theme of attempting to describe and explain the processes through which a driver constantly monitors his or her environment, making continuous decisions about vital behaviours that impact on vehicle speed and trajectory. Each model provides a high level description of driving task with feedback loops denoting the constant processing and behavioural response required by the driver. In testing their models, Fuller et al.(2008) and Kinnear et al. (2008) found support for dissociation between drivers’ ratings of feelings of risk and calculated risk estimate. Meanwhile, Charlton and Starkey (2011) have argued that the results of their longitudinal simulator study provides evidence of two modes of driving: a ‘top-down’ cognitive, deliberative mode and a ‘bottom up’ automated mode involving little or no conscious attention. However, these experiments only report participants’ subjective appraisal and do not include more objective physiological demonstrations of emotion activation during driving.

Interestingly there have been some historical studies measuring skin conductance during driving. Hulbert (1957), Michaels (1960) and Taylor (1964) all reported finding that skin conductance responses were related to observable traffic events. Helander (1978), from a study of sixty Volvo drivers, reported that SCR and brake pressure were correlated to the order of .95 during on-the-road driving. While this is suggestive of an influence of affect, Helander (1978) also reports that SCR preceded accelerator release by 0.2 seconds and brake application by 1.9 seconds suggesting that the affective component may indeed be anticipatory. Although Helander (1978) accounted for skin conductance response latency, these results must still be viewed with caution due to the methodological difficulties involved in determining precise SCR timing.

More recently Crundall et al. (2003) measured drivers’ SCR in relation to hazardous events. Police drivers and a matched control group of normal experienced drivers were compared to novice drivers in response to police pursuit and emergency response videos. Analyses of SCRs, which Crundall et al. (2003, p169) considered “indicative of sudden increases in hazard awareness”, found that police drivers produced statistically significantly more SCRs than experienced and novice drivers to an immediate and identifiable hazard. While experienced drivers produced more SCRs than novice drivers, the difference between these two groups did not reach statistical significance. Crundall et al. (2003) conclude that police drivers were aware of a greater number of arousing stimuli.

A further measure in this study was drivers’ cognitive hazard ratings of the clips. It is reported that the differences between driver groups’ hazard ratings did not reach statistical significance (Crundall et al., 2003). Further, it was reported that differences between groups for the number of hazards they reported did not reach statistical significance. That police drivers physiologically responded to more stimuli but reported the same number of hazards as the other groups led Crundall et al. (2003, p172) to conclude:

“the police drivers were most sensitive to the number of potentially hazardous events, at least at a physiological level, yet there is no evidence that this resulted in changes in the number of hazards reported.”

These findings add further support to the argument that psycho-physiological measures could be symptomatic of automated processes of risk appraisal and add support to the idea that humans have two ways of appraising risk: risk as analysis and risk as feelings, as suggested by Slovic et al. (2002, 2004).

The Crundall et al. (2003) study was set up to detect responses to immediately hazardous events. However, it could be argued that a learned automatic response would be advantageous in advance of a hazardous event; that is, during the development of a hazard rather than immediately prior to a hazard. Fuller (2011), for example, explains that what distinguishes experienced and inexperienced drivers is the ability to detect, decide and respond in advance of a hazard so that the hazard does not in fact develop at all. This behavioral response (for example a slight reduction in speed by lifting ones foot from the accelerator pedal) controls the demand of the driving task and maintains a significant safety margin for the driver. Inexperienced drivers, by their very nature, lack the experience required to detect potential hazards and therefore drive into situations that compromise their safety margin, putting them at the mercy of any further sudden increase in demand.

## This study

The aim of the present study was to test theory discussed here and examine whether an affective component could be detected from inexperienced and experienced drivers in the lead up to a potential hazard using dynamic stimuli. The study focused on drivers’ cognitive and psycho-physiological responses during defined periods of hazard development. Three groups of driver were recruited; in addition to licensed inexperienced and experienced drivers, a group of learner drivers were also recruited. Hazard Perception video clips were purchased under contract from the Driving Standards Agency (DSA) in the United Kingdom (UK); the clips are similar to those used in the Hazard Perception section of the UK Driving Test.

Participants’ SCR was measured in addition to a continuous cognitive rating of risk using a slider response box, similar to that of Pelz and Krupat’s (1973) ‘Apprehension Meter’.

It was predicted that experienced drivers would demonstrate more SCRs in anticipation of a potential hazard compared to the inexperienced group, and also the learner group. Further, it was expected that while SCRs were more likely for all groups in response to an immediate and obvious hazard, a difference between the groups would remain, with experienced drivers more likely to produce an SCR than inexperienced and learner drivers. Although Crundall et al. (2003) did not find a statistically significant difference for this measure, this may have been due to the stimuli used; the DSA hazard perception clips used in this study were validated to distinguish between novice and experienced drivers, albeit as measured by reaction time (Grayson and Sexton, 2002). With regard to the cognitive appraisal of risk, it was assumed that although the measurement was via continuous slider rating rather than reaction time, this would also differ by experience level based on the general weight of evidence in the hazard perception literature. Therefore, it was expected that there would be an effect of experience on hazard ratings in anticipation of the hazard and in response to the hazard event whereby experienced drivers’ mean ratings in each period would be greater than those of inexperienced and learner drivers.

# Method

## Design

A 3 (experience group) x 2 (hazard section) mixed experimental design was utilized to test for participants psycho-physiological and cognitive responses to hazard perception clips. There were three levels of driver experience: learner, inexperienced and experienced. The groups were compared for their responses during defined developing hazard and hazard sections (see Results: Definitions for SCR Analysis, below). This design was applied to twelve hazard perception clips.

Continuous cognitive hazard ratings were taken in response to the clips. These indexed the participants’ continuous current ratings of risk via a response box with a sliding scale of 0 to 10. Physiological measures included participants’ skin conductance response (SCR) and respiration amplitude.

## Participants

Eleven learner drivers (5 male, 6 female), 21 inexperienced (9 male, 12 female) and 18 experienced drivers (10 male, 8 female) took part in the experiment. Inexperienced drivers were defined as having held a driving license for less than 3 years (mean=13.33 months, SD=8.86, range 1 to 29) and experienced drivers as having held their license for over 3 years (mean=86.22 months, SD=43.63, range 36 to 168).

Participant ages were deliberately kept to within similar age ranges to minimize the effect of age. The learner driver group had a mean age of 21.7 years (SD=2.9, range 17.6 to 27.3); the inexperienced driver group had a mean age of 21.7 years (SD=3.6, range 17.8 to 33.8); and the experienced driver group had a mean age of 25.4 years (SD=2.9, range20.3 to 31.0).

The learner driver group had driven a mean of 83 miles (134 kms) (SD=142, range 10 to 500 miles) in the last 12 months. The inexperience driver group had driven a mean of 2,662 miles (4284 kms) (SD=3,784, range 20 to 12,000 miles) in the last 12 months. The experienced driver group had driven a mean of 6,355 miles (10,228 kms) (SD=11,940, range 40 to 50,000 miles) in the last 12 months.

Participants were recruited via a local newspaper advertisement and posters on notice boards around the University of Strathclyde, Glasgow, Scotland. The advertisement sought people with a valid UK driving licence who drove regularly, or those who were actively learning to drive. Potential participants were informed that they were taking part in a general study related to driving; hazard perception was not mentioned until participants were debriefed upon completion of the experiment.

## Materials

Hazard perception clips were purchased from the Driving Standards Agency (DSA) under contract. The clips had been developed and tested by TRL (Transport Research Laboratory) for the Road Safety Division of the Department for Transport when constructing the Hazard Perception component of the current U.K. driving test (Grayson and Sexton, 2002). The clips used in the experiment are not used in the official test. Twelve clips were selected to represent a variety of hazards and a variety of driving scenarios from residential, single and dual carriageway roads.

Each hazard perception clip was around one minute in length (range 46.8 to 67.2 seconds) and involved one major hazard. The hazardous periods lasted for between 4.8 and 11.9 seconds. Although the hazard periods were roughly defined on the purchased CD-ROM, exact timing of a start point and critical moment point were defined using digital video editing software. The twelve clips were randomly presented full screen on a 19” monitor using Superlab 4 experiment generator software. A typical hazard perception clip provides approximately 60 degrees of visual angle to the front of the car, and contains no mirror information.

Participants’ hazard rating was dynamically measured throughout the duration of the clip using a slider box. The slider ranged from 0 to 10 and was labeled ‘Safe’ at one end (0) and ‘Hazardous’ at the other (10). The slider was reset to ‘Safe’ at the beginning of every clip. The slider was connected and measured through a Biopac MP35 system. Participants’ SCR and respiration were also measured by the Biopac MP35 system using electrodermal pre-settings with Biopac EL507 SCRS isotonic gel disposable electrodes and a respiratory transducer. Biopac BSL Pro software was used to record and analyze the data.

## Procedure

Participants were seated approximately 60 centimeters from the computer monitor with the slider at a comfortable distance on the desk. Electrodes were attached on the palmar surface of the medial phalanx of the middle and index fingers of the non-preferred hand. Participants were asked to position a belt attached to a respiratory transducer around their chest and to take several large breaths in order to check the recording equipment was operational and to provide a comparison respiration trace. Participants were informed that they would see twelve clips of normal driving scenarios and asked to imagine that they were the driver of the vehicle and to continuously rate the level of risk shown in each clip. It was not mentioned that there were any hazards in the scenes they would encounter. In order for participants to become accustomed to the slider and to check the equipment, each participant had one practice trial before they began.

# Results

## Definitions for SCR Analysis

For an SCR to be included in the data, it had to be equal to or exceed 0.05 µS (Dawson et al., 2000). Timing markers and a scoring system were devised for analysis and are explained below.

### Hazard start marker

The start of the hazard was defined using digital video editing equipment. The person or vehicle that eventually became the hazard was defined and analyzed for the first frame in which that item occurred. This was therefore the Hazard Start Marker as it was the first moment at which the hazard could possibly be identified as potentially affecting the driving situation.

This practice was followed for all clips except one, where two bikers ride along a parallel road for a considerable period of time. It is only when the parallel road then joins with the driver’s road that a hazard ensues. For this clip the hazard start marker was defined from the moment at which the junction between the two roads became visible.

### Critical moment marker

The critical moment was defined by the researchers as the moment at which the driver in the hazard perception clip takes avoiding action to the hazard. Avoiding action involved either braking (changing speed) or steering (changing trajectory) of the vehicle. Again, using digital video editing equipment allowed for exact timing of this moment.

### Event period

Preliminary analysis suggested that a large SCR around the Critical Moment Marker was common. This was defined as an Event Response; a response to an immediate and obvious hazard. This was not considered to be anticipatory in nature as the hazard was clearly visible at the time of the response. As the critical moment was the moment at which the driver in the clip responded to the hazard (i.e. the last opportunity to avoid a collision), some drivers demonstrated this event response just prior to the defined Critical Moment Marker. To allow for event response variation, a period of time was defined around the Critical Moment Marker that would separate these responses from genuine anticipatory responses. This period of time was termed the Event Period. The Event Period was defined from 75% of the total hazard time for each clip to three seconds after the Critical Moment Marker (see Figure 1). All participants’ event responses fell within this period. Three seconds after the Critical Moment was included as three seconds after a stimulus is presented is the recommended response latency for SCR data (Levinson and Edelberg, 1985; Barry, 1990).

### Anticipatory period

As a result of defining the Event Period, an area that started from the Hazard Start Marker to 75% of the total time of the hazard remained. This area was termed the Anticipatory Period and any responses within this duration would be considered an anticipatory response to the buildup of a hazard. It is these anticipatory responses that are the main focus of the study and are deemed crucial in a processing system designed to avoid the threat of an imminent risk, in this case the risk of a collision.

Due to the response latency of SCRs (Levinson and Edelberg, 1985), any response within one second of the Hazard Start was not included as this may have been caused by something which happened prior to the start of the hazard period. A demonstration of the Anticipatory Period, Event Period and timing markers is shown in Figure 1.

Hazard Start

75% marker

Critical Moment

3 seconds (after Critical Moment) marker

Anticipatory Period

Event Period

1 second (after Hazard Start) marker

Time

**Figure 1: Demonstration of timing markers and areas used to extract SCR data from participants responses (with an example SCR trace)**

### Calculating SCR scores

Anticipatory and event scores were calculated by collating the number of clips in which a participant demonstrated an SCR response within the anticipatory or event period that was equal to or greater than 0.05 µS. If a participant had more than one SCR response within the anticipatory or event period, this was only counted as having demonstrated one response for the purpose of the respective score. All participants viewed twelve hazard perception clips and therefore had twelve SCR readings that could be coded for each period using the above definition. However, as SCR is an extremely sensitive measure, interference caused by respiration or movement could cause a change in SCR that compromises the reliability of measuring a psycho-physiological response to the experimental stimuli. Participants were monitored during the experiment for behavior that could cause a SCR artifact (e.g. deep breaths, yawning, sneezing, body movement). Where these were noted, the data point was not considered in the calculation of the Anticipatory Score or the Event Score. All data were scored blind to participant group and were reviewed by two researchers. There were no disagreements as to whether an SCR should be included or not.

There were at least forty-one data points for each of the anticipatory and event periods in each clip.

The following equation was used to determine each participant’s Anticipatory Score and Event Score:

No. of clips with an SCR

Score (%) = --------------------------------- x 100

No. of clips

These scores thus represent the proportion of clips on which participants’ displayed anticipatory and event responses.

Five participants were excluded from the analyses altogether. Data was excluded where possible interference had been identified by the researchers or was visible from the data, as noted above. Of these participants, four were from the inexperienced group (2 male, 2 female) and one was from the experienced group (female). All remaining participants included in the analysis had data for at least nine clips.

## Analysis of SCR scores

Preliminary analyses revealed no significant main effects of age or gender and no interaction with the other variables hence it was omitted from the following analyses. Anticipatory and event scores were analyzed using a 3 x 2 mixed Analysis of Variance (ANOVA) with experience level (learner, inexperienced and experienced) as between subjects’ factor and hazard period (anticipatory and event) as within subjects’ factor. There was a statistically significant main effect of hazard period (F(1, 42)=56.1, p<.001, MSE=9,211, ηp2=.572) indicating that there was a difference between the overall anticipatory score and the event score. Analysis of the overall mean scores indicates that this is because the event mean score of 63.8 (SD=33.54) was higher than the anticipatory mean score of 42.83 (SD=32.62).

The test of between subjects effects revealed a statistically significant main effect of experience level (F(2, 42)=7.57, p=.002, MSE=11,745, ηp2=.265). Exploration of mean scores suggests that inexperienced drivers scored higher than learners and experienced drivers scored higher than inexperienced drivers in both the anticipatory and event periods, as shown in Figure 2. Pairwise comparison of the marginal means revealed that there is a statistically significant difference between the experienced group and both the inexperienced (p<.05) and learner groups (p<.01).

There was no significant effect of the interaction between experience level and hazard period (F(2, 42)=2.4, p=.10, MSE=395, ηp2=.103), suggesting that there was no statistically significant difference in the distribution of anticipatory and event scores by experience level.

**Figure 2: Graph of Anticipatory Score and Event Score means by experience level with Standard Error bars**

### Post-licence experience – learning to anticipate hazards

Fuller (2011) proposes that what distinguishes experienced and inexperienced drivers is the ability to detect, decide and respond in advance of a hazard so that the hazard does not in fact develop at all. A substantial body of research supports that inexperienced drivers, by their very nature, lack the experience required to detect potential hazards. To investigate this, inexperienced drivers’ anticipatory scores were analyzed further. Based on McCartt et al. (2003) who demonstrated the relationship between number of miles driven and crash risk, the inexperience group was split into those who had driven less than 1,000 miles (1,609 kms) in the last 12 months (n=11) and those who had driven more than 1,000 miles in the last 12 months (n=6). The less-than-1,000-miles group had an anticipatory score of 22.58 (SD=25.9), similar to the learner group, whereas the more-than-1,000-miles group had an anticipatory score of 51.85 (SD=22.2).

The two inexperienced driver groups’ anticipatory scores were compared to the learner and experienced groups. ANOVA results determine that there was a statistically significant main effect of group (F(3,41)=8.2, p<.001, MSE=5,855, ηp2=.375). Tukey post hoc analysis revealed statistically significant differences between the experienced group and both learners (p=.001) and the less-than-1,000-miles inexperienced group (p=.001). No statistically significant difference was found between experienced drivers and the more-than-1,000-miles inexperienced group. There was also no statistically significant difference between the learner and the less-than-1,000 miles groups. However, there was a statistically significant difference between the two inexperienced groups (p<.05).

When these two groups are plotted with all driver groups (see Figure 3) a pattern emerges whereby inexperienced drivers who have driven less than 1,000 miles in the previous 12 months do not differ from learner drivers, while inexperienced drivers who have driven more than 1,000 miles in the last 12 months demonstrate a mid-range score between the inexperienced average and that of experienced drivers.

**Figure 3: Graph of Anticipatory Score by experience group with Standard Error bars and polynomial trend line**

## Slider response

Cognitive hazard ratings were dynamically recorded via a slider which ranged from ‘Safe’ (0) to ‘Hazardous’ (10). To compare participants’ hazard ratings, slider data was extracted using the timing markers defined for extracting the SCR data, although it was not necessary to accommodate for physiological delay. There were therefore two periods for measurement: anticipatory (hazard start to 75%) and event (75% to critical moment). Using Biopac BSL Pro software, participants’ mean ratings for the two periods were calculated for each clip. The mean rating provides an indication of how hazardous a participant rated this section of the clip.

Figure 4 shows participants’ mean scores of their mean slider rating from the anticipatory and the event periods. This graphical representation suggests little difference between the hazard ratings of the three groups, similar to the results of Crundall et al. (2003).

**Figure 4: Figure of mean slider ratings by experience group for the anticipatory and event periods with Standard Error bars**

Anticipatory and event mean ratings were analyzed using a 3 x 2 mixed ANOVA with experience level (learner, inexperienced and experienced) as the between subjects’ factor and hazard period (anticipatory and event) as the within subjects’ factor. There was a statistically significant main effect of hazard period (F(1, 42)=392, p<.001, MSE=114, ηp2=.903). Figure 4 shows this is due to higher ratings during the event period (5.59 (SD=1.98) than during the anticipatory period 3.23 (SD=1.8).

There was no statistically significant effect of group (F(2,42)<1, MSE=1.78, ηp2=.012).

There was a statistically significant hazard\*group interaction (F(2, 42)=8.9, p=.001, MSE=2.6, ηp2=.298) indicating a difference in the distribution of group scores in the anticipatory and event periods. Analysis of the hazard periods independently found no effect of experience level on either the anticipatory period (F(2,42)<1, MSE=1.51, ηp2=.021) or the hazard period (F(2,42)<1, MSE=2.86, ηp2=.033). Exploratory analysis suggests that the hazard\*group interaction may be due to rank order differences within the groups.

# Discussion

The results of the current study support the existence of a system that utilizes affective appraisal to anticipate hazards when driving. Experienced drivers were twice as likely to produce an SCR to developing hazards as inexperienced drivers and almost three times as likely as learner drivers. This differentiation was statistically significant even when age and gender were controlled for. The results are also highlight dissociation between drivers’ affective appraisal of hazards and their cognitive appraisal of risk.

## Two Forms of Risk Appraisal

As well as supporting Slovic et al.’s (2002, 2004) definitions of risk appraisal, the results further the findings of Fuller et al. (2008), Kinnear et al. (2008) and Crundall et al. (2003). Results demonstrate a distinction between cognitive and affective appraisal in anticipation of a hazard that is mediated by driving experience. There were no statistically significant differences between the three driver groups’ mean cognitive hazard ratings either during the development of a hazard or at the time of a hazard. This is intriguing as experienced drivers produced statistically significantly more SCRs during the development of hazards compared with inexperienced and learner drivers. It is all the more intriguing given that the stimuli used have previously been validated to distinguish between experienced and inexperienced drivers (Grayson and Sexton, 2002). The validation was however based on hazard detection response time whereby experienced drivers responded earlier than novice drivers. This measure of cognitive detection may be underpinned by an affective and automated detection available to experienced drivers, as suggested by the results of this study. It is still interesting, therefore, that general mean ratings of riskiness or hazardousness did not differ between the groups.

## Inexperienced drivers’ anticipatory SCRs

An important finding was that inexperienced drivers who had driven less than 1,000 miles (1,609 kms) in the last twelve months had a mean anticipatory score almost identical to that of the learner driver group. Conversely, inexperienced drivers who had driven more than 1,000 miles in the last twelve months demonstrated a score that appeared to show signs of progress towards the level of experienced drivers. The presentation of these scores in graphical form exhibits a pattern that strongly suggests a learning curve mediated by driving experience. Examination of novice driver crash rates shows that crash risk reduces dramatically during the first 1,000 miles of licensed driving (McCartt et al., 2003). Given that novice drivers are usually not undergoing any education or training during this post-license period, one must consider what is it that novice drivers are learning? The results of the current study would suggest that they may be learning to link environmental cues to potential hazards with feelings and emotion that allow for faster processing and attentional awareness of potential hazards.

In support of this, Sagberg and Bjornskau (2006) found that reaction times to hazard perception reduced with increased driving experience in novice drivers. This could be suggestive of decision making becoming more automated and would theoretically suggest a shift from an ‘analytic’ appraisal of risk to an ‘experiential’ appraisal of risk, as defined by Slovic et al. (2002, 2004). Further support for learning through experience has been reported by Charlton and Starkey (2011) who describe a longitudinal study of drivers in a repeated simulator environment. They found that experienced drivers ‘proceduralise’ the driving task moving from ‘top down’ cognitive, effortful driving to ‘bottom up’ automated driving. Charlton and Starkey go on to propose that these two processing states work in tandem to guide and maintain driver behaviour, even in experienced drivers. They define the processes as an ‘operating process’ and a ‘monitoring process’. The operating process involves conscious attention and is relied upon when drivers are inexperienced or when a driver is in a new, unusual or challenging driving situation. The ‘monitoring process’ is described as an unconscious error monitoring system that requires little cognitive effort or engagement. The monitoring process is said to be continuously engaged in the driving task comparing stimuli from the environment with learned representations of previous instances that have been gained through experience. The experiment and results reported here suggest that, should such a monitoring process exist, it may involve an affective component which may be a key connection between the monitoring and operating process, particularly in response to potential hazards.

## Learners

Although no statistical difference was found in SCR event score between experienced and inexperienced drivers in response to the critical moment of the hazard there was, however, a statistically significant difference between the experienced drivers and the learners. It is not clear why learner drivers should produce less SCRs in response to an obviously dangerous moment. It may be that due to their inexperience they simply do not have an appreciation of the inherent dangers involved in driving. Supervised learner driving is exceptionally safe compared with even experienced solo driving (Mayhew et al., 2003) and maybe this is why learner drivers have yet to appreciate the realistic risks involved with driving. In spite of this, learner drivers still demonstrated, on average, an anticipatory score of twenty-three percent which suggests that they have the potential for demonstrating psycho-physiological responses to developing hazards. This value could represent a baseline level of affective hazard appraisal that could be verified in future work.

## Somatic Marker Hypothesis

The results of the current study seem to suggest a learning curve of psycho-physiological responses in anticipation of hazards, formulated from driving experience as indexed by number of miles driven. These results could be interpreted within the framework of the Somatic Marker Hypothesis (Damasio, 1994) in that emotionally-valenced driving experiences may be acting to construct somatic responses to hazardous situations and provide a physiological ‘warning’ to the driver. The fundamental feature of Somatic Marker Hypothesis Theory is that the physiological responses are generated prior to the behavioural decision. The current study makes the assumption that any SCRs generated within the anticipatory period can be interpreted in a similar way to SCRs within the anticipatory period prior to deck selection in the Iowa Gambling Task (e.g. Bechara and Damasio, 2005) in that it would bias the driver’s behavioural response in advance of the hazard. This viewpoint is also consistent with Helander’s (1978) suggestion that SCRs seemed to be anticipatory in nature and in the real world might lead to a potential hazard being negated and not developing at all. The potential demonstration of somatic markers out-with the gambling task is important given critique of the IGT (see Dunn et al., 2006; Maia and McClelland, 2004). Although laboratory-based, the current study demonstrates psycho-physiological feedback for a quotidian activity and highlights the potential anticipatory nature of such responses. The neurological mechanisms that are the basis of the Somatic Marker Hypothesis are not examined here and an area for future interest may be to determine regions of neural activity during a hazard perception task.

## Limitations, relevance to other domains and suggestions for future research

While SCRs can also indicate an increase in workload, as well as the engagement of emotion-based systems, Patten et al. (2006) demonstrated that experienced drivers showed less cognitive workload demands that novice drivers or low mileage drivers. The current study showed the opposite pattern of electrodermal responses as would be predicted by a simple disparity in mental workload between the groups suggesting that an affect-based interpretation of SCR difference is reasonable. It is clear that experienced drivers are more likely to produce SCRs during the development of a hazard, but the question remains as to whether these would precede and cause an actual behavioural response (e.g. braking) when driving? Future research could build upon the current study by use of a simulator or real time driving with measures of accelerator release or braking to determine if the SCRs are predictive of a behavioural response. Of course, any such study will have the same methodological problem as Helander (1978) with regard to SCR latency.

Recent debate within the driver behaviour modelling literature has focused on the role of ‘unconscious feelings’ influencing driver decision making and behaviour; for example, Fuller (2011), Vaa (2007) and Kinnear (2008) all draw on the ideas of the Somatic Marker Hypothesis. However, Lewis-Evans and Rothengatter (2009) provide a rebuttal to the idea of emotions or feelings acting unconsciously suggesting that the Somatic Marker Hypothesis defines feelings as conscious perceptions of an internal body state. Kinnear and Helman (in press) argue that the definition used by Lewis-Evans and Rothengatter is outdated and is superseded by advances in neuroscience (e.g. Damasio, 2003) and experimental studies that demonstrate the influence of affective reactions on behaviour in the absence of conscious awareness (e.g. Winkielman and Berridge, 2004). Indeed, citing results from the Iowa Gambling Task, Bechara and Damasio specifically state that “the anticipatory SCRs acquired during the pre-hunch period are an example...... consciously pondering on which deck to choose from (a secondary inducer) elicits a covert somatic response which is an expression of the bias process that leads the subject to choose the correct deck without any awareness of why the choice was made" (pg 341-342). The emphasis within the Somatic Marker Hypothesis is that the signals are emotion-based rather than necessarily unconscious leading Bechara et al. (2005) to suggest that “emotion-related signals assist cognitive processes even when they are non-conscious” (pg 159). The current study and the discussed literature both suggest that consideration of emotion-based signals contributing to cognitive hazard perception and subsequent decision making is an important and potentially fruitful direction for research in novice driver safety and it is certainly premature to rule out the influence of either conscious or unconscious emotion on driving behaviour.

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1. See Dunn, Dalgleish and Lawrence (2006) for a critical review of the Iowa Gambling Task. [↑](#footnote-ref-1)