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Differences in FRN and P300 amplitudes among hockey fans versus non-hockey fans in response to relevant and irrelevant information.

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Abstract

Sports bettors tend to rely on statistical information about an athlete or team's past performance even though this type of information often has no predictive value. The belief that this statistical information can help predict future performance is typically held by experts and novices alike. A recent study conducted by Cheng and colleagues (in preparation) suggests that sports bettors do not process decision outcomes that are based on relevant information in the same way that they process decision outcomes based on irrelevant information. Specifically, they found differences in the event-related potential component known as Feedback-Related Negativity (FRN), such that FRNs were larger in response to outcomes of betting decisions made on information considered to be relevant (i.e., predictive) compared to outcomes based on decisions made on information considered to be irrelevant. The different levels of expectancies indexed by the FRN occurred regardless of the true predictive power of the information guiding the betting decisions. In the present thesis, we tested whether previous experience as a fan of a sport would influence the expectations regarding the predictive power of statistical information. In three experiments, the FRN amplitudes in response to receiving outcomes that resulted from betting decisions made using a well-known hockey statistic (GAA: goals against average) were recorded from hockey fans and non-fans. In Experiment 1 participants had a 75% probability of receiving the expected win trial when they selected the more favourable team (i.e. lower GAA) in a relevant information condition, and the same 75% chance of winning they selected a team based on their team name (irrelevant condition). Results showed the effects of information relevance among fans only and there were no differences between fans and non-fans in response to outcomes that violated expectancy in the relevant condition. In Experiment 2 the probability of winning a bet was set to 50% in both the relevant and irrelevant conditions. Results showed that effects of information relevance were absent among fans and non-fans, and fans did not show larger FRN amplitudes

compared to non-fans in the relevant condition. In Experiment 3 only relevant information was presented and participants performed the first part of the experiment with a 75% probability of receiving a win when they selected the more favourable team, and a 50% probability in the second half of their session. Results showed no differences between fans and non-fans when outcomes violated their expectancy when the more favourable team was selected. The P300 component was also investigated and generally showed larger amplitudes in response to loss trials when they were less frequent (i.e. when the probability of receiving a win was 75%). Overall, the results confirm that the perceived relevance of statistic information affects the processing, but that very little experience with that statistic is necessary to produce expectancies.

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Introduction

Sports bettors tend to rely heavily on information, such as past performances and home field advantage, which they expect to be a strong factor in predicting outcomes of games (Wood, 1992; Woodland & Woodland, 2001). Reliance on this information creates an expectancy about statistical information and this expectancy seems to be held by individuals in general regardless of their exposure and experience level with sports betting (Wood 1992; Woodland & Woodland, 2001). Although statistical information has been shown to be useful in increasing winning opportunities above chance level (Rogers, 1998) in some cases, it has also been shown that it is not useful in some other cases. For example, home hockey teams win approximately 50% of the time (Woodland & Woodland, 2001), and bets placed on horseracing using certain statistical information do not yield better outcomes than chance (Ladouceur, Giroux, & Jacques, 1998). Furthermore, Woodland and Woodland (2001) have also shown that individuals show a tendency to bet on 'favourites' rather than 'underdogs', despite the fact that the profitability opportunities are no higher when betting on favourites. Due to this expectancy, sport statistics can be interpreted as relevant information when making decisions, while any type of non-statistical information can be perceived as irrelevant when making decisions, as it does not create an expectancy.

Sports bettors have been shown to take into account a wide range of relevant and irrelevant information when making sports bets (York, 2002). It has also been shown that the more information (relevant or irrelevant) they take into account, the more confident they are about their decisions (Lamarache, 1988), despite the finding that this does not result in improved outcomes (Allcock, 1987). However, sports bettors do not seem to process decision outcomes that are based on relevant information in the same way that they process decision outcomes that are based on irrelevant information (Cheng et al., in preparation). Through their investigation of the event-related potentials

(ERPs) related to processing decision outcomes, Cheng and colleagues found differences in FRN and P300 in response to decisions that were based on relevant information, compared to those that were based on irrelevant information. Their results suggest that, despite the fact that sports bettors might make use of a wide range of information, relevant information creates a stronger expectancy for the outcome of a decision, thus resulting in a larger electrophysiological response when the expected outcome does not occur. On the other hand, information that is perceived to be irrelevant leads to a weaker expectancy for the outcome of a decision, thus resulting in a smaller electrophysiological response when the expected outcome does not occur.

The question addressed in this thesis is whether sports bettors who have formed expectancies about how particular statistics relate to performance outcomes process bet outcomes differently than sports bettors who do not possess these expectations. The main goal of this thesis is to investigate possible differences in electrophysiological responses between sports bettors with knowledge and experience with particular pieces of relevant and irrelevant sports related information, compared to sports bettors without this knowledge and experience. Some of information that sports bettors use are statistical for example, horse lifetime winning percentage (Cheng et al., in preparation) and some are non-statistical for example home-field advantage (Woodland & Woodland, 2001). Research investigating the differences in performance between sports bettors with knowledge and experience with the sports and bettors with no such experience has yielded mixed results. For instance, Rogers (1998) has shown that knowledgeable sports bettors outperform novice individuals, while other researchers have shown no significant differences between the two populations (Anderson, Edman & Ekman, 2005; Ladouceur et al., 1998). The question remains as to whether sports bettors with knowledge and experience with the sports differ in the way they process information related to a specific sport compared to novice sports bettors. To our knowledge, there is no study in the literature that explores this question by investigating the electrophysiological responses that are related to decision making; namely the feedback-related negativity (FRN) and the P300.

The Feedback-Related Negativity (FRN).

Accumulating research has shown that the Anterior Cingulate Cortex (ACC) plays a significant role in the evaluation of decision outcomes, which has led to the suggestion that the ACC functions as a performance monitoring centre (Hajcak, Holroyd, Moser, & Simons, 2005; Holroyd & Coles, 2002; Miltner, Braun & Coles, 1997; Oliviera, McDonald, & Goodman, 2007). This suggestion is based on the finding that unexpected outcomes elicit an ERP component, called the FRN (Holroyd & Coles, 2002; Miltner et al., 1997), and source localization has linked the generation of this component to the ACC (Holroyd & Coles, 2002; Miltner et al., 1997). The FRN shows a maximal peak around 250 ms after the presentation of feedback (Holroyd & Coles, 2002).

Earlier studies have concluded that the FRN is elicited in response to unfavourable (negative) outcomes only (Hajcak, Moser, Holroyd, & Simons, 2007; Holroyd & Coles, 2002; Miltner et al., 1997; Ullsperger & Von Cramon, 2003). These results led to the suggestion that the activity of the ACC functions as a reward-prediction system that signals an error when outcomes are worse than expected (Hajcak, Moser, Holroyd, & Simons, 2007; Holroyd & Coles, 2002; Miltner et al., 1997; Ullsperger & Von Cramon, 2003). However, later studies challenged those conclusions, and argued that the manipulation of positive and negative outcomes in those earlier studies biased the results (Kobza & Bellebaum, 2013; Oliveira et al., 2007). Specifically, only negative feedback constituted a deviation from participants' expectancies, while positive feedback was expected to be obtained on the majority of trials. The later studies employed paradigms where positive and negative feedback could constitute a deviation from expectancy on a number of trials, and results showed larger FRN in response to both kinds of feedback as long as they deviated from participants' expectancies. Supporting evidence from functional Magnetic Resonance Imaging (fMRI) studies (Walton et al., 2004) and single-cell recordings (Williams, Bush, Rauch, Cosgrove, & Eskandar, 2004) have shown activity in the ACC following positive outcomes that deviate from individuals' expectancies; adding to the argument that the ACC monitors positive as well negative outcomes (Oliveira et al., 2007). The results of the later studies are taken to indicate that activity in the ACC, as indexed by the FRN, reflects a system that compares decision outcomes to an expectancy instead of a strictly reward versus non-reward system (Itagaki & Katayama, 2008; Kobza & Bellebaum, 2013; Luu & Pederson, 2004; Oliveira et al., 2007). This is referred to as the e*xpectancy-deviation hypothesis* (Oliveira et al., 2007).

Effects of Expectancies on the FRN

To demonstrate the effects of expectancies on the FRN, Pfabigan and colleagues (2011) trained participants with cues that were associated with specific win and loss percentages for a number of trials. Following the training period, the win and loss percentages were changed and the modulations of the FRN amplitudes as a result of these changes were observed. Initially, cue “1” was associated with 100% gain, cue “2” with 75% gain, and cue “3” with 100% loss. Afterwards, the percentages associated with cue “1” and cue “3” were changed, such that participants received 75% gain when cue “1” was presented (instead of 100% during the training trials), and 75% loss when cue “3” was presented (instead of 100% during training). The percentages associated with cue “2” remained the same, which served as the control condition. The researchers compared the differences in FRN amplitudes across the two periods for cues “1” and “3,” with the difference in FRN amplitudes across the two periods for cue “2”. Results showed larger FRN amplitudes in response to loss trials, regardless of whether the percentages were changed or not; this finding was consistent with previous studies that showed larger FRN amplitudes in response to loss outcomes in general (Gehring & Willoughby, 2002; Hajcak et al., 2005; Holroyd & Coles, 2002; Miltner et al., 1997). More importantly, FRN amplitudes were even larger when participants received a loss when cue"1" was presented which was an unexpected outcome. Participants also showed larger FRN amplitudes when they received a win when cue "3" was presented, once again this was an unexpected outcome based on their initial exposure with cue. These results were taken to show that, as a result of exposure to the cues and their associated win/loss percentages, participants formed expectancies about these cues and their associated outcomes. Thus, outcomes that deviated from these expectancies elicited larger FRN amplitudes. It has been argued that the larger FRN amplitudes observed in response to loss outcomes can be taken as supporting evidence for the expectancy-deviation hypothesis. Oliveira and colleagues (2007) have shown that participants tend to be "overoptimistic" with their predictions about their own task performance. This causes them to expect to receive more positive than negative outcomes, making negative outcomes deviate even more from their expectancy.

Moreover, Chase, Swainson, Durham, Benham and Cools (2011) were able to demonstrate that participants can form and reform expectancies about stimuli within a task. Accordingly, FRN amplitudes correspond to deviations from the expectancies held at a specific point throughout the task. Chase and colleagues employed a reversal-learning task where participants learned to select one of two stimuli to receive a reward on 80% of the trials, and to avoid the other stimulus that resulted in punishment on 80% of the trials. The stimulus that was associated with the reward on 80% of the trials was alternated throughout the task, and participants had to adjust their selections accordingly. This paradigm allowed participants to form an expectancy that one of the two stimuli was the rewarding stimulus for a stretch of trials, and when this stimulus was then changed to a punishing stimulus (unknown to the participants), it created a deviation from their expectancy. The results of this study indicated that after only a few losing trials, participants were able to quickly detect the change and switch to selecting the other stimulus. Importantly, during the losing trials before the participants adapted their behavior and switched to the other stimulus, but after the reward-to-punishment change occurred, larger FRN amplitudes were elicited relative to the loss trials recorded before the reward-to-punishment change occurred (i.e. the expected losses). These results suggest that participants were able to form and reform expectancies online, and were able to monitor their performance based on these expectancies. Based on this research it has been concluded that increases in FRN amplitudes reflect the detection of a deviations from an expectancy, which is thought to play an important role in the monitoring of one's performance as well as the signaling of behavioural adjustments when necessary (Chase et al., 2011, Hajcak et al., 2005; Oliviera et al., 2007).

Furthermore, the FRN reflects more than just deviations from one's own expectancies, but a more general learning mechanism (Hajcak et al., 2003; Holroyd & Coles, 2002; Oliviera et al., 2007), whether decisions are made by the individual themselves or others. Larger FRN amplitudes are also observed in response to outcomes that deviate from expectancies based on decisions made by others. In a study by Yu and Zhou (2006) participants performed a probabilistic learning task where they had to learn to respond to stimuli that maximize their gains and minimize their losses. Participants performed the task and also observed another participant (confederate) perform the same task in an alternating manner. Results showed larger FRN amplitudes in response to outcomes that deviated from the participants' expectancies when they performed the task. But more importantly, larger FRN amplitudes were also obtained in response to outcomes that deviated from participants' expectancies when decisions were made by others. Learning takes place by monitoring outcomes that are the result of one's own decisions (Hajcak et al., 2003; Holroyd & Coles, 2002), but learning can also take place by monitoring outcomes that are the result of decisions made by others (von Borries, et al., 2013; Yu & Zhou, 2006).

P300

The P300 is an ERP component that is widely investigated along with the FRN in studies involving decision making. The P300 is a positive deflection with peak latency between 300-600 ms post stimulus presentation. Although the P300 is recorded from many electrodes, it has the strongest signal over the parietal lobe (Snyder & Hillyard, 1976). It is the most studied ERP component as it is elicited by a wide range of cognitive processes related to evaluation and decision making (San Martin, 2012). It is widely known to be elicited in oddball paradigms, where an infrequent stimulus is embedded in a sequence of repeated frequent stimuli. The infrequent stimuli in this paradigm usually elicit larger P300 amplitudes than the frequent stimuli, and these effects are found across all modalities of stimulus presentation (Duncan-Johnson & Donchin, 1977).

The P300 is thought to reflect a mismatch between the expected representation of a stimulus, and the actual representation of that stimulus (Donchin & Coles, 1988; Hajcak et al., 2005; Nieuwenhuis et al., 2005). This mismatch calls for allocating greater attention resources to the infrequent stimulus in order to update the internal representation. This theory has been termed the context-update hypothesis (Donchin & Coles, 1988). According to their hypothesis, Donchin and Coles suggest that the P300 reflects greater attention to infrequent stimuli in order to update the existing mental stimulus-outcome representation and respond effectively to the task at hand. There is support for the context-update hypothesis and the role of the P300 in signaling greater attention to infrequent stimuli. A study by von Borries and colleagues (2013) provided support for this hypothesis by showing P300 amplitude modulation in response to frequent and infrequent stimuli. For a number of trials, participants were presented with a few cards, each followed by a particular outcome. The task was to indicate what the expected outcome was when presented with a certain card. After a number of trials, a change in the card-outcome pairing was introduced and the cards were now associated with different outcomes for another sequence of trials. This card-outcome pairing was manipulated many times throughout the experiment. The rationale for this experiment was that the initial sequence will cause the participants to form stimulus-outcome representations that they come to expect when they encounter the cards. However, when the change is introduced it would create a deviation from the initial stimulus-outcome representation for the first few trials in the new sequence until the participants incorporate the new stimulus-outcome representation and respond accordingly. Results showed larger P300 amplitudes for the trials that deviated from participants' expectancies (at the beginning of a new sequence), than trials that confirmed participants' expectancies in the initial sequence. Therefore, P300 constitutes an important learning tool that helps individuals adjust to stimuli and respond to the task accordingly (Donchin & Coles, 1988; Nieuwenhuis et al., 2005; von Borries et al., 2013).

Some neurophysiological studies have provided further evidence for this close relationship between P300 and learning. For example, P300 amplitudes were larger in response to stimuli that were encoded and later recalled in a task compared to stimuli that were not recalled (Paller, Kutas, & Mayes, 1987; Wagner, Koutstaal, & Schacter, 1999). There is also evidence for larger P300 amplitudes when encoding infrequent stimuli compared to frequent ones in a task, but only if those stimuli were task-relevant and recalled later in the task (Fabiani, Karis & Donchin, 1986). As for the context-update hypothesis, Van Petten and Senkfor (1996) observed that stimuli that do not relate to existing expectancies show smaller P300 amplitudes during encoding than stimuli that do relate to existing expectancies. These results were taken to suggest that information related to existing expectancies needs to be integrated, and therefore larger P300 amplitudes are recorded during the processing of these stimuli (Wagner et al., 1999). On the other hand, information that does not relate to existing expectancies does not call for context-updating because they do not violate, nor require incorporation into present knowledge and thus elicit smaller P300 amplitudes (Nieuwenhuis, 2011).

P300 and Outcome Valence

There is debate in the field about whether outcome valence has an effect on P300 and whether P300 indexes more than just the context of stimuli (Cohen et al., 2007; San Martin, 2012). Some studies have suggested that P300 amplitudes are larger in response to negative outcomes compared to positive outcomes (Cohen et al., 2007; Frank et al., 2005). However, these studies have overlooked the fact that participants could learn to avoid negative feedback as the experiment progressed, making negative feedback less frequent and subjectively less likely to be encountered (San Martin, 2012). Other studies have demonstrated the complete opposite trend by showing larger P300 amplitudes in response to positive outcomes compared to negative outcomes (Hajcak et al., 2007; Toyomaki & Murohashi, 2005), even when positive outcomes were more likely to be encountered (Bellebaum & Daum, 2008). While a study by Wu and Zhou (2009) reported larger P300 amplitudes in response to positive outcomes compared to negative outcomes only if positive outcomes deviated from participants' expectancies. These contrasting results suggest that the effects of outcome valence on P300 may interact with more robust mediators, namely stimulus frequency and subjective probability (Horst, Johnson, and Donchin, 1980; San Martin, 2012; Nieuwenhuis, 2011).

P300 and Subjective Probability

P300 is thought to be mediated by another important aspect in decision making called subjective probability. Subjective probability refers to the perception of the frequency of occurrence of a stimulus as a result of prior experience with the stimulus. This is different from objective probability, which refers to the actual frequency of occurrence of the stimulus (Johnson & Donchin, 1980; Nieuwenhuis, 2011). Subjective probability is thought to be independent of objective probability (Rosenfeld et al., 2005), which is the overall global frequency, and subjective probability has a larger impact on P300 (Squires et al, 1976; Holm et al., 2006). For example, in the oddball paradigm, target stimuli have been shown to elicit larger P300 amplitudes when they were preceded by non-target stimuli compared to when they were preceded by target stimuli; despite the same objective probability for the target stimulus in both cases (Squires et al, 1976; Holm et al., 2006).

It has been suggested that P300 reflects the amount of attention necessary to incorporate frequencies and adjust to respond to stimuli accordingly (Donchin & Cohen, 1967; Radlo et al., 2001; Squires et al., 1977). In the study by Pfabigan and colleagues (2011) described earlier, during the practice session participants encountered three different cues that were followed by certain outcomes, cue “1” was associated with 100% reward, cue “2” was associated with 75% reward and cue “3” was associated with 100% non-reward. During the experimental session the probabilities of reward and non reward were changed for cues “1” and “3”, cue “1” was associated with 75% reward and cue “3” with 75% non-reward, while the probabilities for cue “2” remained the same. The rationale was participants would form subjective expectancies of reward in response to cue “1” and subjective expectancies of non-reward to cue “3” and subsequent contradicting outcomes would constitute a deviation from their expectancy. Results showed that P300 amplitudes were larger after subjectively unexpected outcomes, compared to subjectively expected outcomes. These findings are in line with Donchin and Cole's Context-updating hypothesis (1988), participants formed specific expectancies about the probability of reward associated with specific cues and when these expectancies were violated, greater attentional resources were allocated to incorporate this information and update the neural representation of their expectancy.

The relationship between FRN and P300

The FRN and the P300 can be thought of as indices of complementary processes aimed to detect decision outcomes that deviate from expectancies and lead to behavioural adjustments. The FRN reflects outcomes that deviate from individuals' expectancies, where larger amplitudes indicate that outcomes were not in agreement with what was expected (Gehring & Willoughby, 2002; Hajcak et al., 2005; Holroyd & Coles, 2002; Miltner et al., 1997). The FRN has been shown to function at an implicit level as Walsh and Anderson (2011) have shown that instructing participants about reward probabilities altered participants' behavioural choices according to the instructions. However, FRN amplitudes were still larger in response to outcomes that deviated from participants' initial expectancies despite the fact that instructions warned them about such deviations. FRN amplitudes eventually adjusted after a few trials and deviations from participants' initial expectancies did not elicit larger amplitudes. Therefore, experience with the stimuli is very important for FRN, which suggests that FRN reflects monitoring outcomes at an implicit level. As for the P300, it has been shown to reflect the monitoring of outcomes at the explicit level. For example, Chase and colleagues (2011) showed that P300 amplitudes were larger in response to outcomes that preceded behavioural adjustments, compared to outcomes that did not precede such adjustments. Chase and colleagues (2011) also showed that larger FRN amplitudes were observed in response to outcomes that deviated from participants' expectancies but did not precede behavioural adjustments. Chase and colleagues (2011) suggested that such results support the argument that FRN and P300 are complementary components in the process of optimal decision making. However, other evidence suggests that the relationship between FRN and P300 is not that predictable and in different contexts, their relationship differs (Cohen & Ranganath, 2007; Sallet, Camille & Procyk, 2013; Walsh & Anderson, 2011).

Information Relevance and its Impact on FRN and P300

Cheng et al. (in preparation) investigated the differences in the FRN and P300 components in response to decisions that were based on relevant information, compared to decisions that were based on irrelevant information. Cheng and colleagues hypothesized that outcomes that deviate from participants' expectancies would elicit larger FRN amplitudes, compared to outcomes that did not deviate from their expectancies, and that this modulation of the FRN would interact with the relevance of the information being used to form the expectancy. Specifically, they hypothesized that loss trials would elicit larger FRN amplitudes when decisions were based on statistical information (relevant), compared to non-statistical information (irrelevant). Relevant information in their study consisted of statistical information about the lifetime winning percentages of racetrack horses, while the irrelevant information consisted of horses' coat colours. Research has shown that individuals rely heavily on statistical information, such as past winning percentages and other statistics to inform their decisions when placing bets (Tryfos et al., 1984; Wood 1992; Woodland, & Woodland, 2001). Therefore, statistical information is considered to be a relevant piece of information, since individuals have expectancy that such information can predict the outcome of a decision. On the other hand, information such as horses' coat colours and other non-statistical information are considered irrelevant, since individuals do not tend to form an expectancy that these forms of information will predict their decision outcomes. These hypotheses were tested in three experiments.

In Experiment 1, participants viewed information about two horses (A and B) in each trial and were instructed to select the horse that they expected to win the race based on the information given. There were two conditions: one with relevant information and the other with irrelevant information. In the relevant information condition, the lifetime winning percentages of the horses were presented; for example Horse A with a 78% lifetime winning percentage, and Horse B with a 65% lifetime winning percentage. In the irrelevant condition, the colours of the horse's coats were presented; for example Horse A is black and Horse B is hazelnut. Immediately after the bet was placed, the participant received feedback indicating whether their selection was correct (win feedback), or incorrect (loss feedback). In the relevant information condition, participants had a 75% chance of receiving win feedback when they selected the horse with the higher lifetime winning percentage. On the other hand, in the irrelevant information condition win feedback was predetermined to be received on 75% of the trials, regardless of which horse the participant selected. Behavioural results showed that participants selected the horse with the higher winning percentage on 90% of the trials, which lead to an average winning percentage of 76% in the relevant condition. This was taken as supporting evidence for that notion that participants expected that the horse with the higher lifetime winning percentage was going to win and that they believed this information was relevant in predicting the outcome of the race.

ERP results indicated that the FRN amplitudes were larger in response to loss trials in both information conditions, a general finding regarding the effects of outcome valence on FRN (Holroyd & Coles, 2002,Hajcak et al., 2005; Miltner et al., 1997; Polizzi et al., 2010). More importantly, loss feedback received in the relevant condition when selecting the horse with the higher lifetime winning percentage, elicited larger FRN amplitudes than loss feedback received in the irrelevant condition. These results were taken to suggest an effect of information relevance on FRN modulation. Cheng and colleagues (in preparation) explained that in the relevant condition, participants had the expectancy that the horse with the higher lifetime winning percentage would win the race, and when the outcome deviated from this expectancy, larger FRN amplitudes were elicited reflecting this mismatch. On the other hand, in the irrelevant condition participants did not have an expectancy regarding to the relationship between the colour of the horse and the probability of the horse winning the race, thus loss trials did not constitute a deviation from their expectancy. As for the P300, amplitudes were larger following infrequent feedback (loss trials) compared to frequent feedback (win trials). These results are consistent with previous findings in the literature, suggesting greater attentional resources are allocated to infrequent stimuli (Donchin & Coles, 1988, Nieuwenhuis et al., 2005).

According to Hauser and colleagues' argument (2014), since loss trials were infrequent the effects of outcome valence on FRN could have overlapped with the effects of information relevance that were observed in Experiment 1. To disentangle this possible overlap, in Experiment 2 the frequency of win and loss feedback was equated and the effect of relevance on FRN amplitudes was once again investigated. In the relevant condition, participants received win feedback on 50% of the trials when they selected the horse with the higher lifetime winning percentage, and a win on 50% of the trials in the irrelevant condition regardless of horse colour they selected. Behavioural results showed that participants selected the horse with the higher lifetime winning percentage on 66% of the trials in the relevant condition, despite the fact that using this strategy only resulted in a win 50% of the time. The fact that participants continued to bet on the horse with the higher lifetime winning percentage, despite not winning any more than chance, provides support for the theory that individuals have an expectancy that using statistical information will optimize their performance.

Furthermore, the effect of relevance on the FRN amplitudes were demonstrated again as the FRN amplitudes elicited by loss feedback were larger when the horse with the higher lifetime winning percentage was selected, compared to loss feedback in the irrelevant condition. Therefore, these results suggest that the effect of relevance on FRN amplitudes observed in Experiment 1 were not strictly due to an overlap between expectancy and valence. Rather, loss feedback when the horse with the higher lifetime winning percentage was selected constituted a deviation from the participants' expectancies, compared to the irrelevant condition. However, unlike Experiment 1, which showed larger P300 amplitudes in response to loss feedback, Experiment 2 did not show this effect, as P300 amplitudes were not different in response to loss feedback compared to win feedback. This was expected as loss feedback was as frequent as win feedback and P300 amplitudes show no differences when the stimulus frequencies are equated (Campbell et al., 1979).

To further investigate the effects of relevance that were found in Experiments 1 and 2, Cheng and colleagues conducted a third experiment. In the relevant condition, selecting the horse with the higher lifetime winning percentage yielded a win on only 25% of the trials, while win feedback in the irrelevant condition was set to 25% regardless of which horse colour the participant selected. Therefore, the optimal strategy in this experiment was to select the horse with the lower lifetime winning percentage, which is contrary to participants' expectancies. Behavioural results showed that participants quickly learned to select the horse with lower lifetime winning percentage of trials to maximize their wins. Therefore, participants did not make their decisions based on the expectancy they initially had about statistical information, but based on the reverse of that expectancy. The results of this third experiment showed no effect of information relevance on the FRN amplitudes.

Cheng and colleagues results suggest that despite the fact that participants learned that selecting the horse with the lower lifetime winning percentage was the optimal strategy, their decisions were not based on the expectancy they initially had about the statistical information. Their decisions were based on overriding their initial expectancies and therefore loss feedback in the relevant condition did not constitute a deviation from expectancies. In addition, the effects of outcome valence were still observed, larger FRN amplitudes were elicited in response to loss trials compared to win trials in both conditions. This adds further support for the notion that the effect of information relevance on FRN amplitudes is separate from the effect of outcome valence, since both types of effects were observed (Hauser et al., 2014). As for P300, amplitudes were not modulated in response to win and loss feedback despite the lower frequency of loss trials. However, Cheng and colleagues (in preparation) argue that could be because participants did not base their decisions on the expectancy they initially had about the statistical information.

Current study

Building on the work reported by Cheng and colleagues (in preparation), the current study sought to investigate another possible factor that may influence the FRN component. Cheng and colleagues (in preparation) argue that participants come into an experiment with the expectancy that certain types of information can strongly predict decision outcomes. Cheng and colleagues also argue that because of this expectancy, statistical information is considered to be a relevant piece of information, and any outcome that deviates from this expectancy will elicits large FRN amplitudes. This expectancy seems to be held by individuals in general whether they have experience with the type of statistical information being used or not (Wood, 1992; Woodland & Woodland, 2001).

One question that arises from Cheng and colleagues results is whether individual differences can modulate the FRN component. More specifically, will a group that has knowledge and experience in a particular domain show different FRN modulation when performing a task that taps into that domain, relative to a group that acquires knowledge about that domain while performing an experimental task? We hypothesized that when experts in a domain use their expertise to make a decision, they would expect to receive rewarding feedback. Thus, any deviation from this expectancy would elicit a large FRN component. On the other hand, when a novice group of individuals use the same information to make a decision, their lack of expertise would lead to a weaker expectancy for positive feedback. Thus, in this group of novices any deviation from the expectancy would result in a relatively smaller FRN. In the group of experts, this deviation from their expectancy would tap into stimulus-outcome representations about their domain of expertise that are already formed through years of experience with the domain. While in the novice group that acquires knowledge during the experimental session, stimulus-outcome representations should be the result of learning that takes place throughout the experiment.

In order to test the hypothesis that experience within a particular domain may influence how individuals process feedback when using knowledge about that domain to make decisions, we choose to focus on hockey fans. Specifically, we presented hockey fans and non-fans with a popular statistic in hockey referred to as Goals Against Average (GAA), and asked them to use this information to decide which of two hockey teams would win a game. GAA represents the average number of goals that a team allows into their net over the course of a season. It is a strong predictor of the outcomes of games as teams with a lower GAA tend to win more often, and finish on top of the standings. To hockey fans, this knowledge has been formed through years of following and learning about the game of hockey. This knowledge leads to an expectancy that a team with a low GAA is very likely to beat a team with a considerably higher GAA. Non-hockey fans might have a gained expectancy that stats like GAA can be predictors of outcomes, but they form a more specific expectancy as they perform a hockey betting task.

A similar two-choice task to the one in Cheng and colleagues (in preparation) was used for this study. There were three experiments; the first two experiments differed in their probabilities of winning on each trial, and the third experiment included relevant information only. These studies also employed the use of two different types of information; relevant and irrelevant as in Cheng and colleagues (in preparation). Relevant information in this study consisted of the GAA statistic, whereas the irrelevant information consisted of names of European hockey teams. GAA is considered to be relevant information since hockey fans and non-fans should perform the task with the expectancy that a team with a low GAA is very likely to beat a team with considerably higher GAA. On the other hand, European team names were chosen as irrelevant information since they are related to hockey, yet fans and non-fans should not have an expectancy about how these teams will perform. In the current study, it was expected that loss feedback in the relevant condition would elicit larger FRN amplitudes compared to loss feedback in the irrelevant condition replicating the findings reported by Cheng and colleagues (in preparation). More importantly, FRN amplitudes were expected to be larger for fans compared to non-fans following loss feedback in the relevant information condition. Fans base their decisions on the knowledge and the strong expectancy they have formed about the GAA statistic that is the result of following the game of hockey for a long time. Non-fans have a weaker expectancy about GAA as they come to form this expectancy by performing the task. As for the P300, it was not expected to be modulated by the differences in the strength of the expectancies held by the hockey fans and non-hockey fans. However, P300 was expected to be modulated by the probability of each type of feedback, where less probable feedback should elicit larger P300 amplitudes compared to more probable feedback (Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1977; Nieuwenhuis, 2011). However, when both types of feedback are equally probable, P300 amplitudes are expected to be similar (Campbell et al., 1979).

Experiment 1

It was expected that fans would select the team with the lower GAA on the majority of trials as a result of their knowledge of the GAA statistic. The probability of receiving win feedback in this experiment was set to 75% if the team with the lower GAA was selected in the relevant condition. While the probability of receiving win feedback in the irrelevant condition was predetermined at 75% regardless of which team was selected. This manipulation of the probability so that participants received win feedback 75% of the time was implemented to reinforce the expectancy that hockey fans have about the GAA, that is it is a strong predictor of the outcomes of games. As for the non-fans, this manipulation would teach the non-fans that GAA can be used to as a predictor of the outcomes of games.

For non-fans, it was also expected that they would select the team with lower GAA on the majority of trials. Although non-fans were not specifically knowledgeable about the GAA statistic, they would be able to logically deduce that a team that has fewer goals scored against them will likely win more games. Furthermore, this assumption would quickly be validated, as picking the team with the lower GAA would result in win feedback 75% of the time. Based on this validation, we suggest that these non-fans would then form an expectancy that teams with lower a GAA would win. Loss feedback when the team with lower GAA was selected would thus constitute a deviation from the expectancy for both fans and non-fans and was expected to elicit larger FRN amplitudes compared to win feedback, similarly to the results reported by Cheng et al. (in preparation). However, it was expected that fans would show larger FRN amplitudes in response to loss feedback, since to fans loss feedback was a deviation from an expectancy that is based on knowledge and experience with the GAA statistic, relative to the non-fans who had newly acquired the information about the GAA statistic. In the irrelevant condition, it was expected that loss feedback would elicit larger FRN amplitudes compared to win feedback, a general finding in response to loss feedback (Gehring & Willoughby, 2002; Holroyd & Coles, 2002; Miltner et al., 1997). However, loss feedback in the irrelevant condition was expected to elicit smaller FRN amplitudes than loss feedback in the relevant condition. In addition, no differences between fans and non-fans were expected in the irrelevant condition. As for P300 component, larger amplitudes were expected in response to loss feedback since it would be infrequent compared to win feedback (Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1977; Nieuwenhuis, 2011). However, no differences were expected due to condition, nor group, for the P300; loss feedback should elicit equally large amplitudes in the relevant condition compared to the irrelevant condition, and among fans compared to non-fans.

Method

Participants performed a decision making task, where on each trial they were shown information about two teams and were instructed to select the team they believed would win a hockey game. Participants read information on the screen that provided one of two types of information on which to base their predictions; relevant or irrelevant information. The relevant information consisted of the GAA statistic over the course of the season for each team, whereas the irrelevant information consisted of professional European hockey team names. Relevant information and irrelevant information were presented in separate blocks; there were two blocks of relevant information and two blocks of irrelevant information, for a total of four experimental blocks.

Apparatus.

Electroencephalogram (EEG) data were collected using a 64-electrode Neuroscan Quik-cap (Compumedics USA, El Paso, TX). Additional electrodes were placed above, below, and to the side of each eye to detect eye blinks and other ocular artifacts. Online data collection was digitized at a sampling rate of 250 Hz using Neuroscan Synamps 2 amplifier. EEG recordings and analysis were performed using Neuroscan Scan 4.4 software (Compumedics USA, El Paso, TX). Impedances for the electrodes were kept below 5 KΩ throughout the experiment.

Participants.

Forty right-handed participants (23 females) with normal to corrected-to-normal vision from Wilfrid Laurier University's Psychology Research Experience Program (PREP) participated in exchange for course credit. Participants' ages ranged between 18-22 (*M* = 19.6, *SD* = 1.92), and there were 21 hockey fans and 19 non-fans. Data from two participants were excluded due to excessive EEG artifacts, therefore, data from 38 participants were included in the analysis (22 females, *M* = 19.6, *SD* = 1.92), with 19 hockey fans and 19 non-fans. All participants signed a consent form explaining the type of data recording that is used in the experiment, potential risks, and other related issues as required by the Research Ethics Board at Wilfrid Laurier University.

Procedure and Design.

After signing the consent form, participants completed a number of questionnaires to assess some aspects related to the experiment. First, they completed a Handedness questionnaire (see Appendix A) to ensure that they were right-handed. Next, they completed a Hockey Knowledge questionnaire (see Appendix B) to assess their knowledge of hockey; this questionnaire was used to determine whether participants were hockey fans or non-fans. Afterwards, they completed the South Oaks Gambling Screen (SOGS, Lesieur & Blume, 1987) to assess their gambling habits, as gambling habits could have an impact on information processing for the current experiment. After the questionnaires were completed, the EEG cap was applied in an electrically shielded room, where the experiment took place. Participants were seated approximately 70 cm away from a Dell P190SB 19" Flat Panel computer monitor, where the instructions and the task were displayed. Participants used a 4-button Neuroscan response pad to indicate their responses during the task. Instructions, task trials, and feedback were controlled using STIM 2.0 (NeuroScan, Herndon, VA).

In the instructions, participants were informed briefly about the task and their chance of winning a $100 Tim Horton's gift card if they earned the highest score (determined by receiving the greatest amount of win feedback). Since non-fans did not have a strong understanding of GAA, they were given the following brief definition: GAA is the average number of goals a team allows per game over the course of a season. Participants were taken through 8 practice trials to familiarize them with the task and to demonstrate the effects of eye blinks on data collection. Participants were instructed that there were 400 total trials, 200 included information about team GAA spread over two blocks of 100 games, and 200 included team names spread over two blocks of 100 games. Participants were also told that each trial was an actual game that took place within the last few seasons, and that all games were selected at random to be included in the task.

Participants were encouraged to evaluate the information provided in each trial, and to select the team they predict had won the game accordingly. In the relevant condition, each trial started with an information screen that displayed “Team A” with its GAA underneath and next to it “Team B” with its GAA underneath (see Figure 1). After a response was made by pressing button “1” to select “Team A”, or button “2” to select “Team B”, a fixation cross appeared for 850 ms, followed by a green cross to indicate a win and a red bar to indicate a loss. Both win and loss stimuli remained on the screen for 1500 ms. In the irrelevant condition, trials followed the same sequence of events, the only difference was that the information screen displayed European hockey team names under “Team A” and “Team B”, instead of GAA scores (see Figure 1).

Team's GAAs in the relevant condition were generated according to the range of this statistic over the last 10 years in the National Hockey League (NHL), which was found to be between 1.5 and 3.71. This range was used to constitute the upper and lower limits for this statistic, as the purpose was to make participants believe that these statistics were actually derived from real teams and that they were betting on actual games that had taken place. Afterwards, a sequence of 200 unique pairs of GAAs that were separated by 1.7 were generated, and each pair was used as the GAA for "Team A" and "Team B" in a trial. The purpose of the 1.7 difference in the GAAs was to clearly label one team as having a low GAA and the other as having a high GAA, as this difference separates the strong teams from the weak ones. This in turn allowed the deviation from expectancy to be clear; for example, if a participant predicts the team with the low GAA to win and receives a loss feedback instead, this result would be opposite to what they would expect. After the 200 unique pairs were generated, an online randomizer (http://www.randomizer.org) was used to randomly assign the pairs in order so that "Team A" was the team with the low GAA as often as "Team B" throughout each block. As for the team names in the irrelevant condition, they were gathered from a website that lists all the European professional hockey teams (http://www.flashscore.com). Two hundred teams were selected from the website and 200 unique pairs were created by randomly selecting one team as "Team A" and another as "Team B".

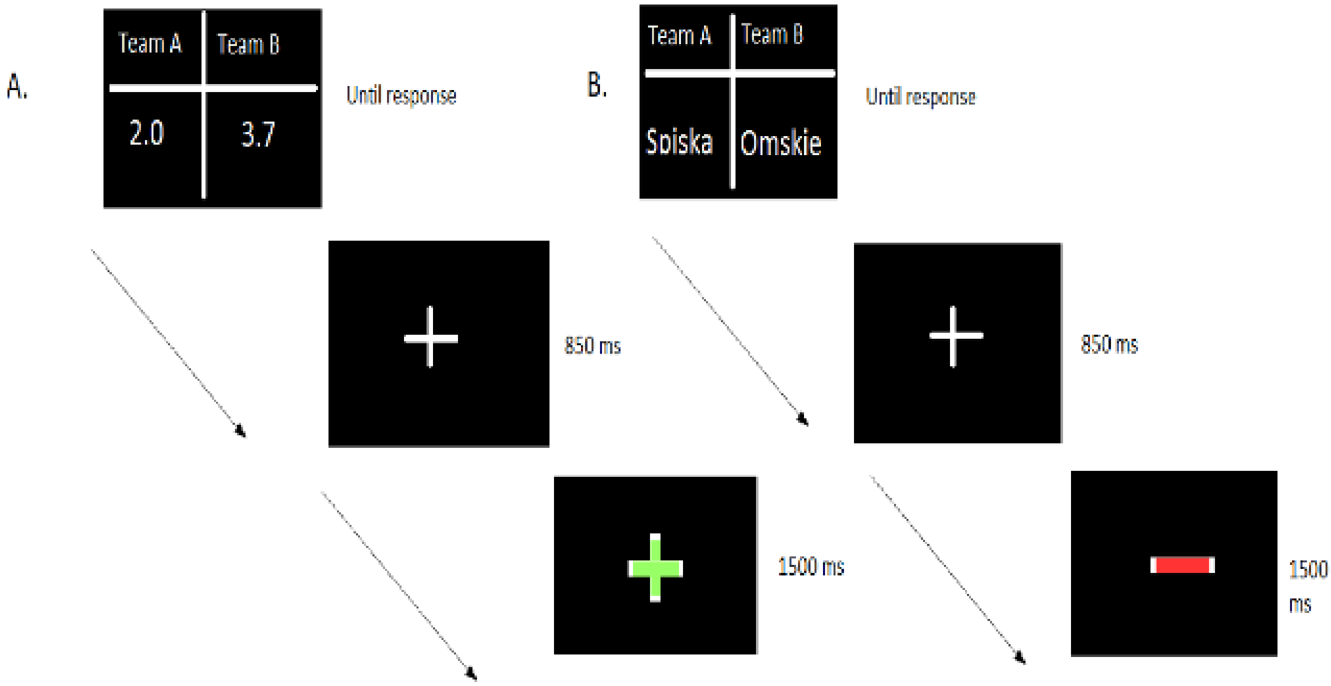

Figure 1: Sequence of events in trials
A) An example of win feedback in the relevant condition and B) an example of loss feedback in the irrelevant condition. Each trial started with an information screen that displayed the piece of information related to the block type (relevant vs. irrelevant), after a response was made, a fixation cross appeared for 850 ms followed by the feedback which remained for 1500 ms.

The experiment consisted of 400 trials that spread over 4 blocks, two of which included relevant information only, and the other two included irrelevant information only. The blocks were presented in an alternating manner, and participants always started with a relevant block. Participants were asked to make their decisions in a timely manner; however, they were encouraged to take as long of a break as needed between blocks. The distribution of win trials in the relevant condition was set up randomly by using the online randomizer (http://www.randomizer.org) in a way that 75% of the trials yielded a win if the team with the lower GAA was selected. The distribution of win trials in the irrelevant condition was set up using the same online randomizer in a way that 75% of trials yielded a win, regardless of participants' selections.

The winning percentage in the relevant condition was predetermined such that participants had a 75% chance of receiving win feedback on each trial if they selected the team with the lower GAA. In the irrelevant condition, the winning percentage was predetermined at 75% regardless of which team the participants selected on each trial. The purpose of the winning percentage manipulation was to reinforce participants' existing expectancies about the two types of information. Specifically, the manipulation was intended to reinforce the fact that team GAA is a relevant piece of information in predicting outcomes of games, since participants won on the majority of the trials where the team with the lower GAA was selected. While the names of non-popular teams was an irrelevant piece of information in predicting outcomes of games, since they randomly selected to yield win or loss trials.

ERP recording and analysis.

ERP data were collected using all 64 electrodes, which were referenced offline to the mastoid electrodes (M1 and M2). Data were filtered using a band pass of 1 Hz (12 dB/octave) to 30 Hz (24 dB/octave). Epochs were created from -100 to 600 ms around the feedback stimulus; these epochs were then baseline corrected using a 100 ms pre-stimulus period. Finally, trials contaminated with artifacts exceeding the threshold of ±50 μV were rejected.

Amplitude grand averages for the six possible outcomes were created. The relevant condition contained four possible outcomes: select low GAA and win (low_win), select low GAA and lose (low_lose), select high GAA and win (high_win), and select high GAA and lose (high_lose). The irrelevant condition contained only two possible outcomes, since win and loss trials were predetermined: irrelevant win (Irr_win) and irrelevant loss (Irr_loss). Since participants rarely selected the teams with the high GAA in the relevant condition, the final analyses included two outcomes (low_loss) and (low_win) from the relevant condition and (Irr_win) and (Irr_lose) from the irrelevant condition.

FRN amplitudes were extracted at the central electrode Fz, while P300 amplitudes were extracted from the parietal electrode Pz, as these electrodes are where these components have been shown to be maximal (Chen, Suo, Yuan & Feng, 2011). FRN peaks were identified as the most negative peaks between 200-350 ms after the presentation of the feedback stimulus, while P3 peaks were identified as the most positive peaks between 250-600 ms after the presentation of the feedback stimulus (Chen et al., 2011). Due to the smaller number of trials in (low_loss) and (Irr_loss), down-sampling of the trials in some conditions was a necessary step for comparisons of the differences in amplitude peaks among the conditions. For each participant, the trials in each condition were randomly down-sampled to the number of trials in the condition with the lowest number of trials. Behavioural data, which included the frequency of selecting the team with the lower GAA were collected as participants performed the task.

Statistical Analysis.

The extracted peak amplitudes for FRN were subjected to a repeated-measure ANOVA using SPSS (version 19.1, IBM Corp.), with hockey expertise (fans vs. non-fans) as a between-subjects factor, and the relevance of the information (relevant vs. irrelevant) and outcome (wins vs. losses) as within-subjects factors. The extracted P300 amplitudes were also subjected to the same type of analysis using the same factors as in the FRN analysis. Behavioural data were measured by determining the proportion of times the team with the lower GAA was selected compared to the number of times the team with high GAA was selected on each trial in the relevant condition.

Results

Behavioural results.

Fans in the relevant information condition selected the team with the lower GAA on 95% and 93% of trials in the first and second blocks respectively, which resulted in receiving win trials on 74% of trials in both blocks. On the other hand, non-fans selected the team with the lower GAA on 88% of trials in both blocks, which resulted in receiving win trials on 72% of trials in both blocks. As for the irrelevant information condition, fans and non-fans received win trials on 75% of the trials regardless of their selection. Also, see *Figure 2* for the number of accepted trials before and after down sampling.

Condition	Average number of accepted trials after down sampling	Average number of accepted trials before down sampling
Low-Win	35.2	110.5
Low-loss	35.2	35.2
Irr-Win	35.2	107.8
Irr-Loss	35.2	36.4

Figure 2: Number of accepted trials before and after downsampling in Experiment 1

FRN Amplitudes.

A 2 (Group: fans vs. Non-fans) X 2 (Relevance: relevant condition vs. Irrelevant condition) X 2 (Outcome: wins vs. losses) RM-ANOVA yielded a main effect of relevance on FRN peak amplitudes, $F(1,36) = 11.081$, p = .002, indicating that FRN amplitudes were larger in response to relevant information (*M*= .016, *SD*= .386) compared to irrelevant information (*M*= 1.256, *SD*= .597) (See Figures 3 & 4). There was also a main effect of outcome valence on FRN amplitudes $F(1,36) = 12.637$, p = .001, indicating that FRN amplitudes were larger in response to loss trials (*M*= -.372, *SD*= .637) compared to win trials (*M*= 1.644, *SD*= .437). An interaction effect between relevance and outcome was not significant $F(1,36) = 3.930$, p = .055.

An interaction between relevance and group was significant *F*(1,36) = 4.981, p = .032. Follow up tests reveal that fans showed larger FRN amplitudes in response to a loss in the relevant condition compared to loss in the irrelevant condition *F*(1,18) = 14.138, p = .001. However, non-fans did not show a significant difference between a loss in the relevant condition compared to the irrelevant condition *F*(1,18) = .664 p = .426. No main effect of group was found *F*(1,36) = 1.271, p = .287. (See Figures 3,4 & 5)

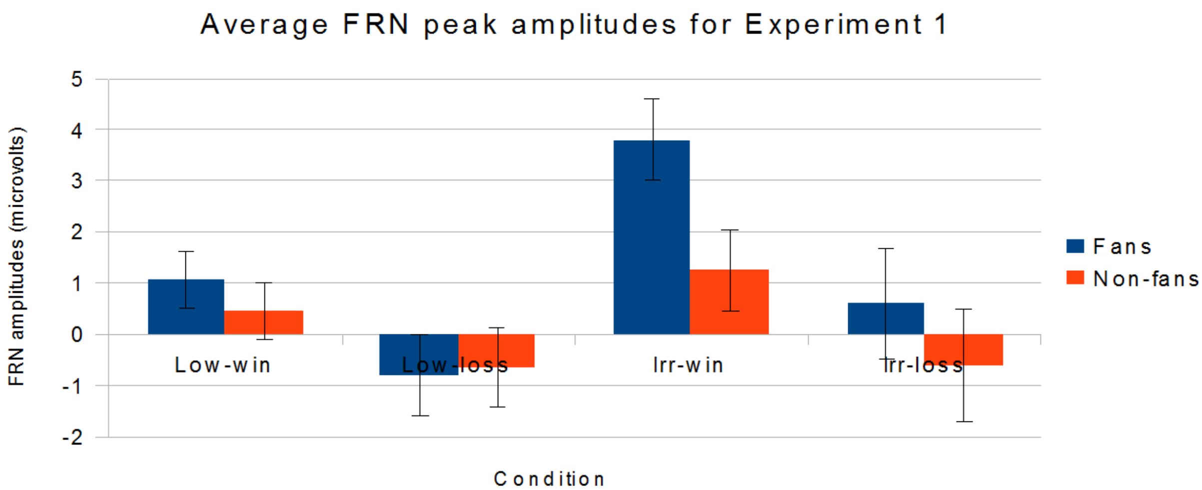

Figure 3: FRN average peak amplitudes for Experiment 1.
Bars represent standard error.

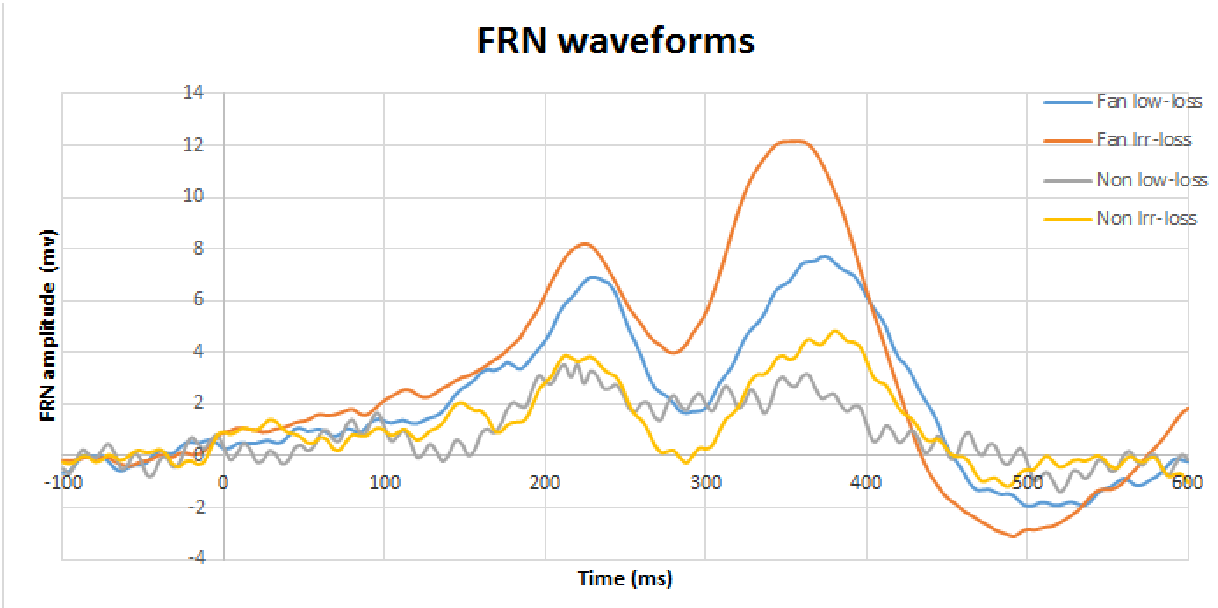

Figure 4: FRN average waveforms for losses in Experiment 1

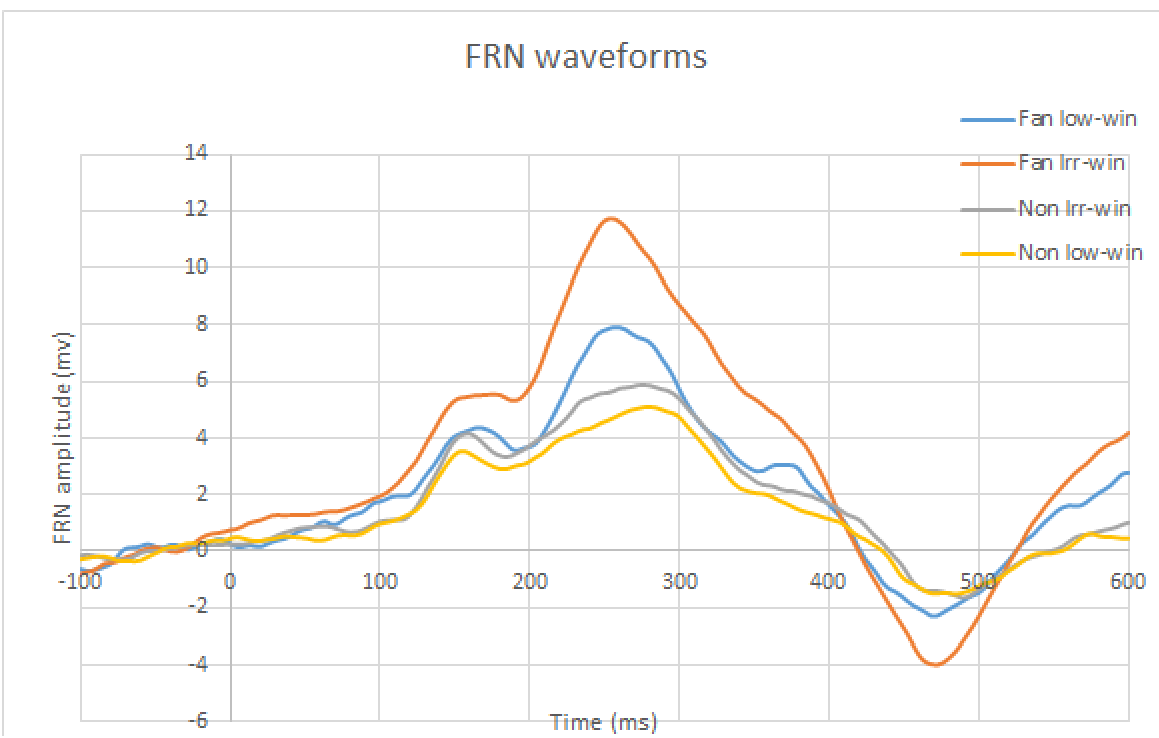

Figure 5: FRN average waveforms for wins in Experiment 1

P300 Amplitudes.

A 2 (Group: fans vs. Non-fans) X 2 (Relevance: relevant condition vs. Irrelevant condition) X 2 (Outcome: wins vs. losses) RM-ANOVA yielded a main effect of relevance on P300 peak amplitudes, $F(1,36) = 41.702$, $p < .001$, indicating that P300 peak amplitudes were larger in response to irrelevant information (*M*= 8.743, *SD*= .549) compared to relevant information (*M*= 6.581, *SD*= .461). There also was a main effect of outcome, $F(1,36) = 15.503$, $p < .001$, indicating that P300 amplitudes were larger in response to loss trials (*M*= 8.426, *SD*= .575) compared to win trials (*M*= 6.897, *SD*= .451). The interaction between relevance and outcome failed to reach significance, $F(1,36) = 3.6$, $p= .07$. (See Figures 4 &5).

The RM-ANOVA also revealed a main effect of group, $F(1,36) = 9.503$, $p = .004$, indicating that P300 amplitudes were larger for fans (*M*= 8.956, *SD*= .698) compared to non-fans (*M*= 6.076, *SD*= .650). There was an interaction between group and relevance $F(1,36) = 5.684$, $p = .024$. Follow up 2(Outcome: wins vs losses) X 2 (Relevance: relevant vs. irrelevant) RM-ANOVA was conducted for fans yielded a main effect of outcome $F(1,14) = 10.53$, $p = .006$, indicating that P300 amplitudes were larger in response to loss trials (*M*= 7.94, *SD*= .727) compared to win trials (*M*= 9.96, *SD*= .913). As for non-fans, there was a main effect of relevance $F(1,15) = 8.356$, $p =.011$, indicating that P300 amplitudes were larger in response to irrelevant information (*M*= 5.4, *SD*= .555) compared to relevant information (*M*= 6.71, *SD*= .634). (See Figure 6,7 & 8)

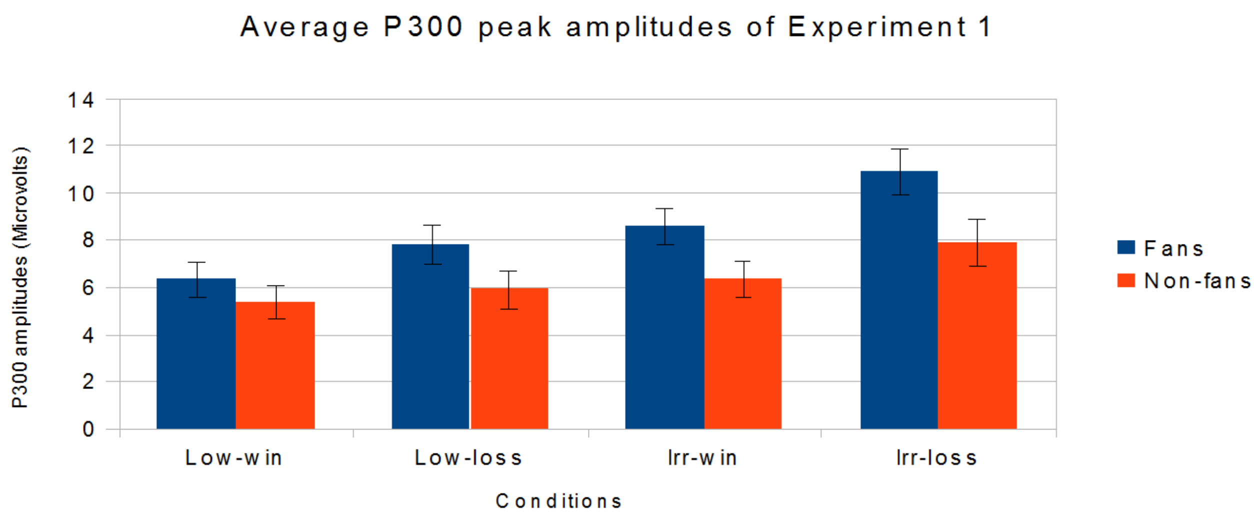

Figure 6: P300 average peak amplitudes in Experiment 1
Bars represent standard error.

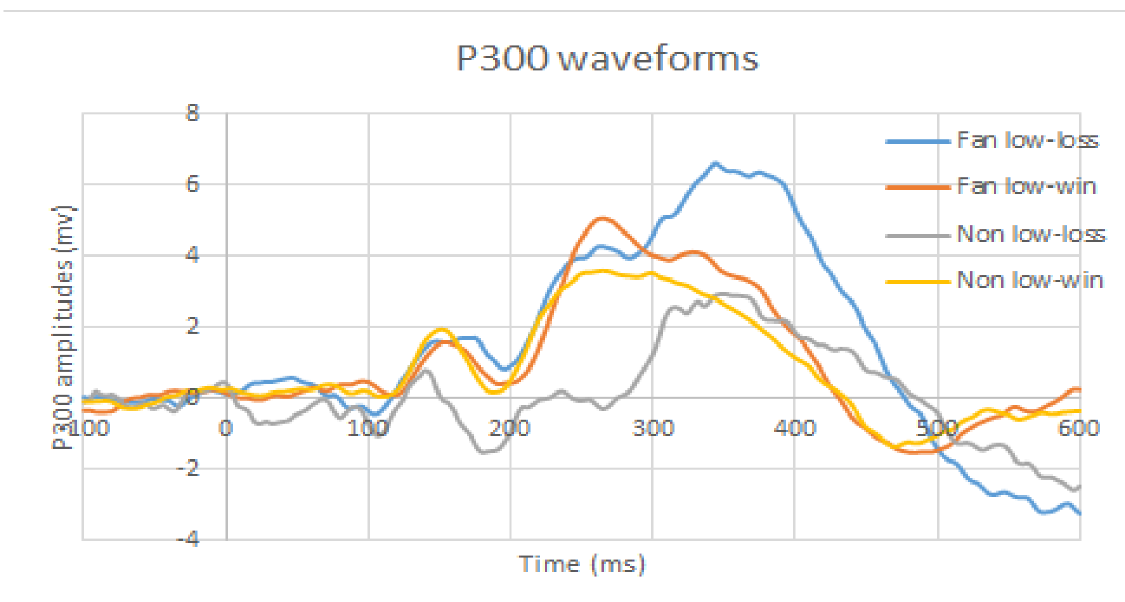

Figure 7: P300 average waveforms for relevant conditions in Experiment 1

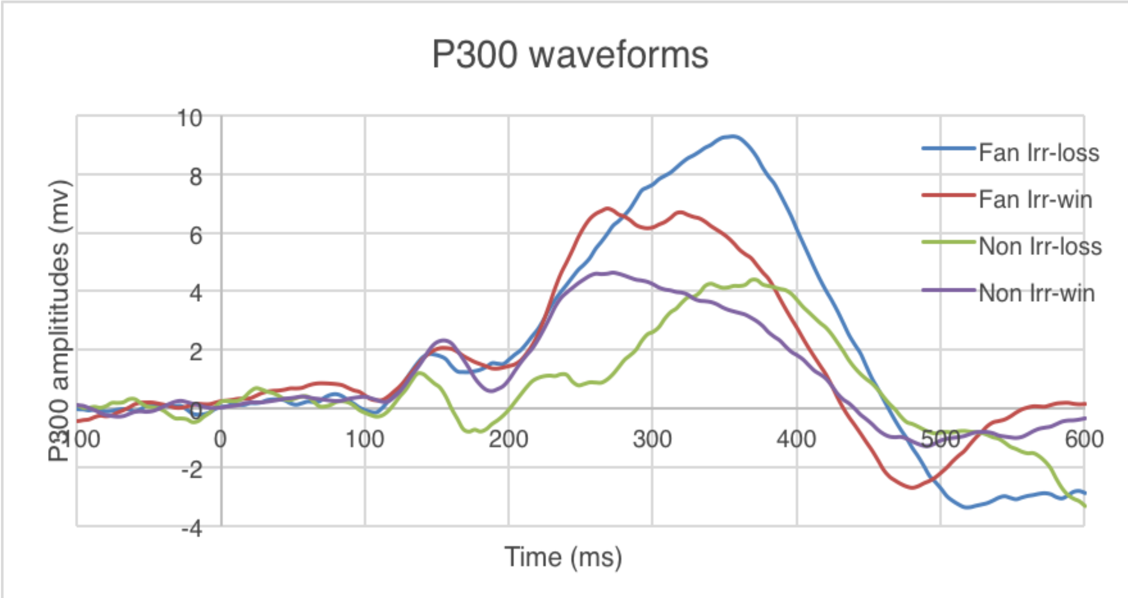

Figure 8: P300 average waveforms for irrelevant conditions in Experiment 1

Discussion

Experiment 1 aimed to replicate the effects of information relevance reported by Cheng and colleagues (in preparation), where loss feedback presented after bets made using relevant information elicited larger FRN amplitudes than loss feedback presented after bets placed using irrelevant information. Based on these previous results, both fans and non-fans were expected to have larger FRN amplitudes in response to loss feedback in the relevant condition, compared to the irrelevant condition. In addition, fans were expected to have larger FRNs following loss feedback relative to non-fans in the relevant information condition. Specifically, when the team with the lower GAA was selected to beat the team with the considerably higher GAA and loss feedback was received, fans were expected to have larger FRNs than non-fans. As for P300, there were no differences expected between fans and non-fans. However, larger P300 amplitudes were expected in response to the less frequent stimulus, which was the loss feedback in both conditions.

FRN results showed three main findings. First, there was an effect of outcome valence on FRN amplitudes regardless of the condition, with larger FRN amplitudes were elicited by loss feedback compared to win feedback for both fans and non-fans. Second, there was an effect of information relevance that was similar to that observed by Cheng and colleagues (in preparation); however, among fans only. Fans showed larger FRN amplitudes in response to loss trials in the relevant condition compared to the irrelevant in Experiment 1. Third, no support for the hypothesis that fans would show larger FRN amplitudes compared to non-fans in response to loss feedback in the relevant condition was found. Rather, both fans and non-fans showed similar FRN amplitudes in response to loss feedback in the relevant condition.

Both fans and non-fans showed an effect of outcome valence on FRN amplitudes. Amplitudes were larger in response to loss trials compared to win trials regardless of the condition. These effects are a common finding in the literature on the FRN component (Cheng et al., in preparation; Gehring & Willoughby, 2002; Holroyd & Coles, 2002; Miltner et al., 1997). Some have argued that the FRN reflects unfavourable outcomes only (i.e. loss outcomes; Gehrig & Willoughby, 2002; Hajcak et al., 2006; Miltner et al., 1997). However, Oliveira et al. (2007) argued that loss outcomes elicit larger FRN amplitudes since loss feedback constitutes a deviation from expectancy, because participants' goal is always to maximize their reward. Therefore, larger FRN amplitudes are always elicited in response to loss trials since participants' expectancy is reward on the majority of trials (Oliveira et al., 2007). However, Olivera et al. (2007) also demonstrated that larger FRN amplitudes can also be elicited in response to win feedback if this feedback deviates from the participants' expectancy. It was not possible to test the hypothesis of Oliviera and colleagues (2007) in Experiment 1 since both fans and non-fans rarely selected the team with the higher GAA. Therefore, it was not possible to test whether larger FRN amplitudes were also elicited in response to outcomes that were better than expected. As a result, the outcomes being worse than expected is a plausible explanation for why larger FRN amplitudes were observed following loss feedback in this experiment (Gehring & Willoughby, 2002; Hajcak et al., 2006; Miltner et al., 1997).

In this experiment, it is presumed that both fans and non-fans formed expectancies about the ability of the GAA statistic to predict wins in the relevant information condition, and their decisions were based on these expectancies. Behavioural results confirmed that both fans and non-fans believed that GAA could help predict the winner of the game, as they selected the team with the lower GAA on 94% and 88% of the trials, respectively. The effect of information relevance on FRN amplitudes reported by Cheng and colleagues (in preparation) suggests that decision outcomes which are based on relevant information are processed differently than decision outcomes which are based on irrelevant information. In the relevant condition, participants made their decisions based on the expectancy that the GAA statistic could help them to predict the outcome of a game. In the irrelevant condition, their decisions were not made based on relevant information, rather unknown European team names, thus they would not have as great of an expectancy that they would win their bet. Therefore, loss feedback in the relevant condition constituted a deviation from their expectancy, compared to the irrelevant condition, and thus larger FRN amplitudes were elicited in the relevant condition.

Fans showed the effect of information relevance, as FRN amplitudes were larger in response to loss trials in the relevant condition compared to the irrelevant. However, non-fans did not show the effects of information relevance, as FRN amplitudes in response to loss trials in the relevant condition were not different compared to the irrelevant. When both fans and non-fans selected the team with the lower GAA and received a loss trial, larger FRN amplitudes were expected as a reflection of deviation from expectancy (Gehring & Willoughby, 2002; Hajcak et al., 2005; Holroyd & Coles, 2002; Kobza & Bellebaum, 2013; Oliveira et al., 2007; Miltner et al., 1997). Therefore, loss trials in this condition were expected to elicit smaller FRN amplitudes compared to loss trials in the relevant condition (Cheng et al., in preparation). In the irrelevant condition, both fans and non-fans did not make their decisions based on an expectancy and large FRN amplitudes were not expected. Unknown team names were not expected to help predict outcomes, as was confirmed after the experiment.

One possible explanation for the contradicting finding of equally large FRN amplitudes among non-fans in response to loss feedback in both conditions is the 75% probability of receiving win feedback in both conditions. The majority of the non-fans mentioned that they attempted to find patterns and strategies, such as selecting the team that appeared to be from countries where hockey is known to be a popular game. Although there were no such patterns, as win and loss feedback was randomly predetermined, the 75% win probability might have contributed to false expectancies of such patterns. That in turn, could have contributed to a partial or weak expectancy about these teams among non-fans, and thus loss feedback would have constituted a deviation from this weak expectancy as reflected by the larger FRN amplitudes. Fans, on the other hand, mentioned that from the beginning of the experiment they had no expectancies about these teams as they understood it is impossible to predict patterns or strategies about the teams that they are unfamiliar with and their decisions were made at random.

We hypothesized that this experiment would demonstrate that hockey fans, as a result of their knowledge and experience with the GAA statistic, would elicit a larger FRN following loss feedback, relative to hockey fans that were only familiarized with the statistic at the beginning of the experiment. However, we did not find that fans demonstrated larger FRN amplitudes to loss feedback in the relevant information condition, compared to non-fans. Both fans and non-fans showed equally large

FRN amplitudes in response to loss feedback in the relevant condition. Larger FRN amplitudes among fans were expected since fans would have come into the experiment with an expectancy that a team with a lower GAA was very likely to beat a team with a considerably higher GAA. This expectancy is the result of following the game of hockey for years and experiencing such results. Therefore, if they selected a team with a lower GAA and received loss feedback, this outcome would have constituted a deviation from their expectancy and would be reflected by larger FRN amplitudes (Gehring & Willoughby, 2002; Hajcak et al., 2005; Holroyd & Coles, 2002; Kobza & Bellebaum, 2013; Oliveira et al., 2007; Miltner et al., 1997). Non-fans on the other hand were given a definition of the GAA statistic, and it is likely that they could deduce that teams with a lower GAA would win more often, but since they had no previous experience with this statistic, it was presumed that they would form a weaker expectancy of its ability to predict the outcome of a hockey game. However, selecting the team with the lower GAA was rewarded on 75% of the trials, which would have reinforced this weak expectancy. Therefore, if they selected the team with the lower GAA and received loss feedback, this outcome would have also constituted a deviation from their expectancy and would have been reflected through larger FRN amplitudes. However, it was expected that fans would show larger FRN amplitudes since this outcome is a deviation from their long-held expectancy compared to a deviation from an expectancy that was reinforced among non-fans as they performed the experiment.

As for the P300, the results of this first experiment provided support for the hypothesis that loss feedback would elicit larger amplitudes compared to win feedback across both populations. Amplitudes were larger in response to the infrequent stimulus (i.e. loss feedback) compared to the frequent stimulus (i.e. win feedback) among both fans and non-fans. This finding is very common in studies of P300 (Cheng et al., in preparation; Donchin & Coles, 1988; Johnson & Donchin, 1977; Nieuwenhuis, 2011). According to Donchin and Cole's Context-update hypothesis (1988), larger P300 amplitudes reflect the allocation of greater attentional resources towards infrequent stimuli in order to incorporate this information into an existing internal representations. According to this hypothesis, infrequent stimuli elicit greater attention since they signal a mismatch between what is expected to be the outcome on most trials, and the actual outcome. In the relevant condition, participants expected to receive a win on the majority of trials as a result of their expectancies about GAA. Therefore, both fans and non-fans needed to update their internal representations of reward probabilities in response to loss trials in both conditions and that was reflected by the larger P300 amplitudes.

Unexpectedly, both fans and non-fans showed larger P300 amplitudes in the irrelevant condition compared to the relevant. In light of Donchin and Cole's (1988) context-update hypothesis, the results of this experiment show that both fans and non-fans allocated greater attentional resources towards irrelevant information and elicited larger P300 amplitudes as a result. This finding was not observed in the studies reported by Cheng and colleagues (in preparation) as no effect of information relevance on P300 was found. Therefore, under the given probability of receiving a win trial of 75% and the type of irrelevant information used in this experiment, FRN and P300 show similar patterns in response to outcome valence in fans and non-fans, with larger amplitudes in response to loss trials. However, FRN and P300 show dissimilar patterns in response to information relevance among fans, with larger FRN amplitudes in response to loses in the relevant information condition, but larger P300 amplitudes in response to irrelevant information.

Experiment 2

The main purpose of Experiment 2 was to create a stronger deviation from expectancy among fans compared to Experiment 1. Experiencing a 25% probability of receiving a loss trial when team with the lower GAA was selected in Experiment 1 might not have been perceived as a strong deviation from fans' expectancy about GAA. Fans could have expected that a team with low GAA could possibly lose to a team with higher GAA occasionally, while non-fans learned the predictability of the GAA stat as they performed the task. Therefore, there were no differences in FRN amplitudes between fans and non-fans in the relevant condition because there was no strong deviation from fans' expectancy. In addition, it has been argued by Hauser et al. (2014) that it is difficult to separate the effects of outcome valence from the effects of violation of expectancy on FRN amplitudes when loss trials are less frequent than win trials. To address these two issues, the probability of receiving a win trial was decreased to 50% in Experiment 2 when the team with lower GAA was selected. In the irrelevant condition, the probability of receiving a win a trial was also set to 50%, which would further reinforce the expectancy that the European team names are not a strong factor in predicting outcomes of games. Due to this decrease in the probability of receiving a win trial, it was necessary to instruct non-fans about the nature of GAA as a strong factor in predicting outcomes of games to create a similar expectancy to the one they had in Experiment 1. In Experiment 1, non-fans experienced a 75% probability of receiving a win trial when the team with the lower GAA was selected, which reinforced their expectancy about statistics as a strong predictor of outcomes. Therefore, giving non-fans instructions would allow for a more accurate comparison of FRN amplitudes in response to deviations from expectancy between fans and non-fans.

Despite the 50% probability of receiving a win trial, it was expected that fans would select the team with low GAA on the majority of trials as a result of their long-held expectancy and experience with GAA. Non-fans on the other hand, were expected to follow the same trend as a result of their general expectancy about statistics (Wood, 1992; Woodland & Woodland, 2001) and the instructions they were given before the start of the task. It was expected that fans and non-fans would show effects of information relevance, with larger FRN amplitudes in response to relevant information compared to irrelevant information. However, it was expected that fans would show even larger FRN amplitudes compared to non-fans in response to a loss trial when the team with the lower GAA was selected. Because an outcome like that constitutes a deviation from fan's long-held expectancy about hockey compared to non-fans who acquired this expectancy by instructions and performing the task. As for P300, since loss trials were as frequent as win trials, no differences in P300 amplitudes were expected between win and loss trials (Campbell et al., 1979). No differences in P300 were expected either between fans and non-fans since P300 amplitudes were expected to be similar in the relevant compared to the irrelevant condition.

Method

Experiment 1 did not yield the expected differences in FRN amplitudes between fans and non-fans in the relevant condition. The reason could have been that receiving a loss on 25% of trials when the low GAA was selected is not a strong enough deviation from fans' expectancy. It is a reasonable possibility that a team with low GAA loses to a team with considerably higher GAA at times, as fans explained after the experiment. Therefore, the purpose of Experiment 2 was to create a stronger deviation from the expectancy that fans hold in regards to GAA, which is a strong predictor of outcomes of games. To achieve that, the probability of receiving a win trial when the team with the low GAA was selected was decreased to 50%. This was also done to try to replicate the effects of relevance when win probabilities were set to 50% in Cheng et al. (in preparation). Cheng and colleagues (in preparation) found that when winning probabilities were set to 50%, participants showed the effects of relevance on FRN, such that there were larger FRN amplitudes in response to a loss in the relevant condition compared to the irrelevant condition.

The decrease from 75% to 50% probability was necessary, as it has been argued that to separate the effects of outcome valence from the effects of expectancy (i.e. relevance), the frequency of win and loss trials has to be equated. It was expected that decreasing the probability of winning to 50% in the current experiment would yield the effects of relevance that were observed in Cheng et al. (in preparation); it was also expected that the probability decrease will also elicit larger FRN amplitudes among fans than among non-fans in response to a loss trial in the relevant condition. In Experiment 1, non-fans formed an expectancy about GAA as a strong predictor of outcomes of games by receiving a win trial 75% of the time. In Experiment 2, however, the 50% probability of winning was not high enough to reinforce an expectancy about GAA, and therefore it was necessary to reinforce that expectancy in a different way to allow for an accurate comparison between fans and non-fans. Therefore, non-fans in Experiment 2 were given more detailed instructions about the nature of GAA in predicting outcomes of games compared to Experiment 1 (see Appendix C).

Apparatus.

The apparatus for this experiment was the same as in Experiment 1.

Participants.

Forty-five right-handed participants (22 females) were recruited from Wilfrid Laurier University's PREP system for course credit, as well as from the surrounding community for a monetary compensation of $20. Participants' ages ranged between 18-54 (*M* = 22, *SD* = 4.5), and there were 21 hockey fans and 24 non-fans. Data from 11 participants were excluded due to excessive EEG artifacts, therefore data from 34 participants was included in the final analysis (18 females, *M* = 21.5, *SD* = 4.3), with 17 fans and 17 non-fans. All participants agreed to the terms on the consent form, these terms were set up by the Research Ethics Board at Wilfrid Laurier University.

Procedure and Design.

The procedure and design were the same as in Experiment 1, except that the winning probabilities were set to 50% instead of 75%. This manipulation was set up in a way that participants had a 50% probability of receiving a win in the relevant condition if they selected the team with the lower GAA. While in the irrelevant condition, participants had a 50% probability of receiving a win, regardless of which team they selected. The other change from Experiment 1 was that non-fans were given instructions prior to the start of the task about the GAA and how it is used as a factor in predicting outcomes of games.

ERP recording and analysis.

This was identical to Experiment 1.

Statistical Analysis.

There was one extra factor compared to Experiment 1, which was the addition of the block factor, such that the first block in each condition was compared to the second. Since the probability of winning was at 75% in Experiment 1, there were not enough loss trials in the relevant and the irrelevant conditions to include a block factor in the analysis. In Experiment 2, however, the probability of winning was set to 50%, which yielded a sufficient number of loss trials to allow for the block factor to be included in the analysis. The block factor allowed us to evaluate the possible effects due to learning as participants progressed through the experiment. This can be used to asses potential interaction effects with other factors on information processing in fans compared to non-fans. Therefore, the statistical analysis for the FRN amplitudes in Experiment 2 consisted of repeated-measures ANOVA with expertise (fans vs. non-fans) as the between-subjects factor, and relevance (relevant vs. irrelevant), outcome (wins vs. losses), and block (first block vs. second block) as the within-subjects factors. The analysis for P300 amplitudes consisted of a repeated-measures ANOVA with the same factors as the ANOVA that was performed on the FRN amplitudes.

Results

Behavioural results.

Fans in the first block of the relevant information selected the team with the lower GAA on 75% of trials, while in the second block they selected the team with the lower GAA on 67% of trials. On the other hand, non-fans in the first block selected the team with the lower GAA on 65% of trials, while in the second block they selected the team with the lower GAA on 52% of trials. Also, see *Figure 9* for the average number of accepted trials before and after down sampling.

Condition	Average number of accepted trials after down sampling	Average number of accepted trials before down sampling
Low-Win (Block1)(Block2)	(15.3)(15.3)	(15.3)(16.1)
Low-loss (Block1)(Block2)	(15.3)(15.3)	(16.1)(15.7)
Irr-Win (Block1)(Block2)	(15.3)(15.3)	(76.4)(75.2)
Irr-Loss (Block1)(Block2)	(15.3)(15.3)	(77.1)(75.2)

Figure 9: Number of accepted trials before and after downsampling in Experiment 2

FRN Amplitudes.

A 2 (Group: fans vs. Non-fans) X 2 (Relevance: relevant condition vs. Irrelevant condition) X 2 (Outcome: wins vs. Losses) X 2 (Block: block 1 vs. block 2) RM-ANOVA yielded a main effect of outcome valence on FRN amplitudes $F(1,31) = 13.854$, $p = .001$, indicating that FRN amplitudes were larger in response to loss trials (*M*= .952, *SD*= .587) compared to win trials (*M*= 2.739, *SD*= .538). An interaction between group, relevance and block was significant *F*(1,31) = 4.191, *p* = .049, indicating differences in FRN amplitudes between the two groups in response to relevant compared to irrelevant information across the two blocks. Additional post-hoc comparisons revealed a significant difference in FRN amplitudes in response to irrelevant information in block 1 compared to block 2 among non-fans *F*(1,31) = 8.80, p = .031, indicating that non-fans show higher FRN peak amplitudes in block 2 (*M*= 1.708, *SD*= .739) compared to block 1 (*M*= 2.926, *SD*= .809) in the irrelevant information condition. No differences were found among the other post-hoc comparisons. (See Figures 10,11,12 & 13)

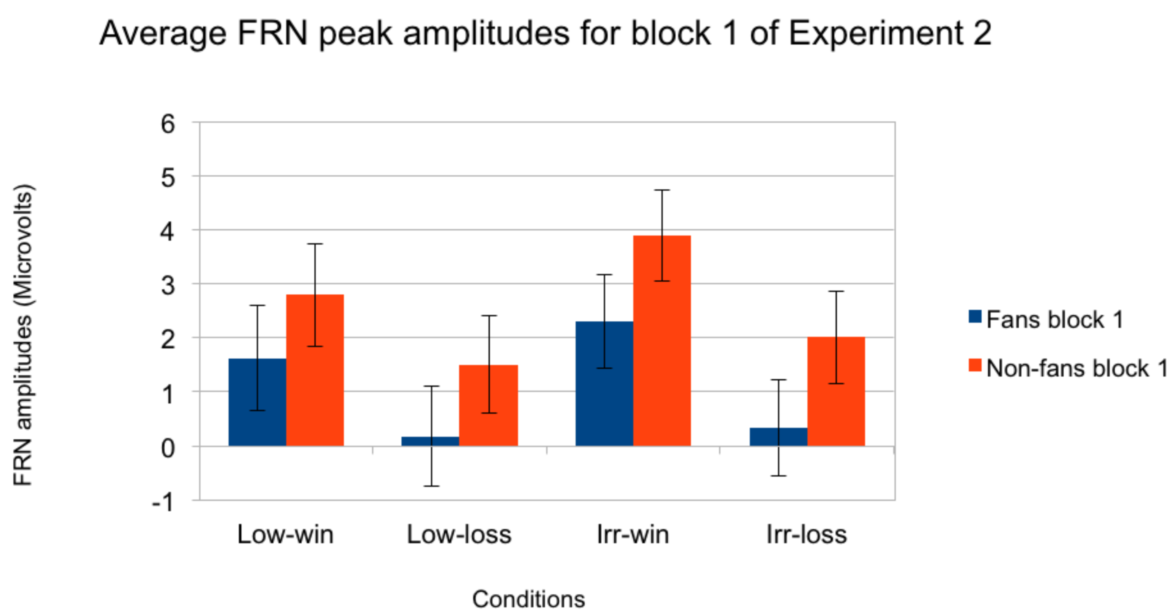

Figure 10: FRN peak amplitudes in block 1 of Experiment 2
Bars represent the standard error.

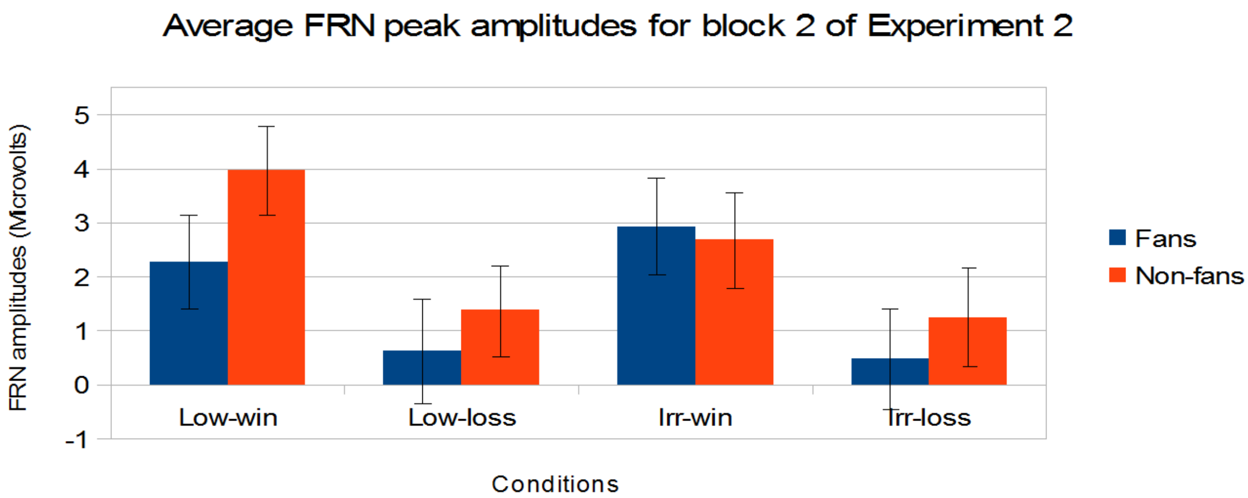

Figure 11: FRN peak amplitudes in block 2 of Experiment 2
Bars represent the standard error.

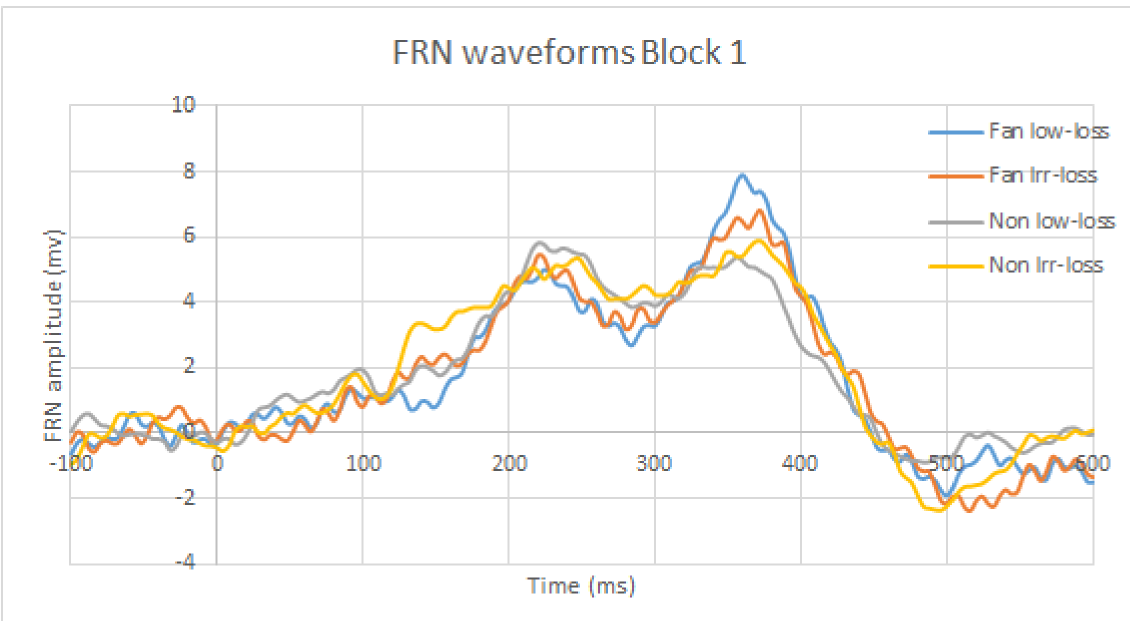

Figure 12: FRN waveforms for loss conditions in block 1 of Experiment 2

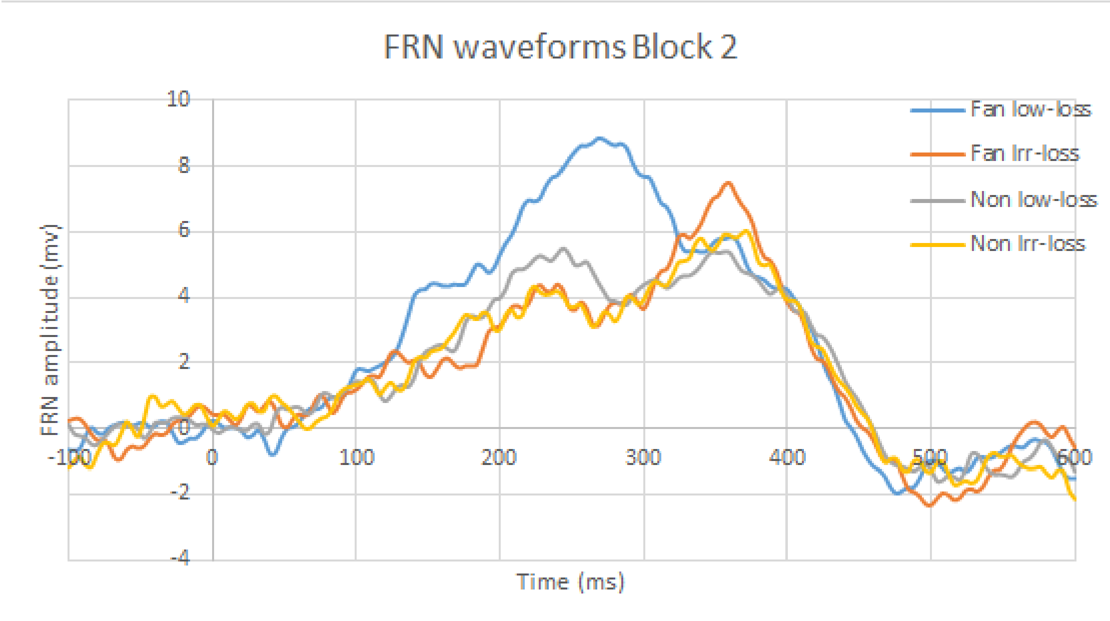

Figure 13: FRN waveforms for loss condition in block 2 of Experiment 2

P300 Amplitudes.

As expected, a 2 (Group: fans vs. Non-fans) X 2 (Relevance: relevant condition vs. Irrelevant condition) X 2 (Outcome: wins vs. Losses) X 2 (Block: block 1 vs. block2) RM-ANOVA yielded no main effect of outcome *F* (1,37)= .362, p = .552. However, the RM-ANOVA yielded a significant interaction between group and block *F* (1,37)= 10.16, *p* = .003, indicating that non-fans show higher P300 amplitudes in block 2 (*M*= 8.25, *SD*= .882) compared to fans in block 2 (*M*= 7.25, *SD*= .933). No main effect of group *F* (1,37)= .064, p = .802, or block *F* (1,37)= 1.48, p = .323 was found. (See Figures 14,15,16 & 17).

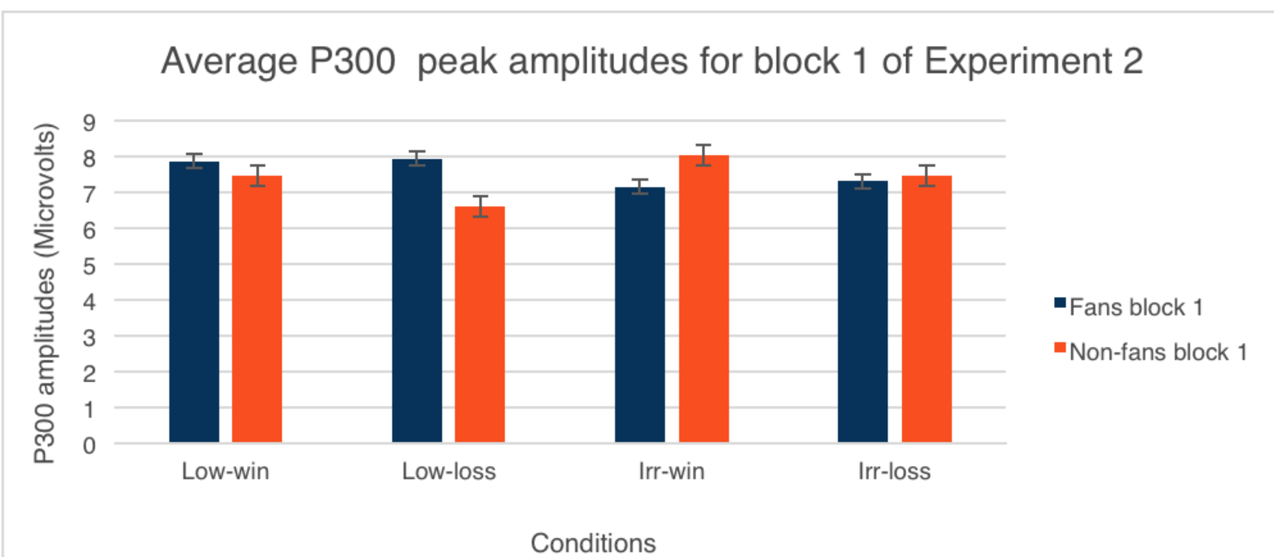

Figure 14: P300 average amplitudes in block 1 of Experiment 2
Bars represent the standard error.

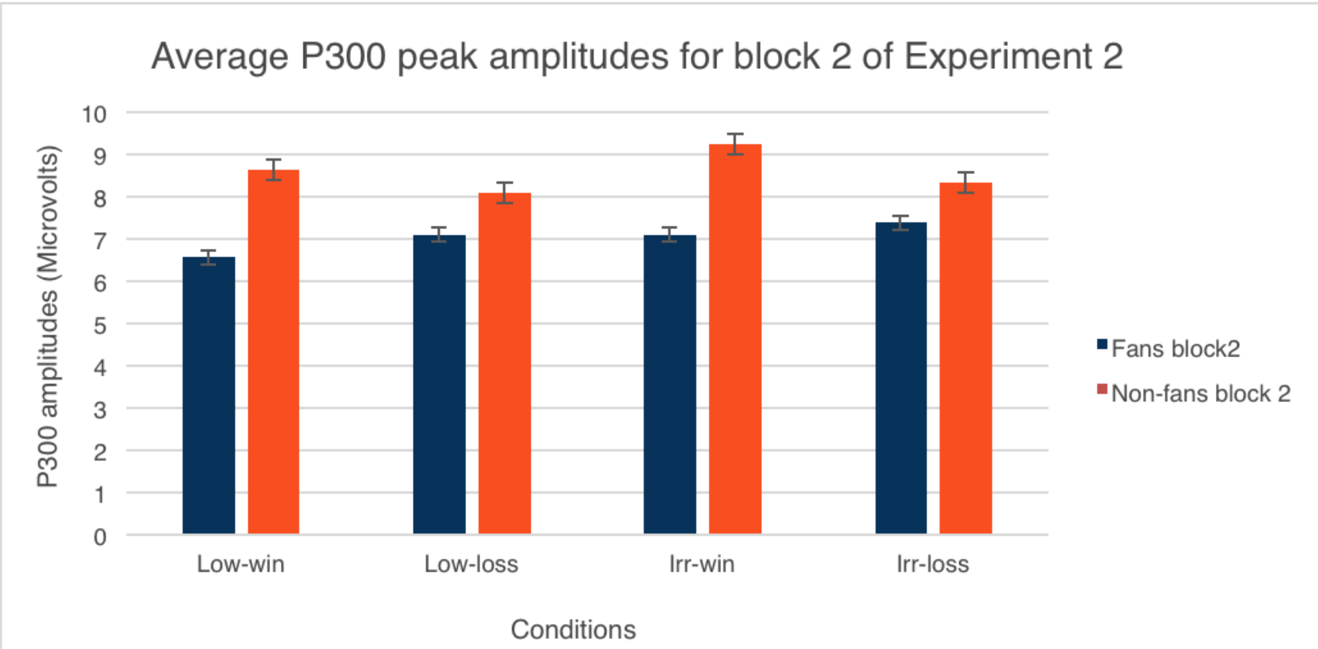

Figure 15: P300 average amplitudes in block 2 of Experiment 2
Bars represent standard error.

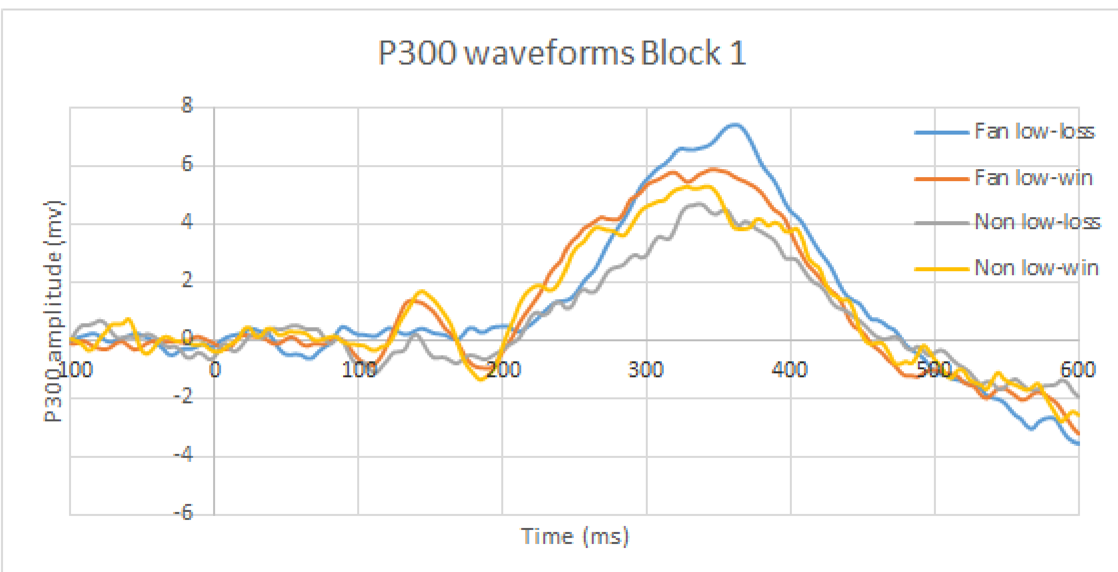

Figure 16: P300 average waveforms for relevant wins and losses in block 1 of Experiment 2

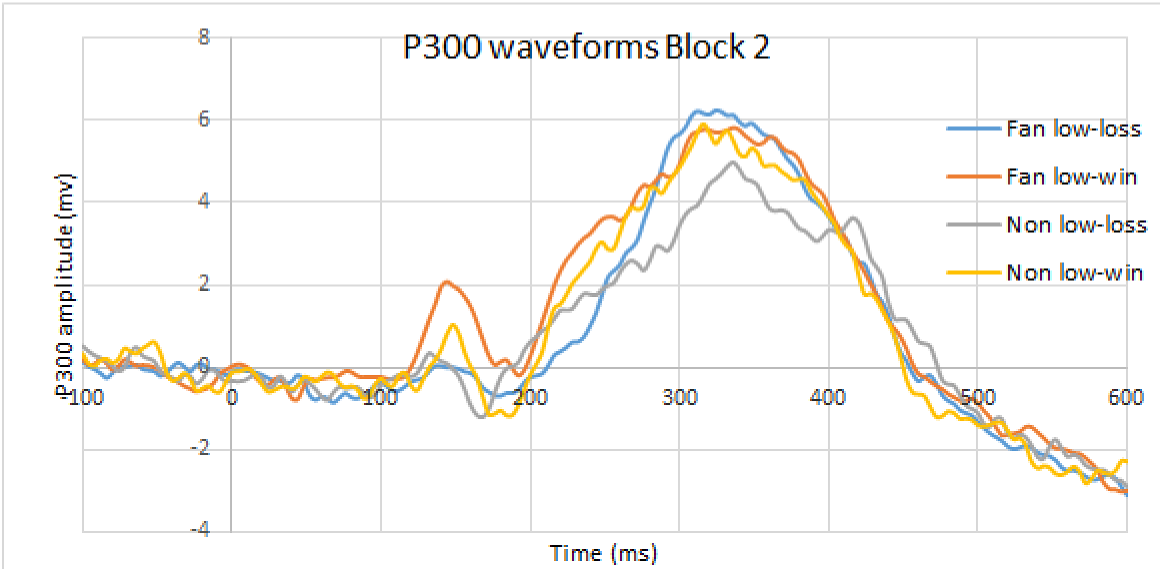

Figure 17: P300 average waveforms for relevant wins and losses in block 2 of Experiment 2

Discussion

Experiment 2 was designed to further investigate the possible differences in FRN amplitudes between fans and non-fans in the relevant condition. Experiment 2 addressed two issues that arose in Experiment 1. First, the 25% chance of a team with lower GAA losing to a team with considerably higher GAA might not have constituted a strong deviation from fans' expectancy. Therefore, the possible differences in FRN were expected to emerge under a stronger deviation from fans' expectancy. Second, in Experiment 1 the effects of information relevance that were found among fans could have been due to the fact that losses were less frequent than wins. To separate the effects of outcome valence from the effects of information relevance (i.e. deviation from expectancy), loss and win trials were equated (Hauser et al., 2014). In Experiment 2 the probability of receiving a win trial when the team with the lower GAA was selected was decreased to 50%. This probability manipulation addressed the two issues in Experiment 1 as it constituted a stronger deviation from fans' expectancy and to separate the effects of information relevance from the effects of outcome valence.

FRN results showed: first, effects of outcome valence on FRN for both fans and non-fans, larger amplitudes in response to loss trials compared to win trials in both conditions and both blocks. Second, fans did not show effects of information relevance in either block, no differences in FRN amplitudes in the relevant condition compared to the irrelevant. As for non-fans, they did not show effects of information relevance in the first block, but they did show them in the second block. However, in the second block the effects were in the opposite direction, larger FRN amplitudes in the irrelevant condition compared to the relevant. Third, no differences in FRN amplitudes between fans and non-fans in the relevant information in either block.

Both fans and non-fans showed the effects of outcome valence on FRN; loss trials elicited larger FRN amplitudes compared to win trials regardless of condition and block. This replicates the finding in Experiment 1 despite the equal probabilities of receiving win and loss trials. These effects of outcome valence on FRN are demonstrated in a large number of studies involving decision making (Cheng et al., in preparation; Gehring & Willoughby, 2002; Holroyd & Coles, 2002; Miltner et al., 1997). Despite the equal probability of receiving loss and win trials, loss trials were unfavourable outcomes since the participants’ goal was to maximize reward. Although participants received more loss trials in Experiment 2 compared to Experiment 1 (25%), loss trials were still unfavourable outcomes. Therefore, larger FRN amplitudes in Experiment 2 reflected the unfavourableness of loss outcomes independent of reward probability (Gehring & Willoughby, 2002; Holroyd & Coles, 2002; Miltner et al., 1997) and relevance of information.

Results for fans in Experiment 2 failed to replicate the effects of information relevance on FRN that were found in Experiment 1. In Experiment 2, FRN amplitudes in response to loss trials in the relevant condition were not larger than in response to loss trials in the irrelevant condition in either block. In Experiment 1, the effects of information relevance were observed because loss trials in the relevant condition constituted a deviation from fans' expectancy. These effects of information relevance were also expected to be observed in Experiment 2, since loss trials in the relevant condition constituted even a bigger deviation from expectancy compared to the irrelevant condition. Cheng et al. (in preparation) were able to show effects of information relevance when the reward probability was decreased from 75% to 50% when the statistically favourable stimulus was selected. However, fans in Experiment 2 failed to show these effects despite the fact that they selected the team with the lower GAA on the majority of trials. Continuing to select the team with the lower GAA despite the 50% chance or reward shows that fans were making their decisions based on their long-held expectancy that the team with the lower GAA had a much higher chance to beat the team with the higher GAA.

Based on the argument by Hauser et al. (2014), to separate the effects of expectancy (i.e. information relevance) from the effects of outcome valence, the effects of information relevance need to be observed when loss and win outcomes are equated. Cheng et al. (in preparation) were able to conclude that the effects of information relevance were separate from the effects of outcome valence. That was because Cheng et al. (in preparation) were able to observe both the effects of information relevance and outcome valence with 75% and 50% chance of reward. Since the effects of information relevance among fans in Experiment 1 were not replicated in Experiment 2. It is not possible to conclude that the effects of information relevance are separate from the effects of outcome valence, at least under the 50% reward probability. Therefore, outcome valence in Experiment 2 (i.e, the unfavorableness of loss outcomes) was the factor affecting FRN and not information relevance. However, this low win probability might have been unrealistic in hockey, which made fans pay less attention to outcome feedback in the relevant condition. As a result, the differences in FRN amplitudes between the relevant and irrelevant conditions were reduced compared to Experiment 1.

As for non-fans, they showed no effects of information relevance on FRN in the first block. However, they showed the reverse effects of information relevance in the second block, as FRN amplitudes were larger in the irrelevant condition compared to the relevant. In Experiment 1, no effects of information relevance were observed among non-fans as FRN amplitudes were similar in both conditions. The reason for that might have been because non-fans showed higher sensitivity towards irrelevant information compared to fans. In Experiment 2, non-fans continued to show even higher sensitivity towards irrelevant information compared to fans, especially in the second block. Regardless of the reason for this oversensitivity towards irrelevant information, it is apparent that there are differences in the way fans and non-fans process irrelevant information. This was unexpected since this irrelevant information was not believed to be a predicting factor to the outcomes of games as non-fans indicated during interviews.

The results of Experiment 2 did not provide support to the possible differences in FRN amplitudes between fans and non-fans in the relevant condition. These differences were expected since fans make their decisions in the relevant information condition based on their long-held expectancy about GAA as a strong factor in predicting outcomes of games. On the other hand, non-fans make their decisions based on the instructions they were given at the start of the experiment and their learning as they perform the task. Results of Experiment 2 showed that fans and non-fans did not show differences in FRN amplitudes in the relevant information in either block. As mentioned above, the low reward probability in the relevant condition might have been seen as unrealistic by fans and they might have paid less attention to outcome feedback as a result. That in turn could have contributed to smaller FRN amplitudes in the relevant condition which might have made it difficult to observe the possible differences compared to non-fans. Behavioural data showed an encouraging trend, however. In the first block of Experiment 2, fans and non-fans selected the team with the lower GAA with a very similar high frequency. In the second block, fans continued to select the team with the lower GAA with a high frequency, whereas non-fans trended towards selecting the team with the lower GAA with a lower frequency, almost at 50%. This shows that fans were more persistent compared to non-fans in selecting the team with the lower GAA despite the low reward probability. This trend shows that fans and non-fans made their decisions based on different expectancies. Therefore, it is possible that differences in FRN amplitudes between fan and fans emerge under different contexts.

As for P300, results of Experiment 1 showed effects of outcome valence on P300, larger amplitudes in response to loss trials compared to win trials. But, loss trials were less frequent than win trials. As a result, it was unclear whether larger P300 amplitudes in response to loss trials reflected outcome valence (i.e, unfavourableness) or the low frequency of loss trials. However, it is a strong finding in the literature that P300 amplitudes are larger in response to infrequent stimuli compared to frequent stimuli (Donchin & Coles, 1988; Johnson & Donchin, 1977; Nieuwenhuis, 2011). On the other hand, it has been shown that no differences in P300 amplitudes are found in response to different stimuli when their frequencies are equal (Campbell et al., 1979; Cheng et al., in preparation). Therefore, no effects of outcome valence on P300 amplitudes in response to loss trials compared to win trials were expected in Experiment 2. In Experiment 2 both fans and non-fans showed no effects of outcome valence on P300 as amplitudes were similar in response to loss compared to win trials. Therefore, it is likely that the larger P300 amplitudes in response to loss trials in Experiment 1 reflected the low frequency of loss trials and not their unfavourableness. According to Donchin and Cole’s Context-update hypothesis (1988), larger P300 amplitudes in response to infrequent stimuli help update reward representations. This is important in order to respond to the task according to these reward representations and maximize reward (Donchin & Coles, 1988; Johnson & Donchin, 1977; Nieuwenhuis, 2011).

Moreover, Experiment 1 showed unexpected effects of information relevance on P300 for both fans and non-fans and in the opposite direction. P300 amplitudes were larger in response to loss trials in the irrelevant condition compared to the relevant. However, in Experiment 2 results were mixed. Fans showed no effects of information relevance in the first block, but lower amplitudes in response to loss trials in the relevant condition in the second block compared to the first. This suggests that their attention towards irrelevant information was maintained throughout the experiment, but their attention towards relevant information decreased by the second block. This provides support to the suspicion that fans might have perceived the 50% probability in the relevant condition as unrealistic and paid less attention to outcome feedback in the second block. Non-fans showed no effects of information relevance in the first block, but in the second block they showed larger P300 amplitudes in response to loss trials in both conditions. This increase in attention towards irrlevant information in the second block could be the result of irrational cognitive process as a result of the 50% reward probability (Ladouceur, 2004; Miller & Currie, 2008). In addition, this increase in attention towards irrlevant information in the second block was possibly the reason for the unexpected larger FRN amplitudes in the irrelevant condition among non-fans.

To summarize the relationship between FRN and P300 in light of the results of Experiment 1 and 2. FRN and P300 seem to respond in a similar manner to outcome valence among both fans and non-fans in Experiment 1; larger amplitudes in response to loss trials. FRN and P300 seem to respond in a somewhat different manner to outcome valence in Experiment 2; larger FRN amplitudes in response to loss trials, while no effects on P300. On the other hand, FRN and P300 seem to respond in a different manner to information relevance especially among fans in Experiment 1; larger FRN amplitudes in response to relevant information and larger P300 amplitudes in the irrelevant information. Whereas in Experiment 2 FRN and P300 show mixed results, with increase in both FRN and P300 amplitudes among non-fans in the irrelevant condition, while fans show decrease in the relevant condition. Therefore, the different win probabilities in Experiments 1 and 2 had different effects on FRN and P300 among fans and non-fans. The majority of these results were not expected as they contradict what was found in Cheng et al. (in preparation) and what was expected based on the hypotheses in these two experiments. However, the type of irrelevant information that was used in Experiments 1 and 2 could have been the reason for the unexpected results for FRN and P300. This is a possibility since Experiments 1 and 2 showed unexpected larger FRN and P300 amplitudes in response to irrelevant information in some conditions and equally large FRN amplitudes in response to both types of information in some other conditions.

Experiment 3

The main purpose of Experiment 3 was to remove any possible effects of the irrelevant condition on FRN in the relevant condition. Specifically, the irrelevant condition could have had a carryover effect on the relevant condition due to the probability of winning 50% of the trials. Research suggests that experiencing reward at 50% can create a number of irrational cognitive processes in gambling games (Ladouceur, 2004; Miller, & Currie, 2008). Irrational cognitive processes could have been generated when experiencing reward at chance level in the irrelevant condition. These irrational processes then carried over to the relevant condition washing out the expected differences in FRN amplitudes between fans and non-fans. This was especially possible among non-fans as they showed larger FRN amplitudes in response to irrelevant information compared to fans in Experiments 1 and 2.

Therefore, Experiment 3 consisted of relevant information only to remove these possible carry over effects.

Another purpose of the experiment is to have a better control over the expectancy about GAA that fans and non-fans have before the introduction of the strong deviation of 50%, where differences in FRN amplitudes are expected to emerge. For non-fans, in Experiment 1 they were not given instructions about the nature of GAA as a strong factor in predicting outcomes of games; however, they selected the team with low GAA on the vast majority of trials. This is because of their general expectancy about statistics as a strong factor in predicting outcomes of games (Wood, 1992; Woodland and Woodland, 2001). This expectancy was reinforced by experiencing reward on 75% of the trials creating an expectancy about GAA specifically. In Experiment 2, they were given instructions about the nature of GAA as a strong factor in predicting outcomes of games, but they did not experience frequent reward and therefore might not have created an expectancy about GAA. Debriefing interviews with non-fans suggested that by the second block of Experiment 2 they were selecting randomly.

In Experiment 3, instructions and reinforcement through experiencing a high percentage of reward were combined to investigate the expected differences in FRN amplitudes between fans and non-fans when they experienced a strong deviation in outcomes from expectancy. To achieve that, the first part of Experiment 3 was designed to reinforce both fans and non-fans' expectancy about GAA as a strong predictor of outcomes of games by exposing them to a 75% chance of winning a trial when they selected the team with the low GAA. To fans, the 75% chance of winning reinforces their long-held expectancy about GAA, while to non-fans; the 75% chance of winning creates and reinforces an expectancy about GAA as a statistic that helps predict the outcomes of games. Thereafter, the strong deviation from expectancy is introduced by rewarding the selection of the team with low GAA on only 50% of trials. This 50% winning probability constitutes a deviation from the long-held expectancy that fans have acquired about GAA over the years; whereas to the non-fans, it is a deviation from an expectancy that they have acquired by performing the task.

It was expected that the results of Experiment 1 would be replicated in the first part of this experiment, with no differences found in FRN amplitudes between fans and non-fans. A 25% probability of a team with low GAA losing to a team with higher GAA is not a strong deviation from expectancy to both fans and non-fans. To fans, this 25% probability is somewhat expected, while to non-fans, this 25% probability matches the instructions that there given about the GAA stat. Therefore, FRN amplitudes were expected to be equally large for loss trials and win trials for both fans and non-fans when the team with low GAA was selected. On the other hand, FRN amplitudes were expected to be larger for fans compared to non-fans in the second part of this experiment where the probability of winning a trial was set to 50%. This probability is a strong deviation from fans' expectancy about GAA that is created through years of following the game and is stronger than non-fans' expectancy that was created through instructions and reinforcement. As for the P300 in the first part of the experiment, it was expected that loss trials would elicit larger P300 amplitudes for both fans and non-fans than win trials since they were infrequent (Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1977). In the second part, P300 was expected to show a similar trend to Experiment 2, where amplitudes are not different for win and loss trials since they were equally frequent (Campbell et al., 1979).

Method

Apparatus.

The apparatus was identical to Experiments 1 and 2.

Participants.

Forty-one right-handed Wilfrid Laurier University undergraduate students (24 females) participated for class credits through PREP. Participants' ages ranged between 18-23 (*M* = 19.1, *SD* = 1.82), with 21 fans and 20 non-fans. Data from two participants were excluded due to excessive EEG artifacts, resulting in data from 39 participants to be included in the analysis (23 females, *M* = 19.2, *SD* = 1.83), with 21 hockey fans and 19 non-fans. All participants signed a consent form explaining the type of data recording that is used in experiment, potential risks, and other related issues as required by the Research Ethics Board at Wilfrid Laurier University.

Procedure and Design.

Those were similar to Experiments 1 and 2, except for the following changes. First, the two blocks of irrelevant information in Experiments 1 and 2 were replaced with two blocks of relevant information (see Figure 1A), resulting in a total of 400 trials of relevant information. Due to this manipulation, each of the 200 unique trials that were used once in Experiments 1 and 2 were used twice in Experiment 3. This was done by randomly allocating the trials among the 4 blocks by using an online randomizer (http://www.randomizer.org) in a way that a trial was never repeated within the same block, and each trial was repeated only twice throughout the experiment. The second change in Experiment 3 was the manipulation of the winning probabilities between the first and the second part of the experiment. The winning probability in the first two blocks (first part) was set to 75% if participants selected the team with the lower GAA on each trial. While in the last two blocks (second part), the winning probability was set to 50% if participants selected the team with the lower GAA on each trial. Participants were not told about the winning probabilities and that the trials were actual NHL hockey games that were selected at random. Participants were also not told that there were two parts to the experiment, and they were given the same instructions as in Experiment 2 (see Appendix C).

ERP recording and analysis.

The recording and analysis was similar to Experiments 1 and 2, except for the exclusion of the outcomes that are related to the irrelevant information condition. Therefore, grand amplitude averages for four outcomes in each part of the experiment were created: select low GAA and win (low_win), select low GAA and lose (low_lose), select high GAA and win (high_win), and select high GAA and lose (high_lose). Since participants rarely selected the teams with the high GAA, final analysis included the two outcomes of (low_lose) and (low_win) in each part. Similar to Experiments 1 and 2, the number of trials in each outcome of (low_lose) and (low_win) in both parts was down-sampled to the number of trials in the outcome with the least number of trials across the two parts.

Statistical Analysis.

The extracted peak amplitudes for FRN were subjected to a repeated-measures ANOVA using SPSS (version 19.1, IBM Corp.), with hockey expertise (fan vs. non-fan) as the between-subjects factor, and part of the experiment (part 1 vs. part 2) and outcome (wins vs. losses) as the within-subjects factors. The extracted P300 amplitudes were also subjected to the same type of analysis using the same factors as in the FRN analysis.

Results

Behavioural results.

Fans in the first part of the experiment selected the team with the lower GAA on 95% of trials, while in the second part they selected the team with the lower GAA on 93% of trials. On the other hand, non-fans in the first part of the experiment selected the team with the lower GAA on 94% of trials, while in the second part they selected the team with the lower GAA on 89% of trials. Also, see *Table 3* for the average number of accepted trials before and after down sampling.

Condition	Average number of accepted trials after down sampling	Average number of accepted trials before down sampling
Low-Win (Part1)(Part2)	(37.8)(37.8)	(113.8)(65)
Low-Loss (Part1)(Part2)	(37.8)(37.8)	(37.8)(61.1)

Figure 18: Number of accepted trials before and after downsampling in Experiment 3

FRN Amplitudes.

A 2 (Group: fans vs. Non-fans) X 2 (Outcome: wins vs. Losses) X 2 (Block: block 1 vs. bock2) RM-ANOVA yielded a main effect of outcome F (1,37)= 16.58, p < .0001, indicating that loss trials elicit larger FRN amplitudes (*M*= -.401, *SD*= .474) compared to win trials (*M*= 1.393, *SD*= .470). The ANOVA also yielded a main of block F (1,37)= 19.9, p < .000, indicating that trials in the first part of the experiment elicited larger FRN amplitudes (*M*= -.111, *SD*= .435) compared to trials in the second part (*M*= 1.102, *SD*= .443). Interaction between outcome and block did not reach significance F (1,37) =.229, p = .635. (See Figures 19, 20 & 21).

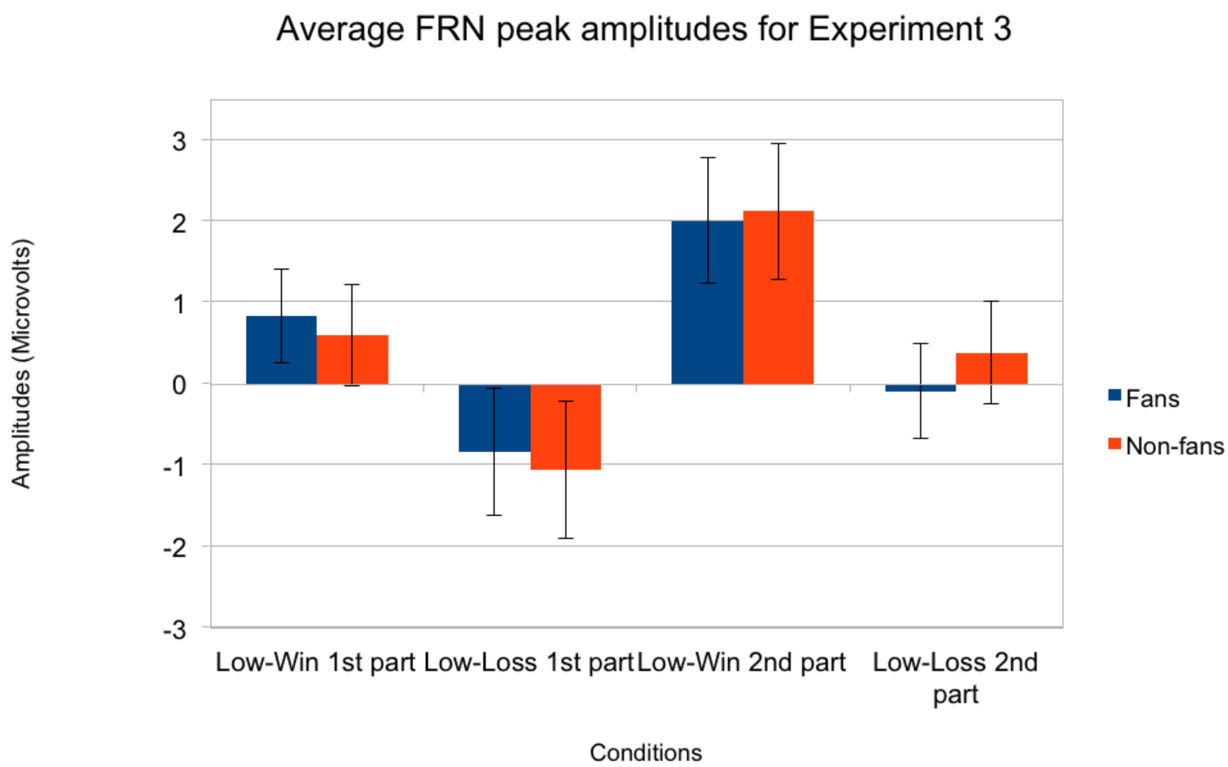

Figure 19: FRN average amplitudes in Experiment 3
Bars represent the standard error.

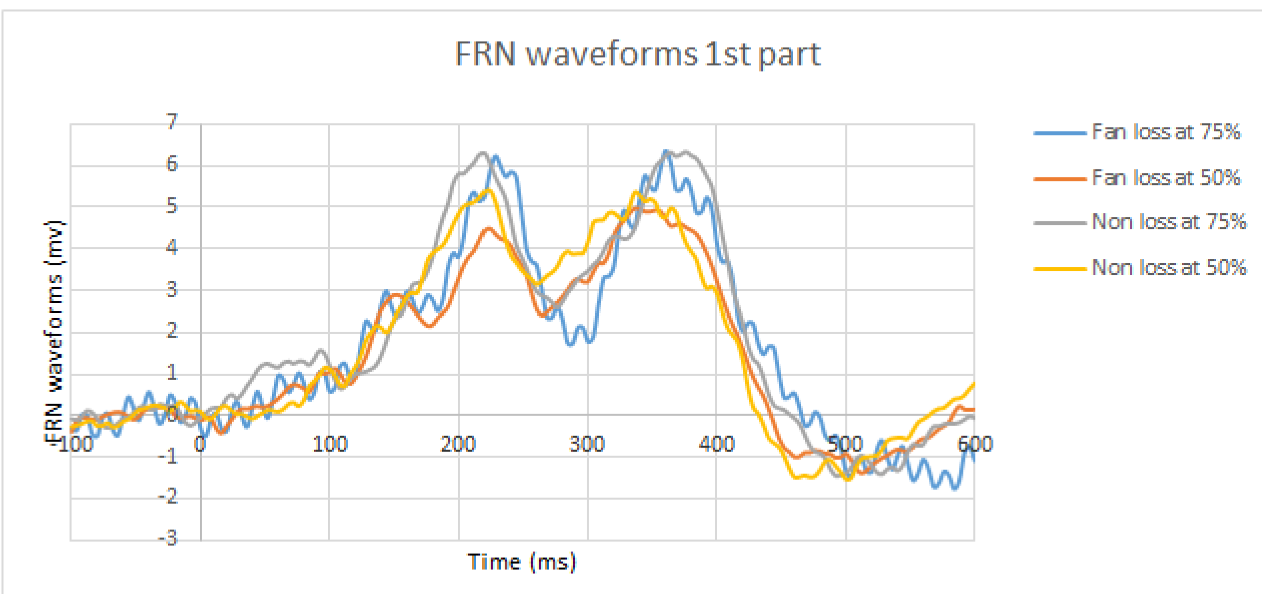

Figure 20: FRN average waveforms for losses in Experiment 3

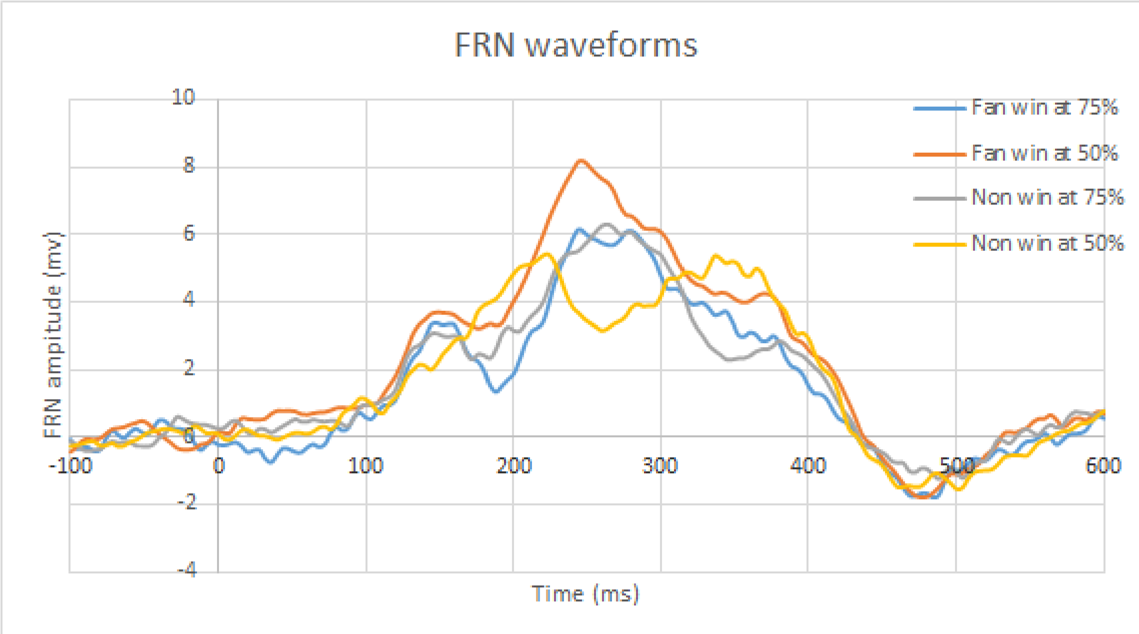

Figure 21: FRN waverforms for wins in Experiment 3

P300 Amplitudes.

A 2 (Group: fans vs. Non-fans) X 2 (Outcome: Wins vs. Losses) X 2 (Block: block 1 vs. block2) RM-ANOVA yielded a main effect of outcome *F* (1,37)= 14.772, *p* < .000, indicating that loss trials elicited larger P300 amplitudes (*M*= 7.718, *SD*= .601) than win trials (*M*= 5.187, *SD*= .475). Contrary to what was expected, a main effect of block did not reach significance *F* (1,37) = .737, *p* = .396. (See Figures 22,23 & 24)

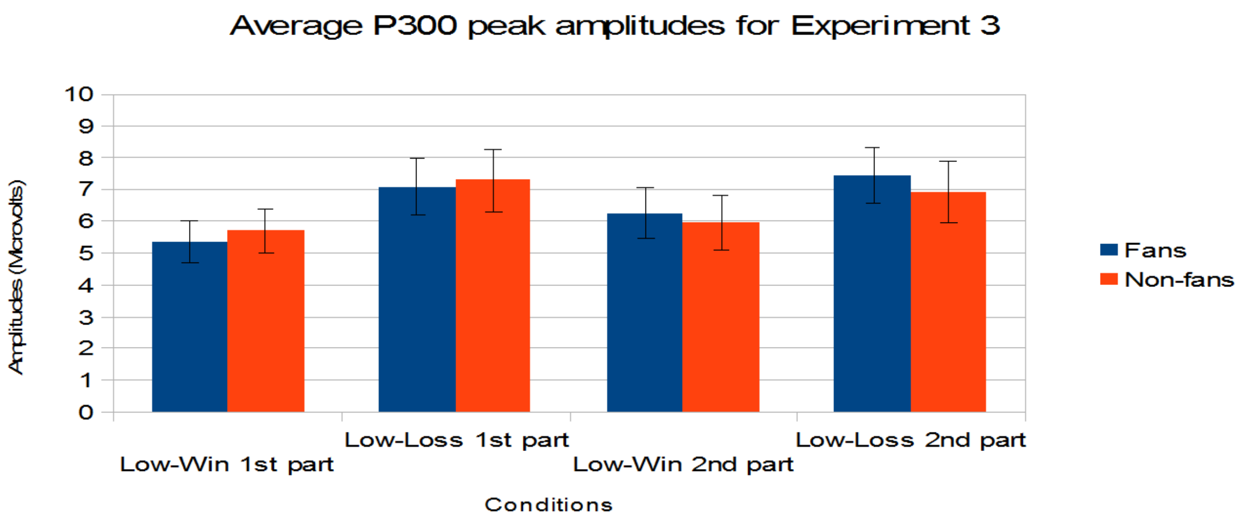

Figure 22: P300 average amplitudes in Experiment 3
Bars represent the standard error.

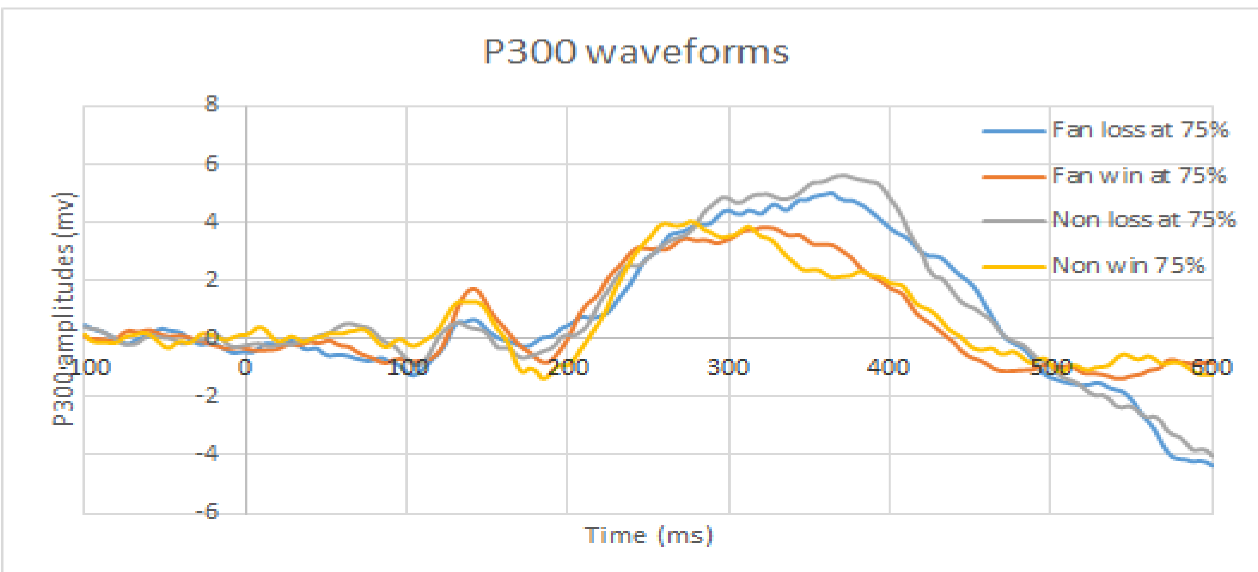

Figure 23: P300 average waveforms for part1 of Experiment 3

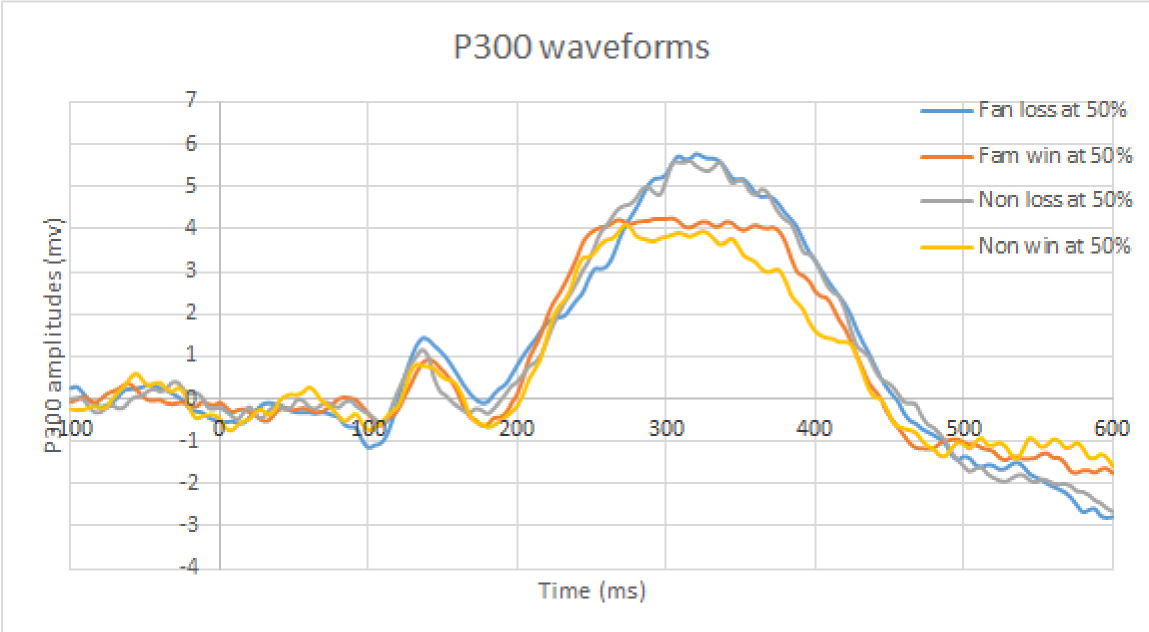

Figure 24: P300 average waveforms for part 2 of Experiment 3

Discussion

Experiment 3 was designed to further investigate the expected differences in FRN in response to a deviation from a long-held expectancy in fans compared to a deviation from an expectancy that is developed by performing the task in non-fans. Results of Experiments 1 and 2 showed trends suggesting that the type of irrelevant information that was used might have had unwanted effects on the relevant condition. Therefore, Experiment 3 excluded the irrelevant information condition to remove these possible effects. In addition, Experiment 3 addressed the issue of lack of control over the expectancies about GAA that fans and non-fans based their decisions on in Experiments 1 and 2. In Experiment 1, non-fans were not given instructions about GAA, but they experienced high reward of 75% and selected the team with the lower GAA on the majority of trials. In Experiment 2, non-fans were given instructions about GAA, but they did not experience high reward and trended towards selecting the team with the lower GAA less frequently than fans. Therefore, in the first part of

Experiment 3 both groups were given instructions about GAA and had their expectancy about GAA reinforced by experiencing a 75% win probability when the team with the lower GAA was selected. Thereafter, both groups experienced a strong deviation from expectancy at 50% win probability and at this win probability; differences in FRN were expected to emerge.

FRN results showed: first, effects of outcome valence on FRN for both fans and non-fans, larger amplitudes in response to loss compared to win trials. These effects were observed under the 75% reward probability in the first part and under the 50% reward probability in the second part. Second, no differences between fans and non-fans in either part, FRN amplitudes were similar in response to loss trials when the team with the lower GAA was selected. Third, FRN amplitudes were larger in the first part of the experiment compared to the second for both fans and non-fans.

Both fans and non-fans showed effects of outcome valence on FRN as amplitudes were larger in response to loss trials compared to win trials in both parts of the experiment. These effects were observed independently of the reward probability. Loss trials elicited larger FRN amplitudes where the reward probability was at 75% in the first part of the experiment and in the second part where the reward probability was at 50%. Moreover, these effects were also observed despite the overall lower FRN amplitudes in the second part of the experimental session. Similar to Experiments 1 and 2, effects of outcome valence on FRN seem to be robust regardless of reward probability. Regardless of the experimental circumstances, loss trials are unfavourable outcomes and elicit larger FRN amplitudes (Cheng et al., in preparation; Gehring & Willoughby, 2002; Holroyd & Coles, 2002; Miltner et al., 1997). Oliveira et al (2007) argued that loss trials always elicit larger FRN amplitudes since loss trials also deviate from participants' expectancy of winning. They showed that larger FRN amplitudes can also be elicited in response to win trials that deviate from participants' expectancy when participants expected a loss and received a win instead. However, it was not possible to test whether FRN reflects deviation from expectancy regardless of the valence of outcomes in Experiment 3 since participants rarely selected the team with the higher GAA.

Results of Experiment 3 did not show differences in FRN between fans and non-fans in either the first or second part of the experimental session. Both fans and non-fans had the expectancy of receiving a win when the team with the lower GAA was selected to beat the team with the considerably higher GAA. Fans have this long-held expectancy as a result of following the game of hockey for years and experiencing such results. On the other hand, non-fans have a general bias that statistical information is a strong predictor of outcomes of games (Wood, 1992; Woodland & Woodland, 2001). They also developed an expectancy about GAA as they received instructions about GAA prior to the experiment and experienced high reward in the first part. Therefore, it was expected that when the team with the lower GAA was selected and the result was a loss, larger FRN amplitudes would be observed as a reflection that this outcome deviated from both fans and non-fans' expectancies. However, based on the results of Experiment 1, no differences were expected in FRN amplitudes between fans and non-fans in response to a loss trial in the first part of Experiment 3. That is because fans indicated that a 25% chance of a team with lower GAA losing to a team with higher GAA is somewhat expected in the game of hockey. At the same time, instructions in Experiment 3 stated that in the game of hockey the team with lower GAA is not expected to beat the team with the considerably higher GAA every time, but is likely to do so. Therefore, both fans and non-fans had expectancies that a 25% probability of receiving a loss trial when selecting the team with the lower GAA is likely. The results showed no differences between fans and non-fans in FRN amplitudes when the team with the lower GAA was selected and a loss trial was the outcome.

Both fans and non-fans showed similar FRN amplitudes in response to loss trials when the team with the lower GAA was selected in the second part compared to the first part. In fact, both fans and non-fans showed even smaller FRN amplitudes in the second part of the experiment compared to the first. The differences in FRN between fans and non-fans were expected to emerge in the second part of the experiment. The 50% probability of receiving a win when the team with the lower GAA was selected is a strong deviation from the expectancies that both fans and non-fans hold about GAA. However, it was expected to elicit larger FRN amplitudes among fans compared to non-fans since it was a deviation from a long-held expectancy compared to a deviation from an expectancy that was developed by non-fans as they performed the first part of the experiment. Results of Experiment 3 did not provide support to this hypothesis.

However, it has been suggested that when individuals learn a representation, the reliance on external feedback is reduced and FRN is reduced as a result (Van Meel & Van Heijningen, 2010). Behavioural data provide some support to this explanation, as both fans and non-fans continued to select the team with the lower GAA on the majority of trials in the second part despite winning on only 50% of trials. This suggests that both fans and non-fans were basing their decisions on the expectancy that lower GAA is the correct choice in the second part and they might have relied less on outcome feedback. P300 results provide some support to this explanation, as both fans and non-fans showed larger P300 amplitudes in response to loss compared to win trials in the first part of the experiment as was expected since loss trials were infrequent. However, and contrary to what was expected, they continued to show larger P300 amplitudes in response to loss trials in the second part despite the fact that loss and win and loss trials were equally frequent. This suggests that both fans and non-fans were still operating by the reward probability that was reinforced in the first part, and perhaps failed to detect the change in reward probability in the second part. Less attention towards feedback makes it harder to detect the possible differences in FRN between fans and non-fans.

As for P300, the first part of Experiment 3 yielded the expected effects of outcome probability. P300 amplitudes were larger in response to loss trials compared to win trials for both fans and non-fans. This was expected since loss trials were the infrequent stimuli compared to win trials (Donchin & Coles, 1988; Johnson & Donchin, 1977; Nieuwenhuis, 2011). These results replicate those in Experiment 1, where the winning probability was set to 75% as well. According to the context-update hypothesis by Donchin and Cole, (1988) larger P300 amplitudes in response to infrequent stimuli represent increased attentional resources towards these stimuli in order to create internal representations about the reward probability, adapt to the reward probabilities and maximize reward. Both fans and non-fans in the first part of the experiment allocated greater attention towards loss trials as they were the infrequent stimuli in order to create a representation that winning is the more frequent outcome when the team with the lower GAA was selected.

However, results in the second part of the experiment, where the winning probability was set to 50%, did not yield the expected results. P300 amplitudes were expected not to show effects of outcome valence as win and loss trials were of equal frequency (Campbell et al, 1979). P300 amplitudes were still larger in response to loss trials compared to win trials for both fans and non-fans. As mentioned earlier, these larger P300 amplitudes in response to loss trials suggest that both fans and non-fans were allocating greater attention towards loss trials despite the fact that they were as frequent as win trials. Therefore under the circumstances of Experiment 3, FRN and P300 show a similar pattern in response to outcome valence in both parts of the experiment for both fans non-fans; larger amplitudes in response to loss trials compared to win trials.

Limitations

There are a few possible explanations for why no differences in the FRN amplitudes were found between fans and non-fans in response to relevant information were not supported. First, it is possible that the GAA statistic was simple to learn. The GAA statistic represents the average number of goals a team allows into their net and the lower the GAA a team has, the less goals they allow and the higher the likelihood of winning games. This characteristic of the lower the statistic the higher the likelihood of winning is found in a number of popular sports that most individuals have exposure to. For example, in soccer the lower the average number of goals a team allows, the higher the chance it has of winning and in baseball the lower the average number of runs a pitcher allows the higher the likelihood of that pitcher winning the game. Therefore, the concept behind the GAA statistic might have not been foreign to non-fans and that could have possibly made it easy for them to apply this concept to the GAA and adapt to the task. This quick learning among non-fans could have affected the FRN in response to loss trials and the failure to observe differences between fans and non-fans as a result. This is especially a challenge since it is difficult to measure FRN and investigate possible differences over the first a few trials within an experimental block where FRN amplitudes might show the highest differences between fans and non-fans.

Another possible limitation is the 50% probability of receiving a win when the team with the lower GAA was selected might have been unrealistic. In Experiments 2 and 3 the 50% probability was meant to serve as a strong deviation from fans' expectancy about GAA and differences in FRN amplitudes between fans and non-fans were expected to be observed. However, this low probability might have been unrealistic and did not reflect what GAA normally predicts in hockey. As a result, fans might have paid less attention to outcome feedback and FRN amplitudes might have not reflected the true response to outcomes that deviate from expectancy. Future research can use win probabilities that represent a strong deviation from fan's expectancy, yet still realistic and do not deter fans from paying attention to outcome feedback. Future research can also experiment with alternating between the 75% and 50% win probabilities if necessary. Since the 75% probability seems to be realistic to fans, future research can alternate between the two probabilities to prevent fans from paying less attention to the 50% probability. As a result, larger FRN amplitudes in response to deviation from expectancy might emerge in the 50% probability condition among fans compared to non-fans.

General Discussion

This thesis aimed to first find consistency with the general observation that FRN amplitudes are larger in response to loss outcome compared to win (Hajcak, Moser, Holroyd, & Simons, 2007; Holroyd & Coles, 2002; Miltner et al., 1997). The second aim of the study was to replicate the effect of information relevance on FRN that was found in Cheng et al. (in preparation). Cheng et al. found that a violation of expectancy involving relevant information elicited larger FRN amplitudes compared to irrelevant information. The third and more important aim of this study was to investigate whether hockey fans would show larger FRN amplitudes in response to a violation of expectancy with relevant information that is related to hockey compared to non-fans. Fans were expected to show larger FRN amplitudes when they select the team with the lower GAA to win a game and the outcome is a loss compared to non-fans. Fans were expected to show larger FRN because of their long-term knowledge about the game of hockey compared to non-fans who learned about GAA by performing the task. Some studies suggest that experts perceive and process information related to their domain of expertise differently than novices (Fattahi et al., 2015; Wright et al., 2013). To our knowledge, there has not been a study that investigates the differences in FRN between experts and novices. If differences do exist, then that would suggest that the level of experience or knowledge adds another factor that modulates FRN.

This study included three experiments that differed in the probability of winning a trial when the team with the lower GAA was selected. Experiment 1 had a 75% win probability with relevant and irrelevant information, Experiment 2 had a 50% win probability with both relevant and irrelevant and Experiment 3 had a 75% in the first part, 50% in the second part and relevant information only. All three experiments demonstrated the valance effect on FRN, larger FRN amplitudes for loss trials compared to win for both fans and non-fans. This is consistent with the literature that the FRN signals unfavourable outcomes (Hajcak, Moser, Holroyd, & Simons, 2007; Holroyd & Coles, 2002; Miltner et al., 1997). The effect of information relevance was expected to be found in Experiments 1 and 2 for both fans and non-fans. Despite the lack of knowledge among non-fans about GAA, statistical information was expected to have more relevance attached to it and larger FRN amplitudes in response to a loss were expected in the relevant condition. However, the effect of information relevance was found only among fans in Experiment 1, larger FRN amplitudes in the relevant condition compared to the irrelevant. This suggests that at least among fans and under a high win probability of 75% a loss when the lower GAA was selected is a bigger surprise than a loss in the irrelevant condition. As for the main hypothesis of larger FRN amplitudes for fans compared to non-fans, results trended in the predicted direction in all three experiments, but no support was found. Limitations in the current study were discussed above and future studies can investigate the differences in FRN between fans and non-fans by addressing those limitations.

However, there was an unexpected finding in this thesis that might provide future directions and add to the literature of FRN and decision making. The unexpected finding was that non-fans showed larger FRN amplitudes in response to loss trials in the irrelevant condition compared to fans. This finding was unexpected given that team names in the irrelevant condition were unknown to both fans and non-fans and which team won the trial was programmed at random. However, non-fans indicated that they tried to find patterns in the irrelevant condition to base their decisions on, while fans did not seem to try to base their decisions on any patterns. This finding could imply that since non-fans perceive themselves as non-experts in hockey; they might try to treat irrelevant information as a predictor of outcomes of games. Sports betting involves a number of information that is irrelevant in predicting outcomes of games that could affect response to outcomes among individuals who are or perceive themselves as non-experts. For example, horseracing tickets include information that can be used to predict horses' performance (i.e. lifetime winning percentage) and other information that is not predictive (i.e. horse coat color or the name of the horse). Future research can investigate the possible effects of irrelevant information on the way relevant information is processed among novice individuals and the overall effects on decision making.

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