<u>Conditioned-stimulus-elicited emotion and outcome expectation have dissociable effects on reward seeking, and are differentially affected by personality: implications for addiction</u>

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Declaration

I hereby declare that this thesis has not been, and will not be, submitted in whole or in part to another University for the award of any other degree.

Signature:

Acknowledgements

In order of appearance:

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Preface

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SUMMARY

A better understanding of the psychological mechanisms underpinning addiction will facilitate its remediation. Some evidence suggests that the emotional properties of drug-paired stimuli themselves drive drug-procurement, while other evidence indicates that the expectation of reward elicited by the stimuli is sufficient to control drug-seeking. The current series of experiments aimed to explicate these seemingly contradictory data, by characterising the roles played in reward seeking by conditioned-stimulus-elicited emotion and expectation in non-dependent samples, before assessing their contribution in smokers. Further data suggest a role of personality in addictive behaviours, thus personality was assessed as a moderator of reward-seeking. Variations of a Pavlovian-to-instrumental transfer design, which tests the ability of reward-associated stimuli to modulate reward seeking, together with questionnaires of personality were applied. It was shown that outcome expectation was consistently necessary for cue-potentiated monetary-reward seeking, and similarly in smokers, cigarette outcome expectation was sufficient for cue-potentiated cigarette-reward seeking. Tentative evidence for the role of conditioned-stimulus emotional value in monetary-reward seeking was found, although this latter result requires scrutiny through additional research. Moderating influences of Extraversion and Neuroticism were found for cue-elicited emotion and outcome expectation, respectively. It is therefore proposed that reward expectancy is necessary for conditioned stimuli to control behaviour. The emotional properties of reward-predictive stimuli may be important for reward seeking in the absence of addiction, but when addiction to reward is present, control of reward seeking can occur via reward expectation only. Data from the role of personality, in moderating the effects of stimulus-elicited emotion or outcome expectation on reward-seeking behaviour, suggest that the control of behaviour by emotion may be facilitated by Extraversion, due to its propensity towards emotional processes, whereas control by expectation may be facilitated by Neuroticism, due to its inclination towards predictive learning.

1 General introduction

1.1 List of abbreviations and glossary

A	Agreeableness
C	Conscientiousness
CC	Counter-conditioning
CS	Conditioned stimulus. Refers to a percept predictive of a reward encountered in a Pavlovian context
CS_+	CS predictive of 50p
CS-	CS predictive of winning nothing
$CS_\pm$	CS non-predictive
CS_{50}	CS predictive of 50p
CS_{10}	CS predictive of 10p
$CS_{10/50}$	CS non-predictive
CS discrimination	Difference between predictive cues (e.g. CS_+ - CS-)
Cue-potentiation	Difference between predictive and non-predictive cues (e.g. CS_+ - $S_\pm$)
E	Extraversion
HA	Harm-Avoidance
LiCl	Lithium-Chloride
N	Neuroticism
NEO	NEO-Personality Inventory-Revised
NS	Novelty-Seeking
O	Openness
O (an)	Outcome. Refers to a reward encountered in an instrumental context.
P	Persistence
PIT	Pavlovian-to-instrumental transfer
R	Response. An instrumental response
RD	Reward-Dependence
RI	Response initiation. Percentage of trials where a response was made
RR	Response rate. Number of responses per second
S	Stimulus. Refers to a percept encountered in an instrumental context
$S_\pm$	Non-predictive grey square from instrumental training
TCI	Temperament & Character Inventory
US	Unconditioned stimulus. Refers to a reward encountered in a Pavlovian context

1.2 Theories of reward-seeking behaviour

Addiction is associated with substantial negative effects (World Health Organisation, 2004, 2009), yet current therapy remains only partially effective (Agboola, McNeill, Coleman, & Bee, 2010; Knapp, Soares, Farrel, & Lima, 2007; Rosner et al., 2010), necessitating that treatment for this disease is improved. In order to establish effective protocols for the prevention and cure of addiction it will be necessary to understand the psychological mechanisms underpinning the disease. But in order to recognise which processes have become pathological it will be necessary to characterise these same processes prior to the development of dysfunction (de Wit & Dickinson, 2009; Hogarth, Balleine, Corbit, & Killcross, 2013). Thus an understanding of 'normal' behaviour directed at obtaining non-drug rewards will provide a model with which to calibrate 'pathological' behaviour directed at obtaining drug-rewards. Once such calibration and comparison has taken place it will be possible to identify and target any aberrant functions, making treatment more effective, efficient, and extensive.

1.2.1 Foundations of contemporary learning theories

The psychological study of learned behaviour began (Berridge, 2000) with the intuitively appealing notion that animals behave as they do because they are either *satisfied* or *annoyed* with the result (Thorndike, 1898). Subsequent theories founded themselves in comparatively objective terms, due to the rising scepticism of the scientific rigour of subjective measurement (Fancher, 1996), describing behaviour in terms of a direct association between environmental stimulus and response (Thorndike, 1911; Watson, 1913). Later formulations of this concept attempted to *explain* behaviour, rather than simply *describe* it, by positing that the association between stimulus and response (S→R) was reinforced by the ability of the result of an action to *reduce* drive (Hull, 1943). For example, a food stimulus elicits an eating response because the resultant calories reduce hunger, thereby reinforcing the food→eating association.

However, drive reduction theories could only account for a subset of an organism's behavioural repertoire, especially those where no explicit reinforcement had been experienced, thus later associative accounts returned to a mediating role of positive subjective states in explaining stimulus-elicited responses. Parallel theories developed, espousing the importance of either the hedonic (Bindra, 1974) or predictive (Bolles, 1972) psychological processes recruited by reward-paired stimuli, with a later formulation stating the co-occurrence of these two systems (Toates, 1986). While contemporary learning theories of behaviour have offered more detailed frameworks (de Wit & Dickinson, 2009; Everitt & Robbins, 2005; Hommel, Masseler, Aschersleben, & Prinz, 2001; Robinson & Berridge, 1993), they all build on the foundations laid by these earlier works (Berridge, 2000).

1.2.2 Negative reinforcement is not necessary for instrumental behaviour

Although the explanatory power of associative theories remains (de Wit & Dickinson, 2009; Everitt & Robbins, 2005), the idea that associations are reinforced by drive *reduction*, or negative reinforcement, has held less favour (Glautier, 2004). A number of experimental manipulations have dissociated negative reinforcement from the propensity to seek reward. For example, Miller, Kessen, and colleagues (Berkun, Kessen, & Miller, 1952; Miller & Kessen, 1952) compared the behaviour of hungry rats who were rewarded either with the ability to drink milk normally, or with infusions of milk directly into their stomachs. The authors found that those allowed to drink normally ate less in a subsequent consumption test, and learned the location of the reward faster, than those given milk directly. Both groups experienced the same dose of milk, thus the hunger-reducing component was balanced, yet those able to taste the milk exhibited a greater degree of reinforcement. Thus negative reinforcement appeared insufficient to explain the results, though it may still have been necessary, as the rats able to taste the milk also experienced its hunger-reducing properties.

However, an experiment showing the reverse dissociation, where rats were allowed to taste food but not experience its nutritional content, suggests that negative reinforcement is neither necessary nor sufficient to influence behaviour. Bedard & Weingarten (1989) used a sham feeding procedure where hungry rats were able to consume sucrose, yet not retain it in their stomachs. Thus they experienced the appetitive taste of sucrose, but not its aversive state reducing capacity. Despite this lack of negative reinforcement, the rats' cumulative consumption continued to rise over the session, thus physiological hunger-reduction was not necessary to sustain feeding behaviour.

Although these studies attest to the lack of effect of negative reinforcement in naturalistic behaviours, such as feeding and foraging, whether they retain their significance when applied to *instrumental* behaviours, i.e. those that have to be explicitly trained, requires further evidence. Such evidence is provided by the serendipitous finding by Olds and Milner (1954) of areas of the brain that, when stimulated electrically, would maintain a novel behaviour. The pair implanted electrodes into the septal area of rats before allowing them free access to a lever that, when pressed, would result in electrode stimulation at the implantation site. Olds and Milner observed high rates of pressing, with one rat amassing nearly 2000 presses in one hour, which appeared unrelated to the reduction of any aversive state. The rats were given free access to food and water, and appeared non-distressed by the experimental procedure, leading the researchers to conclude that the site of activation was responsible for the bringing of pleasure, rather than the removal of pain. Thus this experiment lends further support to the notion that *learned* behaviour, not just instinctive behaviour, can be supported by its ability to experience reward, rather than escape punishment.

Though these collective findings do not contradict the role of negative reinforcement in *all* learned behaviour, they do at least reduce its domination of learning theory, and lend support to the idea that many behaviours are elicited because they are instrumental in gaining something appetitive, not avoiding something aversive. But while this line of evidence attests to the *consequences* of action, more work is needed to clarify the *causes*.

1.2.3 Conditioned-stimuli are necessary for instrumental behaviour

A common thread throughout contemporary learning theory is the involvement of environmental events that have been paired with reward, referred to as *conditioned stimuli* (CSs). Even the overly reductionist theories of Thorndike, Watson, and Hull (Hull, 1943; Thorndike, 1911; Watson, 1913) had at their core the notion that responses were elicited by CSs. However, where those early explanations concerned themselves simply with observable S→R associations, and the role of rewards as reinforcers thereof, these simplistic accounts could not capture the gamut of experimental evidence. Thus while CSs were necessary for something, exactly what required further exploration.

Bolles (1972) argued that CSs were necessary for behaviour because they activated an *expectation* of their associated reward, which in a syllogistic manner then activated its associated instrumental response. Such a hypothesis was predicated on a number of observations that defied explanation in pure reinforcement terms. For example, Tolman (1948) reported that rats allowed to explore a maze initially did so in a non-directed manner, characterised by numerous excursions down dead-ends. However, immediately after finding food in the maze the rats became noticeably more purposive, navigating straight to the food with few errors. Such behaviour appeared far sooner than would be expected by simply S→R explanation, leading Tolman to suggest that the rats had developed a cognitive representation of the maze and its food location.

While Tolman's findings suggested that rats could represent their surroundings, and expect reward in a particular location, whether such expectation was elicited by a particular CS required additional data. Bolles (1972) reported a number of behavioural studies that attested to the role of reward expectation in behaviour, at the expense of reinforcement, that were directly associated with CSs. Such behaviours were broadly referred to as 'autoshaped' due to the apparent self-reinforcement of responding. Such autoshaping was manifested in animals who would interact with a CS, such as a light that was paired with food delivery, despite food delivery being non-contingent on any such interaction. Furthermore, Jenkins & Moore (1973) showed that such interactions were tailored to the available reward, in that when the reward was food animals would demonstrate eating behaviour, whereas when it was water they would engage in drinking patterns. Thus autoshaping was elicited by the CS, and was specific to the US (reward), which Bolles interpreted as indicating that the CS had activated an *expectation* of its associated reward, which in turn initiated an appropriate response.

But contemporaries of Bolles, for example Bindra (1974), questioned the sufficiency of reward expectation in provoking instrumental responding. It had previously been suggested by Konorski (1967) that CS→US associations recruited parallel processes, one cognitive the other emotive, which represented a given reward in terms of its sensory identity and hedonic value, respectively. While Bolles had concentrated on the sensory aspect giving rise to expectancy, Bindra proposed that both forms of representation were necessary, with the value division preparing an organism to respond, and the identity division specifying the form of response. But Bindra went further, arguing that the CS usurped these dissociable properties of the US such that it was attributed with them itself, to the extent that it became a target of consummatory behaviour. Thus the autoshaping results described above occurred not because the animal simply expected reward, but considered the CS as reward. Such predictions find favour in the results of sign-tracking experiments (Flagel, Akil, & Robinson, 2009), where animals will interact with a cue predictive of reward, even at the expense of consuming the reward itself.

However, Bindra's essay implied that the hedonic property of the CS was locked to its history with the US. Thus if the initial CS→US association had formed when the organism valued the US, e.g. if they were hungry and it were food, then the CS would be imbued with an intransigently high hedonic value which should elicit later reward-seeking even if the US were no longer valued, e.g. if they were full. Evidence refuting this intransigence claim led Toates (1986) to reformulate Bindra's ideas to take into account the changing value of the CS. Such reformulation led from a series of experiments by Cabanac (1979; Cabanac & Lafrance, 1990) that investigated the effects of food satiety on taste reactivity. Cabanac showed that the appetitiveness of sucrose taste, i.e. a CS for calorific reward, was reduced after participants became increasingly sated by an intra-venous dose of sucrose. Thus as the value of the US changed, so did the value of the CS, a process termed alliesthesia. The reverse had also been demonstrated, with pleasantness reactions to salt taste being increased by salt deprivation (Berridge, Flynn, Schulkin, & Grill, 1984). This latter study also reported that the change in reaction to oral salt infusion occurred on the first trial of taste reactivity, thus any change in its hedonic value could not be attributed to re-learning the CS→US association. These data therefore suggested to Toates that the hedonic value of a CS could change, in line with the hedonic value of its US, but independent of direct experience with the US.

1.2.4 CS hedonic value may be necessary for instrumental behaviour

1.2.4.1 Manipulating CS hedonic value influences reward-seeking

While the changing value of CSs appears to be a consistent result, the influence of CS value on behaviour appears less consistent. Potential support came from a series of experiments described by Holland (1990) who manipulated the hedonic value of a CS predictive of food reward. Rats were given access to sucrose containing one of two flavours (US_1 and US_2), before these two flavours were paired with two tones (CS_1 and CS_2), respectively. US_2 was then devalued by pairing it with lithium chloride (LiCl) induced illness, before behavioural tests involving the two CSs were conducted. Holland reported that appetitive taste reactions to unflavoured sucrose were reduced in the presence of CS_2 compared to CS_1, in keeping with the taste reactivity studies of Cabanac (1979; Cabanac & Lafrance, 1990) and Berridge (Berridge et al., 1984) above, but went further to describe that *consumption* of sucrose was also reduced by CS_2. Such an effect was not due to an aversion to US_2 itself, because the unique flavour of US_2 was absent in the consumption test, thus it appeared that the reduced hedonic value of CS_2 was responsible for the reduced feeding behaviour.

Support for the translation of this interpretation into humans comes from similar results from Van Gucht and colleagues (Van Gucht, Baeyens, Hermans, & Beckers, 2013; Van Gucht, Baeyens, Vansteenwegen, Hermans, & Beckers, 2010). These authors paired one of two visual CSs (a red or white tray; CS_+ and CS-) with either eating or not eating a chocolate US. They found that this initial acquisition stage developed differential hedonic reactions to the two CSs, with participants rating the CS_+ as more pleasant than the CS-. Van Gucht and colleagues then targeted a devaluation procedure at the CS_+ itself, crucially in the absence of the chocolate US, by pairing it with a bitter solution. This led to the reversal of pleasantness ratings such that the CS+ was now rated less pleasant than the CS-. When chocolate was reintroduced to the scenario, participants exposed to this devaluation procedure ate less in the presence of the CS_+ compared to participants who had undergone the same procedure but without experiencing the bitter solution. Thus the changing value of the CS, distinct from that of the US, was concordant with a change in behaviour.

However, the above studies concentrated on conditioned behaviours, i.e. those that resemble a natural response to a US, thus potentially limiting their generalisation. But expansion of the range of behaviours, from conditioned to instrumental, potentially influenced by CS hedonic value comes from an experiment by Tunstall and colleagues (Tunstall, Verendeev, & Kearns, 2012). The researchers trained rats that pressing a lever in the presence of either a light or tone (CS_1 or CS_2) would deliver cocaine. CS_1 was then devalued, in the absence of cocaine, by pairing it with footshock. Subsequent responding on the lever, again in the absence of cocaine, was reduced in the presence of CS_1 compared to CS_2. Although Tunstall et al did not include measures of CS hedonic value, in combination with the data of Holland (1990) and Van Gucht & colleagues (Van Gucht et al., 2013; Van Gucht et al., 2010), their results indicate that the changing value of a CS is matched by changes in instrumental responding.

1.2.4.2 Reward identity influences reward-seeking

But while these data suggest that CS hedonic value *may* be necessary for instrumental behaviour, they cannot claim that it *is* necessary, because they cannot rule out the role of expectancy. The use of rat participants, as with Holland (1990) and Tunstall et al (2012), renders measures of expectancy difficult, and the study of human participants, as with Van Gucht et al (2013; 2010), confirms that changes in CS hedonic reactions are confounded by changes in US expectancy. Thus while this confound does not itself rule out CS hedonic value as a necessary criterion for instrumental behaviour, Bolles (1972) prediction that reward expectation is sufficient to enable behaviour remains.

Indeed, the sufficiency status of reward expectancy in mediating the causal link between CSs and instrumental responses holds favour with contemporary theory and research of learned behaviour. But the essence of exactly what is expected remains unclear. Ideomotor accounts propose, as their class name may suggest, that the idea of an action's consequence is sufficient to generate that action (Hommel et al., 2001). Such a consequence representation may take purely perceptual form, such that the mere sight, sound, or smell of response outcome may prime its associated response (Ansorge, 2002; Elsner & Hommel, 2001; Fedoroff, Polivy, & Herman, 1997). For example, Elsner & Hommel (2001) trained participants that pressing the left key of a response box elicited a low tone, whereas pressing the right key elicited a high tone. The authors then played either tone during a free response-choice test phase, finding that either tone biased responding towards its associated response.

But this result does not necessarily rely on an *expectation* of an outcome, merely an *experience* of an outcome. However, CSs have been shown to have a similar response-priming effect (Colwill & Rescorla, 1988; Hogarth, Dickinson, Wright, Kouvaraki, & Duka, 2007; Prévost, Liljeholm, Tyszka, & O'Doherty, 2012), in keeping with their ability to produce reward expectation as predicted by Bolles (1972). For instance, a study by Hogarth and colleagues (Hogarth et al., 2007) involved participants learning to expect two rewarding outcomes (money or cigarettes) after presentation of two visual cues (two different shapes), respectively, before learning two instrumental responses (pressing 'D' or 'H') to obtain the same outcomes. In a test phase containing the cues and responses, yet not outcomes, each cue selectively biased response choice towards that associated with the common outcome. The fact that no outcome was present during the test phase, i.e. the test was conducted in extinction, necessitated that any behavioural effect was due to an expectation of reward, rather than an experience of reward.

Furthermore, a later study by Hogarth (2012) confirmed that this biasing effect was due to a sensory expectation, by showing that each cue continued to bias responding despite one of the outcomes being devalued by satiety. In a similar experimental setup, participants learned the same keypress responses, this time for chocolate or cigarettes, before consuming one of the outcomes to satiety. This satiety-driven devaluation treatment was followed by a test phase where pictures of either outcome, serving as CSs, were presented while participants emitted instrumental responses, again in the absence of the actual outcomes. Despite the devaluation procedure, both pictures were equally able to bias responding towards seeking their depicted outcome. Although Hogarth only measured the hedonic value of the chocolate or cigarette rewards, rather than their pictorial CSs, if it is taken that the process of alliesthesia (Cabanac, 1979) caused CS value to drop concomitantly with reward value, then Hogarth's results can be interpreted as showing that CS hedonic value was not necessary to control instrumental responding, rather sensory expectancy of reward was sufficient.

Such a chain of events can be represented as an S→O→R process (de Wit & Dickinson, 2009), where a stimulus (S; perception of a CS) activates the sensory representation of its outcome (O; expectation of a reward), which in turn activates its response (R; instrumental reward-seeking). Such an S→O→R process has been shown to depend on the sensory representation of an outcome, but be autonomous from the value representation, by multiple studies akin to that by Hogarth (2012) described above (Colwill & Rescorla, 1990; Hogarth & Chase, 2011; Holland, 2004). Yet Dickinson and colleagues (de Wit & Dickinson, 2009; Dickinson & Balleine, 1994) propose an alternative route by which environmental stimuli may affect instrumental responding that is sensitive to reward value.

1.2.4.3 Reward hedonic value influences reward-seeking

Instead of a stimulus gaining direct access to an outcome representation as in the S→O→R model, Dickinson and colleagues suggest that the stimulus activates thoughts of potential response options, which in turn activate thoughts of their respective outcomes, which themselves feed back to elicit an instrumental response. Thus the model is represented by an S→R→O chain. As well as changing the order of mental events compared to the S→O→R model, Dickinson and colleagues add that the feedback from outcome representation to instrumental response elicitation is governed by the expected value of the outcome. This has the effect of facilitating a response when its associated outcome is valued, e.g. responding for food when hungry, while inhibiting a response when its associated outcome is not valued, e.g. responding for food when full. Such value-sensitive S→R→O behaviour is referred to by Dickinson and colleagues as goal-directed, while its value-insensitive S→O→R counterpart is referred to as autonomous.

The contention that the R→O portion of the model is goal-directed is well supported (Adams & Dickinson, 1981; Colwill & Rescorla, 1985; Dickinson & Balleine, 1994; Hogarth, 2012). For example, in a test of R→O goal-directedness, Colwill & Rescorla (1985) trained rats to lever press or chain pull for either sucrose or food pellets, respectively. One or other outcome was then devalued by pairing it with nausea, before a test of instrumental responding was conducted in extinction. Goal-directed behaviour was confirmed by the rats' selective reduction of the response that was trained with the now devalued outcome; the response trained with the non-devalued outcome was unaffected. Thus rats' change in behaviour was sensitive to an expectancy of the identity as well as the value of the outcome.

However, the form of this value expectation is suggested to be more cognitive than emotional (Berridge, 2000; de Wit & Dickinson, 2009), and appears to rely on direct experience with the newly valued outcome rather than automatic update after value manipulations. This reliance on experience is illustrated by a paradigm deployed by Dickinson colleagues (Dickinson & Balleine, 1994, 1995; Dickinson, Balleine, Watt, Gonzalez, & Boakes, 1995) which measured instrumental responding after manipulating the level of experience rats had with a reward. Hungry rats were first trained on a single lever-press response to receive food pellets, establishing a high value for food. One group was then given free access to a maintenance diet, whereas the other group remained food-deprived, before both were re-exposed to the pellets previously earned by lever-pressing. Thus the non-deprived group experienced the new low value of pellets, whereas the deprived group continued to experience a high value. All animals were then given access to their maintenance diet, before instrumental responding was tested in extinction. Despite the physiological value of pellets being low for all animals, only those given experience of this low value during re-exposure demonstrated a reduction in lever-pressing. The authors interpret these data as suggesting that goal-directed responding, although controlled by *some* representation of outcome value, is controlled by a *cognitive* representation of the value, based on prior experience, rather than an *emotive* representation, based on current physiological state.

1.2.4.4 CS hedonic value augments reward-seeking

Yet evidence for the activation of such goal-directed behaviour by *conditioned* stimuli, i.e. those directly predictive of rewarding outcomes rather than rewarded responses, remains tentative (Corbit, Janak, & Balleine, 2007; Dickinson & Dawson, 1987; Holland, 2004). Instead, evidence for goal-directed behaviour following a CS may be better explained by a model denoted S[R→O]. In this S[R→O] architecture the S (a conditioned stimulus for reward) does not have direct access to the R, and so cannot *prime* a response, but rather may *augment* an already initiated response. The level of this CS-induced augmentation is predicted to track O value (Robinson & Berridge, 1993; Toates, 1986), but, in contrast to the reliance on experience of a reward's value demonstrated under isolated R→O conditions (Dickinson & Balleine, 1994, 1995; Dickinson et al., 1995), may be immediately sensitive to changes in reward value via the process of alliesthesia (Cabanac, 1979).

Showing support for S[R→O] sensitivity to current reward value, Dickinson & Dawson (Dickinson & Dawson, 1987) trained hungry rats to associate a clicker or a light CS with pellets or liquid sucrose reward, respectively. In a separate training session the rats learned to make a single lever-pressing response to receive both pellets and liquid sucrose. Rats were then switched from a state of hunger to thirst, thus switching the relative balance of value from pellets to liquid sucrose, but were not re-exposed to the rewards in this new state. In support of value sensitivity, when tested in extinction the thirsty rats pressed at a higher rate when presented with the sucrose cue than with the pellet cue. An S→O→R explanation, i.e. behaviour mediated by an expectation of the outcome, is precluded because each cue was equally predictive of its reward. An S→R→O explanation is also ruled out, because rats were able to alter their behaviour without re-learning the value of each reward. Thus an S[R→O] explanation appears most parsimonious, with behaviour augmented by the increased value of the liquid sucrose cue over the pellet cue.

However, the fact that CS and response shared an outcome in the Dickinson & Dawson paper precludes comment on the ability of a CS to have a general effect on a response via an S[R→O] process. It may have been that any response augmentation was specific to that which obtained the outcome predicted by the stimulus. But if all that is required of the CS is for it to possess hedonic value (Toates, 1986) then it should influence an ongoing response regardless of whether CS and response share an outcome (Corbit & Balleine, 2005; Corbit et al., 2007).

Such a general effect of CS hedonic value is demonstrated by Corbit and colleagues (Corbit et al., 2007) using a method that removes the possibility of a CS augmenting a specific instrumental response. The authors trained free-feeding rats to associate three CSs (S1-3; tone, white noise, clicker) with three rewards (O1-3; sucrose, polycose, pellets), respectively, in one phase, then trained the rats to make two instrumental responses (R1&2; left/right lever press) to gain two of the rewards (e.g. sucrose, polycose), in a second phase. Thus S3 was associated with O3, but had no corresponding R3, and so could not have a specific response-augmentation effect. Rats were then tested in extinction on their rate of R1&2 pressing in the presence of S1-3, under conditions of continued satiety and then conditions of hunger. Under satiety, response augmentation was specific, i.e. S1 augmented R1, and S2 augmented R2, but S3 had no effect. However, under hunger, where the hedonic value of the outcome had been increased, S3 enacted an augmentation of both R1&2 indiscriminately, thus demonstrating a general energisation of instrumental responding. Furthermore, this general energisation was sensitive to changes in outcome value, brought about by physiological state changes, without requiring direct experience of the outcome's value in that new state.

Corbit and colleagues' data are therefore suggestive of the effects of conditioned-stimulus hedonic value on instrumental reward-seeking proposed by Bindra (1974) and Toates (1986), in that it would be predicted that the increase in S3 hedonic value would be in line with the increase in O3 hedonic value (Cabanac, 1979). But such a prediction is not verified by Corbit and colleagues' method, because the authors did not measure the hedonic value of the CS directly, thus their results should be more cautiously interpreted as showing a behavioural sensitivity to *reward* value rather than *CS* value.

Yet a series of experiments by Holland (2004) provide converging evidence that Corbit and colleagues' (Corbit et al., 2007) result may not be directly dependent on reward value, leaving open the possibility of behavioural control by CS value. Holland investigated the effects of extended instrumental training on the ability of CSs to control responding, when animals had experienced either one or two rewards. Rats in the single reward group experienced a tone CS paired with a pellet reward, before learning a lever-press response to receive pellets. Rats in the dual reward group experienced a tone and a white-noise CS paired with pellets and sucrose, respectively, before learning a lever-press and a chain-pull response to receive pellets and sucrose, respectively. Half of the animals in each group received minimal instrumental training, whereas the other half received extended instrumental training. Following training, all rats received a reward devaluation manipulation whereby one or other outcome was repeatedly paired with nausea. They were then tested in extinction for the effects of the CSs on responding.

Results showed a dissociation between the single and dual reward groups. Extended training facilitated the response augmentation of the CS in the single reward group, though had little effect on CS augmentation in the dual reward group, who showed an augmentation only when CS and response had a common reward. Furthermore, extended training reduced the devaluation sensitivity of rats in the single group, though had less of an effect on devaluation sensitivity in the dual group.

Holland's (2004) data may be interpreted, albeit tentatively, as indicating that the behaviour of animals in the single reward group was more amenable to CS augmentation of *general* responding than animals in the dual reward group, who displayed more CS augmentation of *specific* responding. The differential effect of extended training on the two groups highlights the different process recruited by the single and dual reward conditions. The dual condition, due to its demonstration of a response-specific effect, may have relied on an S→O→R process, whereas the single condition, if dissociated from the dual condition and therefore not S→O→R, may have relied more heavily on S[R→O]. Moreover, if the single reward condition, characterised by S[R→O] responding, became increasingly less sensitive to current outcome *value*, yet became increasingly more sensitive to CS *presentation*, as training was extended, it may have been that these shifts in performance were underpinned by the increasing control of CS hedonic value.

While such a conclusion requires direct evidence, it finds favour with theories of maladaptive reward seeking (Hogarth et al., 2013; Robinson & Berridge, 1993), such as addiction, and so may provide a viable model with which to compare reward-seeking for natural rewards with seeking of addictive rewards.

1.2.5 Theories of addiction

Just as CSs are argued to play a pivotal role in natural reward-seeking (Bindra, 1974; Bolles, 1972; de Wit & Dickinson, 2009; Toates, 1986), so too are they theorised to control behaviour in addiction. However, whereas natural reward-seeking is amenable to the checks and balances offered by the multiple routes of CS-elicited behaviour outlined above, addiction is characterised by a loss of control of behaviour such that its consequences, e.g. job loss, relationship breakdown, health deterioration, appear to have little influence. Instead, it is argued that drug-paired stimuli exert a powerful influence on behaviour, to the extent that natural-reward-seeking processes become usurped in favour of drug procurement (Altman et al., 1996; American Psychiatric Association, 2000; Robinson & Berridge, 1993; Stewart, de Wit, & Eikelboom, 1984).

Similar to the early theories of natural reward-seeking, early accounts of addiction offered explanations involving aberrant negative reinforcement (Koob & Moal, 1997; Wikler, 1973). But these also failed to account for the available data, primarily the finding that small doses of a drug could elicit drug seeking (Stewart et al., 1984). Such doses, and other CSs associated with subsequent drug effects, are subjectively rated by users as pleasurable (Geier, Pauli, & Mucha, 2000), thus questioning the necessity of negative states in initiating drug seeking.

1.2.5.1 Habit theory

Thus positive reinforcement theories now dominate the addiction literature (Berridge, 2000; Glautier, 2004; Stewart et al., 1984). One such theory, taking its lead from the apparent loss of outcome value representation in addicts, explains addiction as a pathological reliance on habitual behaviours, with the hedonic value of addictive drugs causing especially potent reinforcement of S→R associations (Everitt & Robbins, 2005). Thus responding is directly initiated by drug-paired stimuli, with no influence of outcome representations. Such a hypothesis is supported by data indicating that drugs such as alcohol and cocaine can facilitate the development of habitual responding (Dickinson, Wood, & Smith, 2002; Miles, Everitt, & Dickinson, 2003). For instance, Dickinson and colleagues (Dickinson et al., 2002) trained rats to press two levers to receive either ethanol or pellets. One of the outcomes was then devalued by LiCl pairing, before rats were returned to instrumental responding conditions in extinction. Rats devalued on pellets demonstrated goal-directed behaviour by reducing their press-rate on the pellet lever, but rats devalued on ethanol demonstrated autonomous responding by continuing to press for ethanol as they had done during training. Similar data is provided where cocaine or amphetamine was used in place of ethanol (Miles et al., 2003; Nordquist et al., 2007), thus attesting to the propensity of addictive drugs to encourage habit processes.

However, although S→R processes may dominate under some conditions, the case for habit formation in human addicts remains to be proven (de Wit & Dickinson, 2009; Hogarth & Chase, 2011). For example, although smokers report a tendency for habitual cigarette use which correlates with their level of nicotine dependence (Russell, Peto, & Patel, 1974), laboratory tests suggest that smoking can be goal-directed (Hogarth & Chase, 2011; Hogarth, Dickinson, & Duka, 2010). In a paradigm analogous to the ethanol study of Dickinson and colleagues (Dickinson et al., 2002) above, Hogarth & Chase (2011) trained humans smokers to perform two novel instrumental responses (keyboard presses) for either cigarettes or chocolate, before devaluing one or other reward via satiety. In the subsequent extinction test, participants reduced responding for the devalued outcome, regardless of whether it was cigarettes or chocolate. Similarly, in a more naturalistic setting, Hogarth and colleagues (Hogarth et al., 2010) allowed smokers to inhale normally while reporting their craving to smoke before each puff. The authors found that as the session progressed the rate of inhalation subsided, with the number of puffs consumed across the session predicted by subjective craving for nicotine. Thus using both novel and natural instrumental smoking responses demonstrates a sensitivity to the value of nicotine, evidenced by the shift in choice following devaluation, the reduction in puffing across time, and the correlation with craving (a subjective proxy for outcome value (Tiffany, 1990)).

1.2.5.2 Expectancy theory

Nevertheless, while the human smoking studies of Hogarth and colleagues (Hogarth & Chase, 2011; Hogarth et al., 2010) attest to the goal-directed nature of smoking under free choice conditions, the presentation of a cigarette-paired CS was still able to augment nicotine-seeking, even after devaluation, in these experiments. But rather than lend support to S→R theory, these results instead lend support to expectancy theory (Brandon, Herzog, Irvin, & Gwaltney, 2004; Goldman, 1999; Hogarth & Duka, 2006), in that only participants who reported an expectation of receiving reward displayed an influence of a CS on responding. A series of studies from Hogarth and colleagues (Hogarth et al., 2007; Hogarth & Duka, 2006) attests to the necessity of reward expectation in CS controlled cigarette-seeking, with a review by Hogarth & Duka (2006) extending the requirement of expectation from instrumental responding to conditioned responding, such as the ratings of pleasure, craving, and arousal, attributed to smoking cues.

Although these quasi-experimental investigations of expectancy are merely indicative of its necessary status, experimental manipulation of expectancy confirms its importance in drug-seeking (B. L. Carter & Tiffany, 2001; Hogarth et al., 2014; Juliano & Brandon, 1998). Providing information about cigarette availability influences the magnitude of cigarette craving and seeking. Smokers report increased urges to smoke, and reduced latencies to reach for a cigarette, when verbally instructed that smoking is allowed (B. L. Carter & Tiffany, 2001; Juliano & Brandon, 1998). Additionally, providing availability information in the form of drug CSs also alters instrumental responding for drugs. Hogarth et al (2014) demonstrated that a drug-predictive cue would increase drug-seeking behaviour, but that degrading the relationship between cue and drug abolished its control over drug seeking. Thus, to the extent that availability cues and instructions increase expectancies, targeted manipulation of expectancy bears a causal effect on drug-related responses.

Furthermore, the nature of expectancy is alluded to by the differential success of Pavlovian versus instrumental extinction used by Hogarth et al (2014). Whereas degrading the S□O relationship had little effect on subsequent instrumental responding controlled by the S, degrading an S□R□O relationship reduced S control of a subsequent R. Thus the conclusion from these availability experiments may be that 'expectancy' refers to an increased likelihood of response utility, rather than simply an increased likelihood of outcome existence.

But these data on expectancy may be more broadly relevant to reward learning in general , rather than specifically explaining a unique component of addiction. However, adjunct theories of addiction propose that the expectancies generated in addicts by drug-paired cues are distinct from those generated in non-addicts, thus suggesting a pivotal role of expectancy in addiction. For example, Marlatt and colleagues' cognitive-behavioural model of relapse prevention ascribes particular importance to combating 'positive outcome expectancies' (Hendershot, Witkiewitz, George, & Marlatt, 2011; Witkiewitz & Marlatt, 2004). These positive expectancies are argued to mediate the relationship between 'high risk situations', i.e. environments paired with drugs, and subsequent relapse. Moreover, empirical evidence suggests that chronic drug use amplifies these positive expectancies, more potently than natural rewards, thus indicating a pathological process specific to addiction (Kirchner & Sayette, 2007; Lopez-Vergara et al., 2012; Martens & Gilbert, 2008; Wardell, Read, Colder, & Merrill, 2012).

However, any amplification of positive expectancies by abused drugs may target the *positive* aspect differentially to the *expectancy* aspect. While the positivity of outcome representations may increase (Kirchner & Sayette, 2007), the awareness of outcome representations may in fact decrease (Robinson & Berridge, 1993; Tiffany, 1990). Thus 'expectancy' may not be an explicit, conscious, representation of either drug availability or response utility, but instead be an implicit network of Pavlovian associations and motor programmes. Therefore, although initial reward-seeking may be under conscious control, the development of addiction may coincide with a progressive increase in positive outcome representations, yet a concomitant decrease in awareness of these representations. Indeed, Lamb and colleagues (1991) report that low doses of morphine are sufficient to sustain instrumental responding but do not produce subjective effects different from placebo. Thus their participants continued to seek morphine despite not knowing whether they would receive drug or placebo.

1.2.5.3 Incentive-sensitisation theory

Such a result has therefore led other researchers in the addiction field (Robinson & Berridge, 1993; Tiffany, 1990) to propose that addiction-related behaviours can occur in the absence of conscious knowledge of their consequences. Yet rather than support the assertion of habit theory (Everitt & Robbins, 2005) that addiction is characterised by a *loss* of outcome representation, Robinson & Berridge (1993) propose that addiction is better explained by the *gaining* of a hyper-valued outcome representation. Moreover, the pair argue that this hyper-valuation is transferred to drug CSs, via the process of alliesthesia (Cabanac, 1979), such that CSs are able to control behaviour independent of a conscious representation of the value of the drug itself (Berridge & Robinson, 1995). But in contrast to theories of natural reward, which emphasise the *hedonic* component of value, Robinson & Berridge suggest that drugs sensitise the *motivational* component of value. Thus they argue that pathological drug-seeking occurs because CSs activate a 'wanting' for the drug, rather than a 'liking' of the drug. Although during the initial stages of drug use the hedonic and motivational components of reward may be equally represented (Drevets et al., 2001), after chronic exposure the motivational component begins to dominate via a process of incentive-sensitisation, such that hedonic processes become decoupled from drug seeking.

Such a claim is supported by experiments from Wyvell & Berridge (2000, 2001) who showed that chronic amphetamine treatment was able to potentiate motivated responding without influencing hedonic reactions. Rats were trained to press a lever to receive sucrose, before associating a tone CS with sucrose in the absence of lever-pressing. They were then given six days of amphetamine exposure, before being given an extinction test of lever pressing in the presence of the CS. Compared to control rats who received saline instead of amphetamine, the experimental rats showed increased pressing in the presence of the CS, but not in the absence of the CS. They also showed no differences in a test of sucrose taste reactivity designed to measure hedonic responses. Rats were tested in a drug-free state, thus any effects were due to chronic administration rather than acute substance effects. Furthermore, increased responding was concentrated only in periods when the CS was present, thus the behavioural effect was attributable to the CS and not due to general locomotor activity. Additionally, the hedonic taste reactivity test showed no differences between amphetamine- and saline-treated animals, thus the differential instrumental response effect was not due to differences in hedonic value attributed to sucrose.

However, although Wyvell & Berridge (2000, 2001) argue that CSs gain control of behaviour through motivational processes, and that drugs do not directly influence hedonic reactions to reward, they did not measure the hedonic reaction to the CS itself. Moreover, although the data from Lamb et al (1991), that addicts will work for morphine despite lack of subjective response to the drug, suggest that expectancy is not necessary for *instrumental* responding, it does not address whether expectancy is necessary for *CS-*

potentiated responding. The supporting data for Robinson & Berridge's (1993) theory is based largely on non-human studies, and so cannot adequately assess the role of expectancy in CS-elicited drug-seeking either.

Thus there remains a lack of conclusive evidence for the relative roles of hedonic, motivational, or expectancy responses in mediating CS-elicited reward-seeking and drug addiction. One explanation for this lack of consensus may be that each theory coexists (de Wit & Dickinson, 2009; Hogarth et al., 2013), yet presides over a specific situation depending on the unique dispositions of the organism under test (Cloninger, 1987). Indeed, individual differences in personality have been shown to influence addiction (Cloninger, Przybeck, Svrakic, & Wetzel, 1994; Costa & McCrae, 1992) and natural reward process (Avila, Parcet, Ortet, & Ibáñez-Ribes, 1999; Corr, Pickering, & Gray, 1995; Most, Chun, Widders, & Zald, 2005), and so present a viable target for explaining variation in experimental results.

1.3 Individual differences in addiction and learning

1.3.1 Personality predictors of addiction

Two broad-ranging questionnaires of personality, that have been widely used within addiction research, are the Temperament and Character Inventory (TCI, Cloninger et al., 1994) and the NEO-Personality Inventory-Revised (NEO, Costa & McCrae, 1992). While the TCI’s theoretical background stems from genetic analysis of phenotypic traits (Cloninger, 1987; Stallings, Hewitt, Cloninger, Heath, & Eaves, 1996), the NEO was developed through factor analysis of phenotypic traits (Costa & McCrae, 1992). Thus the two provide subtly different targets for addiction research, yet despite their differing developmental strategies both have provided promising avenues for future investigation (Piedmont, 2001; Pomerleau, Pomerleau, Flessland, & Basson, 1992; Ruiz, Pincus, & Dickinson, 2003). The TCI comprises four higher-order temperament domains of Novelty-Seeking, Harm-Avoidance, Reward-Dependence, and Persistence. The TCI's authors predict that Novelty-Seeking represents a biological system involved in approach of reward, whereas Harm-Avoidance is a proxy for a system dedicated to avoidance of punishment. Reward-Dependence manifests an organism's sensitivity to social reward, with Persistence measuring the ability of an individual to maintain a response despite a lack of immediate reward. In contrast, the NEO's claims of its five higher-order factors are made in more social terms than the TCI's behavioural conception. Neuroticism reflects a propensity to experience and display negative emotion, contrasted with Extraversion which concerns itself with positive emotions. Openness reflects an individual's interest in novel experience, with Agreeableness primarily a dimension recording interpersonal dispositions. Finally Conscientiousness maps a person's ability to adhere to societal convention.

When administering the TCI to addict samples, a consistent finding is an elevated Novelty-Seeking score, relative to normative data from the manual, reported in smokers (Pomerleau et al., 1992; Wills, Vaccaro, & McNamara, 1994), alcoholics (Cannon, Clark, Leeka, & Keefe, 1993; Cloninger, 1987) and polysubstance abusers (Conway, Kane, Ball, Poling, & Rounsaville, 2003). This trait appears to relate to the initiation of drug taking more than the development of addiction, with Pomerleau et al (1992) finding a group-level elevation of Novelty-Seeking in smokers, but no correlation between Novelty-Seeking and dependence severity. Moreover, Conrod & colleagues (2008) report that interventions aimed at sensation-seeking, a moderately correlated trait (Giancola, Zeichner, Newbolt, & Stennett, 1994), reduced the alcohol intake of binge-drinking adolescents at twelve month follow up. While the NEO does not group novelty-seeking traits under a single factor, it contains a lower-order excitement-seeking facet within the Extraversion factor. This excitement-seeking facet was found to correlate with drinking *frequency* but not drinking *problems* in a student sample (2003), and was found to be higher in recreational *and* pathological gamblers, relative to non-gambling controls (Bagby et al., 2007). Thus the data support the notion that novelty-seeking traits mediate an initial gate leading to addiction, but not addiction severity itself.

More pertinent to addiction itself, there is further overlap between the two questionnaires along their anxiety-related dimensions of Harm-Avoidance for the TCI, and Neuroticism for the NEO. The two factors are highly correlated (.7, Cloninger et al., 1994), with convergent findings from multiple researchers reporting significantly higher Harm-Avoidance and Neuroticism in addicted samples compared to controls (Bagby et al., 2007; Le Bon et al., 2004; Piedmont & Ciarrocchi, 1999; Pomerleau et al., 1992). Unlike Novelty-Seeking, this relationship appears more strongly related to addiction severity than the initiation of substance use. For example, Pomerleau and colleagues (1992) found that group-differences between smokers and controls were smaller for Harm-Avoidance, compared to Novelty-Seeking, but that Harm-Avoidance was the only factor to correlate with dependence severity. Moreover, Piedmont & Ciarrocchi (1999) report that opioid-dependent out-patients receiving cognitive therapy for their addiction exhibited reductions in Neuroticism over the course of treatment, with change in Neuroticism correlated with treatment efficacy. Additionally, Ruiz and colleagues (2003) report a greater correlation between Neuroticism and alcohol related problems than Neuroticism and drinking frequency in a student sample.

The suggestion that negative-affective traits engender addiction, rather than initiation of drug use, is further supported by the significant comorbidity found between drug addiction and obsessive-compulsive disorder, which is characterised by a similarly intractable pattern of behaviour (Trull, Waudby, & Sher, 2004). Notable overlap occurs between their personality profiles, with OCD sufferers also exhibiting higher N than the general population (Tackett, Quilty, Sellbom, Rector, & Bagby, 2008), as well as correlations between Harm-Avoidance and symptom severity measures (Ball, Tennen, Poling, Kranzler, & Rounsaville, 1997; Svrakic, Whitehead, Przybeck, & Cloninger, 1993).

Thus traits related to sensation-seeking may predict likelihood of initial drug exposure, whereas traits related to anxiety may be of greatest relevance to addiction severity. But while these epidemiological studies provide a description of drug addiction as characterised by negative-affect, they do not provide an explanation of why such a relationship between anxiety and addiction should occur.

1.3.2 Personality predictors of reward learning

Adding a deeper level of understanding of the involvement of personality in addiction-relevant behaviours are studies investigating the mediating roles of various traits on associative learning tasks. Their general synopsis has been that positive-affective traits facilitate appetitive elements of a task, whereas negative-affective traits facilitate aversive elements of a task (Avila et al., 1999; Corr et al., 1995). Such a summary accords with Cloninger and colleagues' (Cloninger, 1987; Cloninger et al., 1994) assertions that Novelty-Seeking and Harm-Avoidance represent systems of reward approach and punishment avoidance, respectively.

In support of Cloninger's assertions, Corr and colleagues (Corr et al., 1995) tested participants on a classical conditioning task where two different colour CSs (blue or purple) predicted two different monetary USs (winning or losing, respectively). After viewing the CS, participants were asked which of the ensuing USs they expected. The authors found that Reward-Dependence predicted the number of correct 'win' expectancies, whereas Harm-Avoidance predicted the number of correct 'lose' expectancies. Subtle differences were found in an instrumental task, where participants were instructed to follow a moving target on a computer screen with their finger, while the CSs from the conditioning task were intermittently presented. Participants were rewarded with money for following the target quickly on appetitive CS trials, or more slowly on aversive CS trials. Trait anxiety, as measured by the State-Trait Anxiety Inventory (Spielberger, 1983), predicted increases in reaction time on appetitive trials, whereas impulsivity, measured by the Eysenck Personality Scales (Eysenck & Eysenck, 1991), predicted decreases in reaction time on aversive trials. Trait anxiety correlates with Harm-Avoidance, whereas trait impulsivity correlates with Novelty-Seeking (Cloninger et al., 1994). Thus Corr & colleagues' results suggest that TCI traits show *intra*-valence *facilitation* of classical tasks, e.g. positive traits enhance positive outcome learning, yet *inter*-valence *inhibition* of instrumental tasks, e.g. negative traits suppress positive outcome seeking.

Similarly, Avila & colleagues (Avila et al., 1999) report that those with higher anxiety, as defined by the Sensitivity to Punishment Scale (Torrubia, Ávila, Moltó, & Caseras, 2001), had greater difficulty in learning to respond for a smaller immediate punishment in order to receive a larger delayed reward, compared to their lower anxiety peers. Measures of behavioural impulsivity and tolerance to delay were unrelated to performance, thus the authors concluded that trait anxiety reduced participants' ability to form an appetitive association, in accord with Corr & colleagues (Corr et al., 1995).

As well as moderating task learning, further investigations suggest personality also moderates hedonic value experience. Higher self-reports of benzodiazepine withdrawal symptoms are reported for those higher on Harm-Avoidance, whereas physiological measures of benzodiazepine reward, e.g. slowing of saccadic eye movements, correlate positively with Novelty-Seeking (Schweizer, Rickels, De Martinis, Case, & Garcia-Espana, 1998). Similarly, sensation-seeking correlates both with physiological (heart rate) and subjective (pleasantness) responses to acute alcohol intoxication (Brunelle et al., 2004).

Moreover, these results are extended from the experience of the reward itself to the CSs associated with it, in a study conducted by Most and colleagues (Most et al., 2005). The authors presented a rapid stream of images, each of 100ms duration, depicting affectively-neutral landscapes, and instructed participants to respond when they saw a rotated landscape. Interspersed in the visual steam were unpleasant images of, for example, violent crime, which participants were not informed of. Individuals scoring more highly on Harm-Avoidance showed a greater attentional bias for these aversive images, manifested in a slowing of reaction time to the target (rotated) images. Other measures of attentional bias have shown that increased CS gaze duration is associated with increased subjective CS aversiveness (Austin & Duka, 2010), thus the results of Most and colleagues (Most et al., 2005) may suggest increased negative value attribution to CSs from those higher in Harm-Avoidance. A related pattern of results is also demonstrated for NEO factors, with fMRI data showing a correlation between amygdala activity and Extraversion when viewing affectively positive images, in contrast to a correlation between middle temporal gyrus activity and Neuroticism when viewing affectively negative images (Canli et al., 2001).

Thus predispositions to positive affect, measured through e.g. Novelty-Seeking or Extraversion, have been shown to facilitate learning of appetitive tasks, as well as facilitate hedonic value attribution of appetitive CSs. Conversely, predispositions to negative affect, measured through e.g. Harm-Avoidance or Neuroticism, have been shown to facilitate learning of aversive tasks, as well as facilitate [negative] hedonic value attribution of aversive CSs. However, these data implicate personality in aspects of propositional learning, emotional processing, and instrumental responding, in comparative isolation to each other, thus the role of personality in tasks that engender a combination of learning, emotion, and responding requires further scrutiny.

1.4 Experimental protocols for the study of stimulus-elicited behaviour

1.4.1 Pavlovian-to-instrumental-transfer designs

One such experimental protocol that has been used extensively in the study of cue-potentiated behaviour is the Pavlovian-to-instrumental-transfer (PIT) design (e.g. Colwill & Rescorla, 1988, 1990; Corbit et al., 2007; Estes, 1943; Hogarth et al., 2007). The primary importance of the PIT paradigm is that it precludes an explanation for behaviour in terms of direct S→R performance (de Wit & Dickinson, 2009). This is achieved by separate phases of Pavlovian and instrumental training, such that stimulus and response never co-occur in the presence of reward, thus ensuring that no explicit S→R reinforcement process takes place. The PIT design is exemplified in a study conducted by Wyvell & Berridge (2001). The authors trained rats in a Pavlovian phase to associate the sound of a clicker (CS_+) with delivery of sucrose, and to associate the sound of a tone (CS-) with receiving nothing. In the instrumental phase, conducted in the absence of the CSs, the rats were trained to press a lever to receive sucrose. The test phase, where animals were presented with either CS and had the opportunity to press the lever, was conducted in extinction, i.e. without delivery of sucrose. The variable of interest in the test, or transfer, phase was the number of presses made during periods of CS_+, compared to CS- or inter-stimulus-interval (ISI), i.e. the PIT effect. In the case of Wyvell & Berridge this was a positive PIT effect, in that the CS_+ elicited more responses than either ISI or CS-.

The importance of the PIT procedure is that it narrows the number of associative mechanisms able to explain responding during the transfer phase. The extinction condition ensures, firstly, that no learning can occur during the test phase, thus preventing S→R reinforcement explaining behaviour. Secondly, it ensures that any influence of a CS on behaviour occurs via an outcome representation. Thus a PIT effect may occur via an S→O→R process, detailed in section 1.2.4.2 above, or an S[R→O] process, explained in section 1.2.4.4 above. PIT has been separated into *specific* and *general* forms, that may map onto S→O→R and S[R→O], respectively, which confer subtly different patterns of behaviour. The specific form appears to bias response *selection*, with CSs facilitating responses which gain the specific outcome predicted by the CS, whereas the general form appears to *augment* responding, with CSs facilitating responses regardless of outcome congruency.

In an example of specific PIT, Hogarth & colleagues (2007) trained participants to associate one geometric shape with winning cigarettes, and another shape with winning money. In the instrumental phase participants learned to press one key for cigarettes, and another key for money. Then in the transfer phase participants' response selection was tested in the presence of either cue. A specific transfer effect was found, in that the cigarette cue selectively increased the cigarette response, while decreasing the money response, with the opposite pattern shown for the money cue.

However, studies using a specific PIT paradigm have so far shown it to encourage insensitivity to reward hedonic value. These studies have demonstrated that inserting a devaluation phase after Pavlovian and instrumental training has no effect on the subsequent transfer phase, with the ability of CSs to bias responding towards their specific outcomes undampened (Colwill & Rescorla, 1990; Hogarth, 2012; Holland, 2004). Yet the methodological details responsible for this devaluation insensitivity remain to be explicated. One possibility, offered by Holland (2004), is that using rewards that influence different sensory modalities, such as cigarettes versus money, may bias response processes towards those directed by sensory activation, modelled by an S→O→R chain.

In contrast, the general form of PIT may be more amenable to hedonic value, with a select number of studies demonstrating sensitivity to devaluation procedures, suggesting the involvement of an S[R→O] mechanism (Corbit et al., 2007; Dickinson & Dawson, 1987). For instance, Corbit & colleagues (2007) used a modified PIT design that ostensibly combined both specific and general forms. In their Pavlovian phase rats associated three different auditory CSs (CS1-3) with three different food rewards (O1-3), respectively. In the instrumental phase rats learned two lever-press responses (R1-2) to earn two of the same food rewards (O1-2), respectively. Thus the third food reward (O3) had no associated response. The authors claimed that such a protocol would allow specific transfer to occur in the presence of CS1-2, yet only allow general transfer in CS3, because it could not cue a specific response. After a satiety devaluation procedure designed to reduce the value of all three foods, the transfer phase recorded specific transfer in the presence of CS1-2, yet no transfer in CS3. Rats that had not experienced devaluation showed augmentation of responding, compared to ISI, in the presence of all three CSs, with CS3 elevating both Rs equally. Thus specific transfer was insensitive to devaluation, while general transfer occurred only when rewards were valued.

Yet the precise situations that govern whether PIT is displayed require further explanation (Crombag, Galarce, & Holland, 2008; Holland, 2004; Lovibond, 1981, 1983). One aspect of relevance is the ability of the Pavlovian phase to endow CSs with differential hedonic value. Specific PIT studies, such as that of Hogarth & colleagues (2007), have used rewards of *equal* hedonic value, e.g. one cigarette versus its monetary equivalent, precluding the demonstration of differential responding on the grounds of differential CS value. General PIT studies, such as that of Corbit & colleagues (2007), *may* have shown an effect of CS value, but did not measure CS value, and so require further investigation.

1.4.2 Evaluative conditioning

Such investigation into CS hedonic value will involve procedures that encourage the displacement of hedonic value of the US onto the CS. Bindra (1974) argued that this was a corollary of a pairing procedure, but scrutiny of the process of evaluative conditioning (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010), where a CS is endowed with the hedonic qualities of its US, suggests certain criteria need to be met. Early reports of evaluative conditioning confirmed that CSs could acquire affective valence relatively easily (Baeyens, Eelen, van den Bergh, & Crombez, 1989). Baeyens & colleagues (1989) asked participants to sort a set of faces into liked, neutral, and disliked groups. Neutral faces were then paired by the researchers with either liked or disliked faces. After exposure to ten such pairs of neutral with liked or disliked faces, participants reported an increased pleasantness rating for initially neutral pictures paired with liked faces, yet a decreased pleasantness rating for neutral pictures paired with disliked faces. Thus the neutral face CSs had acquired the hedonic value of their valenced face USs. Participants later reported little understanding of the pairings, or the purpose of the experiment, leading Baeyens & colleagues to conclude that the process of evaluative conditioning had occurred outside of conscious awareness.

Yet such a claim of evaluative conditioning outside of awareness was later questioned in a review of the extant literature by Lovibond & Shanks (2002). The pair questioned the sensitivity of Baeyens & colleagues' awareness assessment on the grounds that post-experiment interviews were confounded by memory influences. While Lovibond & Shanks provided additional studies that had made similar claims of evaluative conditioning outside of awareness, all were described as containing insensitive measures of awareness. Thus although participants may have been unaware of any associations at the time of *awareness* assessment, they may have been aware at the time of *evaluative* assessment. In the context of nicotine conditioning, a review by Hogarth & Duka (2006) came to similar conclusions as Lovibond & Shanks, finding that only participants who expected a nicotine US after experiencing its CS showed an evaluative response. Thus it was concluded that expectancy awareness, i.e. the ability to expect a US after presentation of its CS, was a necessary criterion in the display of evaluative conditioning.

Yet these conclusions have been questioned more recently by a meta-analysis conducted by Hofmann & colleagues (2010). This analysis revealed that although evaluative conditioning was *facilitated* by propositional knowledge of CS-US pairings, i.e. conscious awareness of the relationship between the two, propositional knowledge was not *necessary*. Rather, reports of unaware evaluative conditioning were verified, with the strength of effect increasing with the number of CS-US pairings, and decreasing with the time delay between CS and US. Thus evaluative conditioning can occur in the absence of awareness, yet is more reliably found when participants have some degree of knowledge of the predictive properties of the CS. Such a conclusion may therefore allow for the study of CS hedonic value in participants who possess varying degrees of US expectancy.

The implications of the investigations into evaluative conditioning for future PIT designs are that, firstly, Pavlovian phases will elicit stronger evaluative conditioning effects with an increasing number of trials. Secondly, evaluative conditioning will be stronger if the delay between CS and US is reduced as much as is feasible. The most pertinent data from previous PIT research for future PIT designs are that, firstly, using rewards that increasingly share sensory properties may increase the influence of CS-hedonic value on any PIT effect. Secondly, any influence of CS-hedonic value may require reward expectation in order to influence a PIT effect.

1.5 Aims of the current series

The extant literature makes competing claims for the relative importance of emotion versus expectation in the control of human drug-seeking by conditioned stimuli. But in order to understand the pathological processes that are involved in addiction, it will first be necessary to characterise the same processes under non-addiction conditions. On the one hand, a growing literature indicates that emotional responses to reward-associated stimuli can occur in the absence of expectancy (Hofmann et al., 2010), and that such emotional responses may be able to influence reward-seeking (Corbit et al., 2007; Dickinson & Dawson, 1987). On the other, multiple PIT studies have shown a transfer effect only in participants who expect a reward (Bray, Rangel, Shimojo, Balleine, & O'Doherty, 2008; Hogarth et al., 2007; Talmi, Seymour, Dayan, & Dolan, 2008). Furthermore, personality research suggests that the ability of individuals to demonstrate emotional versus propositional responses to reward-associated stimuli is dependent on their propensity to experience negative or positive affect (Canli et al., 2001; Corr et al., 1995).

In light of this research, and the gaps that appear within it, the current body of work was designed to investigate four aspects of reward-seeking that require greater clarity:

1. The ability of the *hedonic value* of reward-paired cues to influence reward-seeking
2. The involvement of reward *expectation* in the effects of reward-paired cues on reward-seeking
3. The moderating role of *personality* in the influence of cue-elicited emotion or outcome expectation on reward-seeking.
4. The potential changes to reward-seeking processes that occur as a result of *addiction*.

2 General methods

2.1 Method

Methodological details common to all experiments of the current series are detailed here. Any differences between methods of an individual experiment and General Methods are specified at each experimental chapter; where no method information exists in a given chapter, details can be assumed to be the same as specified here.

2.1.1 Participants

Participants were University of Sussex students. They were recruited via an online participant database and were compensated for their time financially or with course credit. Recruitment continued until data had been collected from 32 participants (16 male) displaying awareness of the Pavlovian phase contingencies (see *Statistical analyses* below for the operational definition of 'awareness' used in the current body of work). Inclusion criteria were that English was their first language, and that they were in a state of good health, whereas exclusion criteria were that they were currently taking prescription medication (excluding the contraceptive pill), currently receiving treatment for a mental illness, or had a gambling problem. Participants gave written consent before beginning the study, with ethical approval granted by the University of Sussex Life Sciences ethics committee.

2.1.2 Materials

2.1.2.1 Behavioural tasks

The PIT task was run on a PC using E Prime v1.2 software, and displayed on a 50cm LCD screen. The display background during the task was always grey. CSs (see Figure 2.1.2.1[left]) were presented at a size of 10.2 cm^2 at a resolution of 1280 x 1024 pixels. Screen text was black Times New Roman font presented at point size 25. During Pavlovian training responses were recorded using a standard QWERTY keyboard. During instrumental training and transfer the keyboard was replaced by a five button serial response box, oriented such that the buttons were aligned along the sagittal axis. Only the button nearest the participant was active, and was coloured blue to highlight it. Throughout the experiment to the left and right of the response manipulandi was a metal box (height 23 mm, width 190 mm, depth 90mm) with its lid open. Inside the left box were 64 fifty pence coins. The right box was initially empty, but was labelled with "Your 50p box" (see Figure 2.1.2.1[right] for a schematic of the apparatus layout).

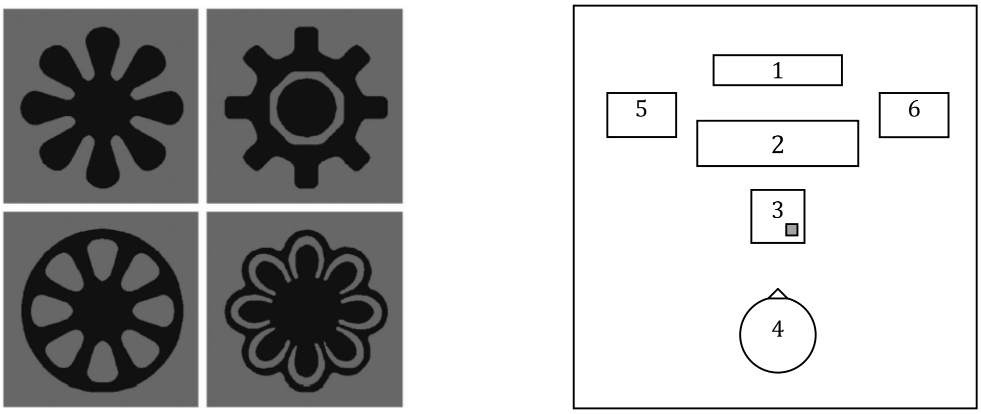

Figure 2.1.2.1. Left panel: stimuli (not to scale) used in Pavlovian and transfer phases of the experiment, roles counterbalanced. Right panel: layout of apparatus within cubicle, aerial view. 1 = LCD screen; 2 = keyboard; 3 = response box; 4 = participant; 5 = 50p coin box; 6 = participant's 50p winnings box. Note that 2 and 3 were both placed in the location of 2 - 2 during Pavlovian training, 3 during instrumental training and transfer.

2.1.2.2 Questionnaires

2.1.2.2.1 Personality

Two personality questionnaires were used – the NEO (Costa & McCrae, 1992) and the TCI (Cloninger et al., 1994). Each contains 240 self-report questions that measure multiple higher-order domains comprising lower-order facets. Both were administered on computer with responses given via a standard keyboard. The NEO comprises 5 factors - Neuroticism, Extraversion, Openness, Agreeableness, Conscientiousness, each comprising 6 facets. Each question is answered on a five-point Likert scale ranging from "strongly agree" through "neutral" to "strongly disagree". Participants responded by pressing a number key from 1 – 5 that corresponded with the five Likert anchors. The TCI comprises 7 domains – 4 temperament domains of Novelty-Seeking, Harm-Avoidance, Reward-Dependence and Persistence; and 3 character domains of Self-Directedness, Cooperativeness, and Self-Transcendence. Each domain, except Persistence, comprises multiple facets. Only scores on the temperament domains and facets were used in the current study. Each question is answered as "true" or "false"; participants responded accordingly by pressing the 'T' or 'F' key. See Table 2.1.2.1 for a list of the factors and facets for each questionnaire used in the current studies, along with a representative question for each.

Table 2.1.2.1. List of factors and their respective facets from each questionnaire, with an example question for each. Questions that are reverse-coded have had their wording changed in this table only for illustrative purposes, e.g. original question "I am rarely sad" reversed to "I am often sad".

Questionnaire	Factor	Facet	Question
NEO			
	Neuroticism		
		Anxiety	I often feel tense and jittery.
		Angry-hostility	I am known as hot-blooded and quick-tempered.
		Depression	I am [often] sad or depressed.
		Self-consciousness	I [often] feel self-conscious when I'm around people.
		Impulsiveness	I have trouble resisting my cravings.
		Vulnerability	I [fail to] keep a cool head in emergencies.
	Extraversion		
		Warmth	I'm known as a warm and friendly person.
		Gregariousness	I like to have a lot of people around me.
		Assertiveness	I am dominant, forceful, and assertive.
		Activity	My life is fast-paced.
		Excitement-seeking	I love the excitement of roller coasters.
		Positive-emotions	I am a cheerful, high-spirited person.
	Openness		
		Fantasy	I have a very active imagination.
		Aesthetics	Aesthetic and artistic concerns aren't very important to me.
		Feelings	I [often] pay attention to my feelings of the moment.
		Actions	I'm pretty set in my ways.
		Ideas	I have a lot of intellectual curiosity.
		Values	I consider myself broad-minded and tolerant of other people's lifestyles.
	Agreeableness		
		Trust	I believe that most people are basically well-intentioned.
		Straightforward	I couldn't deceive anyone even if I wanted to.
		Altruism	I think of myself as a charitable person.
		Compliance	I'm hard-headed and stubborn.
		Modesty	I try to be humble.
		Tender-minded	I would rather be known as "merciful" than as "just".
	Conscientiousness		
		Competence	I am efficient and effective at my work.
		Order	I tend to be somewhat fastidious or

			exacting.
		Dutifulness	I try to perform all the tasks assigned to me conscientiously.
		Achievement-striving	I'm something of a "workaholic".
		Self-discipline	I am a productive person who always gets the job done.
		Deliberation	I think things through before coming to a decision.
TCI			
	Novelty-Seeking		
		Exploratory-excitability	I like to explore new ways to do things.
		Impulsiveness	I usually think about all the facts in detail before I make a decision.
		Extravagance	I prefer spending money rather than saving money.
		Disorderliness	I often break rules and regulations when I think I can get away with it.
	Harm-Avoidance		
		Anticipatory-worry	I think I will have very good luck in the future.
		Fear of uncertainty	I often feel tense and worried in unfamiliar situations.
		Shyness	I often avoid meeting strangers because I lack confidence with people I do not know.
		Fatigability	I have less energy and get tired more quickly than most people.
	Reward-dependence		
		Sentimentality	I am more likely to cry at a sad movie than most people.
		Attachment	I like to discuss my experiences and feelings openly with friends instead of keeping them to myself.
		Dependence	I usually do things my own way - rather than giving in to the wishes of other people.
	Persistence		I am usually so determined that I continue to work long after other people have given up.

2.1.2.2.2 Substance use

Participants' drinking behaviour was measured using a version of the Alcohol Use Questionnaire (AUQ, Mehrabian & Russell, 1978) modified for use with British students. The AUQ gives a Units score, summing units (10ml ethanol) drunk across an average week, a Binge score, comprising questions assessing speed of consumption and frequency of drunkenness, and a Total score, calculated by summing Units and Binge scores. Results involving the AUQ were non-significant throughout the ensuing experiments, and so will not be discussed further.

2.1.3 Design & Procedure

2.1.3.1 Health screening

Upon arrival participants completed a general health questionnaire to ensure that they were eligible for the study.

2.1.3.2 Personality questionnaires

The NEO and TCI were completed immediately before and after the PIT task, respectively; order of questionnaire was counterbalanced.

2.1.3.3 Pavlovian training.

The PIT task comprised three phases. First was a Pavlovian conditioning phase that used a trace conditioning procedure to associate a CS_+ with winning 50p, and a CS- with winning nothing. Money was used as the reward, rather than a primary reward such as food, to ensure its general appeal to participants. Participants first read the instructions below:

> The following task is made up of trials where you can win 50 pence. Each trial will begin with a fixation cross (+) in the centre of the screen, which you should look at. Then two pictures will appear. Immediately afterwards you will be asked to rate how likely you think you are to win 50p, by pressing a number key between 1 and 9. Whether you win is dependent upon which pictures were shown on the screen. Press the spacebar to begin.

After 16 trials the experimenter re-iterated these instructions verbally, to ensure task comprehension, before leaving the participant to complete the remaining trials alone. There were 128 trials in total, 64 winning trials and 64 non-winning trials, divided into 8 blocks of 16. After each block participants were shown a screen that detailed their total winnings for that block (always £4.00), and were instructed to move the amount from the left hand box into the right hand box. Trials began with a black fixation cross in the centre of the screen of duration 1s. This was then replaced by a CS pair aligned horizontally for 3s. An outcome expectancy question then appeared ("How likely are you to win 50p? 1 = Not at all likely 5 = Don't know 9 = Extremely likely") to which participants responded using the horizontal number keys of the main keyboard section. Upon response a grey screen of duration 1s appeared followed by the trial outcome (O) for duration 2s. Os were text reading "You win 50p" or "You win nothing" and were contingent solely upon the CS displayed (and so not dependent on a correct response to the expectancy question). See Figure 2.1.3.1 for a diagram of participants' experience of the PIT task.

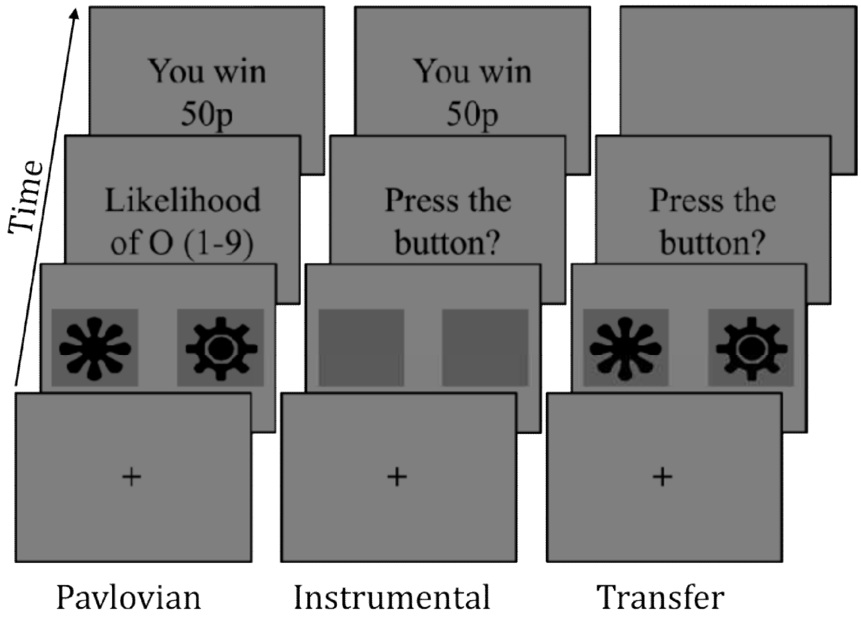

Figure 2.1.3.1. Simplified schematic of PIT procedure.

The four CSs (see Figure 2.1.2.1[left]) were assigned to one of four roles, counterbalanced across participants, denoted hereafter CS_+, CS-, $CS_{\pm}a$, $CS_{\pm}b$. CS_+ was paired with winning 50p, CS- with winning nothing, and both $CS_{\pm}$ were paired equally with winning and non-winning. CS_+ and CS- were associated with their respective O with 100% contingency. Both $CS_{\pm}$ occurred with 50% contingency with each O, and so were non-predictive of either (Robert A. Rescorla, 1967). Each trial presented CS_+ or CS-, combined with $CS_{\pm}a$ or $CS_{\pm}b$. Therefore no trial contained both CS_+ and CS- together, or $CS_{\pm}a$ and $CS_{\pm}b$ together. Horizontal position (left or right) of CS was counterbalanced within participants, order of presentation was random.

2.1.3.4 Emotional evaluations

Immediately after the final block of Pavlovian conditioning participants were asked to rate their subjective emotional evaluations of each CS. This rating session began with the onscreen instruction: "You will now be asked some questions about the four pictures you have seen." Each of the four CSs was presented individually at the central top of the screen with a single rating question and response scale below it. CSs were presented twice, once with the question “How pleasant do you find this picture?" and once with “How anxious does this picture make you feel?" Participants responded using the horizontal number keys, and were instructed to "Press a number key between 1 and 9 to indicate the strength of your feeling, 1 = not at all, 9 = extremely”. Each CS remained on the screen until a response was made, at which point a blank grey screen appeared for a random duration of between 2-2.5s before the next CS and question was presented. Order of CS and question was randomised such that questions pertaining to the same CS were not necessarily consecutive.

2.1.3.5 Instrumental training

Having given their emotional evaluations participants took a five minute break, while the experimenter replaced the keyboard with the response box, before they read the instruction: "In this session, by pressing the blue button a number of times, you will sometimes win 50 pence". The experimenter re-iterated the instructions verbally, this time after 10 trials, to ensure task comprehension, before leaving the participant to complete the task alone.

There were 40 trials in total, divided into 4 blocks of 10. Each block ended with a screen displaying participants' winnings for that block (in this phase the amount was response-contingent), and asked them to move the specified amount into their winnings box. Trials began with a 1s fixation cross positioned centrally. Then a horizontally aligned pair of identical dark grey squares (distinguishable from the lighter background) appeared for 2s. This was followed by a 10s screen asking participants to "Press the button?"; if a response was made within 10s then this question was terminated and a blank screen of duration 18.5s ensued. Response-positive trials then ended with a 2s reinforcement screen stating that "You win 50p" or "You win nothing"; response-negative trials followed the 10s response prompt with a 2s blank screen before the next trial began. Figure 2.1.3.2 presents a timeline of this instrumental trial sequence.

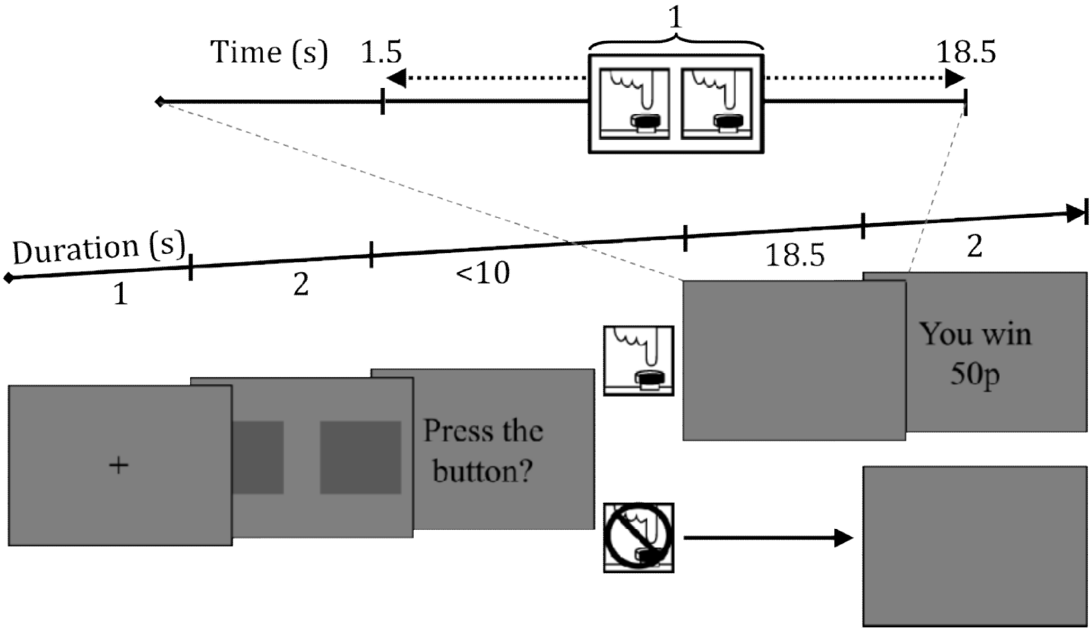

Figure 2.1.3.2. Instrumental training event sequence, indicating screen durations for response-positive and response-negative trials, and response requirements for VI10 schedule during 18.5s blank screen.

Reinforcement was contingent upon a novel combination of variable ratio (VR) and variable interval (VI) schedules. Across trials, reinforcement *availability* was contingent upon a VR2 schedule, such that participants had the *opportunity* to win on 50% of trials. This ensured that the grey squares (hereafter $S_{\pm}$) were non-discriminative of reinforcement and so would create a 'baseline' condition for the ensuing transfer phase. In this context 'baseline' was defined as a situation allowing behaviour that was informed by the current psychological value of the O, i.e. R→O rather than S→R behaviour. Furthermore, within the 50% of trials where reinforcement was available, reinforcer *procurement* was contingent upon a customised VI10 schedule. To *receive* reinforcement participants were required to press at least twice within a 1s window of variable onset (minimum 1.5s) during the 18.5s blank screen (see Figure 2.1.3.2 for pictorial representation of VI schedule). Because participants had no way of predicting the onset of the reinforcement window, this alteration to the traditional VI setup ensured that participants pressed multiple times, rather than simply pressing once towards the end of each trial.

2.1.3.6 Transfer

The transfer phase was integrated with the instrumental training phase so as to appear as a continuation of the same task. It therefore began immediately after the final trial of instrumental training with the following instructions:

> Now you will continue to earn money as before, but you will only be told how much at the end of the session. Sometimes the pictures you saw earlier will be presented. Press the blue button to continue.

Transfer proceeded in much the same way as instrumental training. However, the 2s reinforcement screen was replaced by a 1s blank screen. Thus conditions of nominal extinction were evoked, in that participants were led to believe that they were still winning money, but no reinforcement was provided. This ensured that no new learning occurred in this phase where instrumental responding could be expressed in the presence of the CSs. Furthermore, in place of the $S_{\pm}$, in 1/3 of trials the CS_{+} was presented alongside either $CS_{\pm}$, in another 1/3 the CS- was presented with either $CS_{\pm}$, with the remaining 1/3 presenting the $S_{\pm}$ alone. As with Pavlovian training, position of CS (left/right) was counterbalanced, with presentation order random. There were 96 trials in total, split into 2 blocks of 48. Thus each CS was presented 16 times per block. Blocks were separated by a screen announcing “Halfway. Press the blue button to resume the task.” the duration of which was participant controlled.

2.1.3.7 Post-transfer outcome-expectancy

Upon completion of the transfer phase participants were asked to retrospectively rate their estimated probability of winning 50p during different trial-types (e.g. CS_{+}, $S_{\pm}$). They were instructed on screen to get the experimenter who provided them with a sheet of A4 paper with instructions and 5 visual-analogue scales (VASs). Instructions on the paper read:

> What did you think your chances of winning 50p were, when you had the opportunity to press the blue button, when different pictures were presented? Please start at the top of the page and work your way down as each picture is presented on the screen. Make your answer by drawing a vertical line (I) in the appropriate position on the scale. Press the top button of the response box to continue.

Each VAS comprised a black horizontal line of length 160mm anchored with "Low chance" at the left extreme and "High chance" at the right extreme. After participants had pressed the button a blank screen of randomly defined duration within a range of 1.5-2s ensued before the first CS was presented. Each of the four CSs and the S± was presented individually, in random order, positioned in the central top of the screen. Below it was the question:

> What did you think your chances of winning 50p were, when you had the opportunity to press the blue button, when you saw this picture? Mark your answer on the paper provided. Press the top button to continue.

After the final CS had been presented the end of the task was signalled. The entire PIT procedure took approximately 90mins to complete - 30mins for Pavlovian training, 60mins for the instrumental and transfer phases combined.

2.1.3.8 Alcohol use

After the PIT task participants completed the second personality questionnaire followed by the AUQ, before being debriefed.

2.1.4 Statistical analyses

2.1.4.1 Sample size

To ensure at least one participant in each cell of the full counterbalance matrix (Gender x Questionnaire order x CS counterbalance) 16 participants were required. This was increased to 32 to increase the validity of the regression analyses (Maxwell, 2000).

2.1.4.2 PIT variables

2.1.4.2.1 Awareness

Participants were categorised as either 'aware' or 'unaware' of the CS-US associations based on their expectancy ratings in the final block of Pavlovian training, using criteria based on Hogarth et al (2007). 'Aware' participants were those whose mean rating following each trial was significantly [$p < .05$] different from 5 (i.e. 'don't know') and in the correct direction (i.e. CS+ rating > 5 > CS- rating). 'Unaware' participants were those whose rating for each CS was either not significantly [$p > .10$] different from 5, or was not in a veridical position relative to 5. Participants falling outside either category (e.g. correct expectancy ratings for only one CS, or ratings marginally [$.05 < p < .10$] different from 5) were excluded from further analysis. These criteria ensured the specificity of categorisation – aware participants possessed absolute awareness of the predictive properties of each CS, rather than relative awareness of one compared to the other, and unaware participants demonstrated no consistent understanding of the meaning of either CS.

Awareness was treated as a categorical variable within ANOVAs. But as well as expressing awareness qualitatively it was also analysed quantitatively for correlational purposes.

Whereas an awareness categorisation was based on the final block of Pavlovian training, 'Expectancy discrimination' was calculated as the difference in mean rating for each CS (CS_+ - CS-) across all blocks. Higher values would indicate greater differentiation of the two stimuli. A difference score was computed, as opposed to CS-specific values being used, to control for response bias towards higher or lower numbers, e.g. participants pressing '9' by default would have an artificially inflated score for the CS_+. Thus using a difference score allowed for more reliable quantification of participants' ability to differentiate the CSs.

2.1.4.2.2 *Evaluative conditioning*

The two non-predictive CSs were rated as non-significantly different throughout the current research, and so a single $CS_\pm$ score was calculated from their mean. ANOVAs of emotion ratings used means of each CS. Correlational analyses involving emotion ratings were conducted using the difference between each predictive CS, hereafter 'evaluative discrimination'. This gave a measure of evaluative conditioning attributable solely to each CS's association with reward by controlling for mere exposure (Murphy, Monahan, & Zajonc, 1995) or response bias.

In exploratory analyses of the effects of evaluative discrimination on PIT, an ‘EvaluativeSplit’ dichotomous variable was created, based on a median split of participants’ evaluative discrimination scores. However, this variable did not significantly affect PIT in any of the experimental chapters, as evidenced by the lack of main effects or interactions involving EvaluativeSplit in any behavioural measure of transfer [*Fs* < 1.99, *ps* > .143].

2.1.4.2.3 *Response measurement*

Responses were divided into two aspects – initiation and rate – with each calculated separately for each type of trial, e.g. CS_+, $S_\pm$. Response initiation (RI) was defined as the percentage of trials where at least one response was made. Thus the maximum for each of the three transfer trial-types would be 100%, indicating that a response had been made on every trial of that category. Response rate (RR) was calculated by taking only those trials where a response had been made, calculating the mean number of presses, then dividing by the response window (18.5s) to give a per-second measure. These computations ensured the orthogonality of each variable. While response latency was also recorded, due to a number of participants not pressing at all on certain trials, e.g. CS- trials, missing data caused the effects of this variable to be unreliable and so will not be reported.

Similar to the discrimination scores calculated for awareness and EC, 'transfer discrimination' was calculated for both RI and RR as CS_+ - CS-, to be used in correlational analyses. A 'transfer effect' score was also computed by subtracting $S_\pm$ from either CS_+ or CS- responding, as per Hogarth et al (2010). This transfer effect would quantify the facilitation (or suppression) of responding attributable to the inherent cognitive or emotional properties of the CS itself, independent of the current value of the outcome which would be represented by $S_\pm$ response patterns.

2.1.4.2.4 Transfer expectancy

Preliminary ANOVAs comparing expectancy ratings for the three non-predictive stimuli ($CS_{\pm a \ \& \ b}$, $S_\pm$) showed no significant effects through each study, confirming that they were viewed as equally [un]informative. The two $CSs_\pm$ were therefore dropped from transfer expectancy analyses due to there being no specific $CS_\pm$ trials in transfer.

2.1.4.3 Personality questionnaires

Personality trait raw scores were standardised into *T*-scores (mean = 50, SD = 10) using normative data from university-age samples of mixed gender provided in each questionnaire handbook. For the NEO its five factors were computed using the factor loadings of each of the 30 facets. These factor scores are more orthogonal and have higher validities than their equivalent domain scores, which are calculated simply by summing the relevant facets (McCrae & Costa, 1989). For the TCI it was not possible to compute factor scores, due to a lack of sufficient information in the handbook, and so domain scores were used instead.

2.1.4.4 General statistical procedures

Data were analysed using SPSS 17.0. ANOVAs were conducted where categorical variables were involved. Greenhouse-Geisser method was used to correct for non-sphericity in within-subjects analyses where appropriate. Bonferroni method was used to control for type I error inflation when conducting multiple post-hoc comparisons. Regression analyses used the enter method to assess the unique contribution of each predictor variable whilst controlling for all others included in the model. Simple correlations used Pearson's product-moment. All regression analyses were concentrated on the moderating role of personality on associate learning data. Regressions were also performed within the continuous experimental variables, e.g. awareness discrimination on evaluative discrimination, but are not reported as their results were in line with the equivalent ANOVAs.

3 Specific PIT with two monetary outcomes

An edited version of this chapter is under review at the journal Addiction.

3.1 Abstract

Background - Human Pavlovian-to-instrumental transfer research suggests that outcome expectancy is sufficient to elicit reward-seeking, yet the methods used may have prevented emotional processes from playing a role.

Aim - Thus the aim of this first experiment was to investigate the ability of cue-elicited emotion to influence reward-seeking in a PIT design.

Methods – 55 participants completed the PIT task. The Pavlovian phase associated two visual CSs with winning either 10 pence or 50 pence, respectively; the instrumental phase trained participants to make two different button-pressing responses to win either 10p or 50p, respectively; the transfer phase tested the change in instrumental responding after presentation of either CS.

Results – 32 participants developed expectancy awareness, whereas 13 displayed a complete lack of awareness, after Pavlovian training. Despite this difference in awareness, both groups rated the 50p CS as more pleasant than the 10p CS. Both groups responded similarly during instrumental training, but only the aware group demonstrated PIT in the transfer phase. Furthermore, only specific PIT was demonstrated, with each CS selectively enhancing the response with which it shared an outcome. Neuroticism positively predicted the rate at which aware participants developed propositional knowledge of the Pavlovian contingencies, whereas Extraversion positively predicted the degree to which all participants discriminated the hedonic properties of each CS.

Conclusion – Expectancy awareness is further supported as sufficient to display specific PIT, but the lack of a general PIT effect may suggest that the methods used were not appropriate for the study of cue-induced emotion in reward-seeking. Subsequent studies should therefore simplify the PIT design to include only one reward and response.

3.2 Introduction

Human PIT research to date either confirms that transfer only occurs in participants who expect a specific O after encountering its associated S (Hogarth et al., 2010; Hogarth et al., 2007; Talmi et al., 2008; Trick, Hogarth, & Duka, 2011), or is unable to falsify such expectancy as sufficient (Bray et al., 2008; Nadler, Delgado, & Delamater, 2011; Prévost et al., 2012). While evaluative responses to an S often *accompany* O expectancy responses the two have not been unequivocally dissociated. Therefore the role of S emotional properties in PIT requires further scrutiny.

Assertions of general PIT have relied on the demonstration of increased production of an R in the presence of an S paired with an O not obtainable by the available R (Corbit & Balleine, 2005; Nadler et al., 2011; Prévost et al., 2012). Such a paradigm was operationalised by Corbit & Balleine (2005), who associated Ss 1-3 with Os 1-3, respectively, yet associated only Rs 1 & 2 with Os 1 & 2, respectively. Thus S3 was associated with O3, but O3 was not associated with a corresponding R3. It is argued that any influence of S3 on Rs 1 & 2 can be explained only through its general emotional properties, as there is no associative basis for an expectation of O3 to influence Rs 1 & 2.

However, any influence of S3 may be due to a process of *generalisation* (McLaren & Mackintosh, 2002), rather than general emotion. Participants may have responded to S3 because it shared stimulus dimensions with Ss 1 or 2 (Milton & Wills, 2004), and so generated an expectation of Os 1 or 2. Therefore any transfer of S3 onto Rs 1 or 2 may occur via an expectancy representation rather than an emotional representation. Such a confound may be exacerbated by making inferences about the rate of S3 responding based on comparisons with explicitly unpaired S trials, as was the case with Nadler et al and Prévost et al (2011; 2012). Such a comparison would contain elements of both emotion and expectation, and so could not dissociate the effects of either.

Demonstration of general PIT therefore requires a method of balancing generalisation and expectation across S conditions while retaining differential emotion. The specific-PIT paradigm of Hogarth et al (2007) goes some way to creating such conditions. These authors compared the effects of two novel Ss, paired explicitly with cigarettes and money, respectively, on Rs reinforced with cigarettes and money, respectively. The two Ss were equally generalisable, i.e. they possessed similar sensory properties, and generated expectancies of equal magnitude of their respective Os, thus balancing generalisation and expectancy. However, participants also rated each S as equally emotionally salient, likely due to their association with Os balanced for biological salience, thus precluding any explanation of their behavioural effects in terms of emotion.

Therefore the current experiment built on the paradigm of Hogarth et al (2007), but adapted it to encourage emotional discrimination of the two Ss. Whereas Hogarth et al had used Os of different sensory identity but similar hedonic value, the current paradigm used

Os of similar identity but different value. Money was chosen as the outcome, rather than cigarettes, to ensure that the outcome would be considered rewarding by all participants. 10p and 50p were associated with two Ss, before reinforcing two Rs. A general-PIT effect would be evidenced by increased responding in the presence of the S predicting 50p, relative to the S predicting 10p, regardless of R. Alternatively, a specific-PIT effect would be evidenced by increased responding in the presence of the S predicting one O, relative to the S predicting the other O, but only on the R reinforced with the corresponding O.

3.3 Method

3.3.1 Participants

Participants were 55 University of Sussex students (24 males and 31 females) with a mean age of 21.3 years (range 19-36). Other participant details were as General Methods.

3.3.2 Materials

Details were as General Methods, save for the fact that the there were two tins to the participant's left, one containing 64 10p coins, the other containing 64 50p coins, and so two tins to the participant's right, one labelled 'Your 10p box', the other labelled 'Your 50p box'. There were also two active buttons on the instrumental response box, the nearest and farthest, highlighted blue and with arrows pointing either towards or away from the participant.

3.3.3 Design & Procedure

3.3.3.1 Pavlovian training

Rather than contrast USs of nothing versus 50p, this first experiment contrasted winning 50p with winning 10p, rather than nothing. Therefore CSs are referred to as CS_{10} and CS_{50}. Details were otherwise the same as General Methods, save for the mention of 10p in place of 'nothing'. Therefore the initial instruction screen read:

> The following task is made up of trials where you can win 10 pence and 50 pence. Each trial will begin with a fixation cross (+) in the centre of the screen, which you should look at. Then two pictures will appear. Immediately afterwards you will be asked to rate how likely you think you are to win 10p or 50p. You will then be prompted to press the spacebar to find out how much you have won. The amount you win is dependent upon which pictures were shown on the screen. Press the spacebar to begin.

The US expectancy question asked “How likely are you to win 10p or 50p? 1 = 10p 5 = don't know 9 = 50p”, to which participants responded using the horizontal number keys of the main keyboard section. Upon response a grey screen of duration 1s appeared, followed by an instruction to “Press the spacebar to find out how much you have won”. This grey screen and spacebar press was used to reduce the possibility of participants being reinforced for pressing specific number keys, and so forming differential instrumental responses for different Os prior to the forthcoming instrumental phase of PIT. Because of the inclusion of 10p trials, total winnings for each block were always £4.80.

3.3.3.2 Instrumental training

Due to the inclusion of a second response and outcome, instrumental training in this experiment departed from that described in General Methods. Having given their emotional evaluations participants took a five minute break, while the experimenter replaced the keyboard with the response box, before they read the instructions below:

> In this session, by pressing the up or the down button on the response box, you will be able to win either 10 pence or 50 pence. Pressing one button wins 10p, pressing the other wins 50p. Sometimes you will win the money, sometimes you will win nothing. Trials will start with a fixation cross (+), which you should look at. The cross will then be replaced by two squares. Following this you will be asked to press one of the buttons. You will only win if you press repeatedly while the prompt appears on the screen, and only press one button within each trial. Press either button to begin.

The experimenter re-iterated the instructions verbally, this time after 20 trials, to ensure task comprehension, before leaving the participant to complete the task alone. There were 100 trials in total, divided into 5 blocks of 20. Each block ended with a screen displaying participants’ winnings for that block (in this phase the amount was response-contingent), and asked them to move the specified amount into their winnings boxes. Trials began with a 1s fixation cross positioned centrally. Then a horizontally aligned pair of identical dark grey squares (distinguishable from the lighter background) appeared for 2s. Because these grey squares were associated equally with 10p and 50p, and were therefore non-predictive, they are referred to hereafter as $S_{10/50}$. This was followed by a 4s screen instructing participants to “Press the up or down button”. Unlike the instrumental training described in General Methods section 2.1.3.5, this response prompt was phrased as a statement, rather than a question, and remained on screen throughout responding. The prompt was followed immediately by a 2s reinforcement screen stating that e.g. “You win 50p” or “You win nothing”. Within each trial, reinforcement was contingent upon a similar

VI schedule to that described in General Methods, although in this experiment a VI2.75 schedule operated, due to the response window being only 4s long. This VI setup was based on the method of Trick et al (2011). Furthermore, across trials, presses on the 10p button (R_{10}) were reinforced with a 50% contingency, while presses on the 50p button (R_{50}) carried a 10% contingency. This ensured that the utility of each button was identical and so discouraged a bias towards one response or the other. Response-outcome association was counterbalanced.

3.3.3.3 Transfer

Transfer was identical to that of General Methods, except that the 18.5s response window was reduced to 4s, in line with the participants' experience of instrumental training.

The entire PIT procedure took approximately 60mins to complete - 30mins for Pavlovian training, 30mins for the instrumental and transfer phases combined.

3.3.4 Statistical analyses

Because the 4s response window did not take into account participants' response time to initiate pressing, the RR measure was calculated by dividing mean number of presses by the duration of actual response (i.e. 4s – response latency). This technique ensured that RR was unbiased by reaction time.

3.4 Results

3.4.1 Group-level analyses

3.4.1.1 Expectancy awareness

32 (58%) participants were classified as aware (16 males and females, mean age 21.75, range 19-37), 13 (24%) unaware (3 males and 10 females, mean age 20.38, range 18-22), with 10 (18%) showing partial awareness. These 10 partially aware participants were excluded from further analysis. Aware and unaware groups did not differ significantly in terms of age [$t(43) = 1.22$, $p = .231$] or gender [$\chi^2(1) = 2.75$, $p = .182$].

Due to this individual-level selection criteria, in the final block of Pavlovian training the aware group correctly predicted the occurrence of each US after the presentation of its respective CS, whereas the unaware group was unable to predict the occurrence of either US, as illustrated in Figure 3.4.1.1[left].

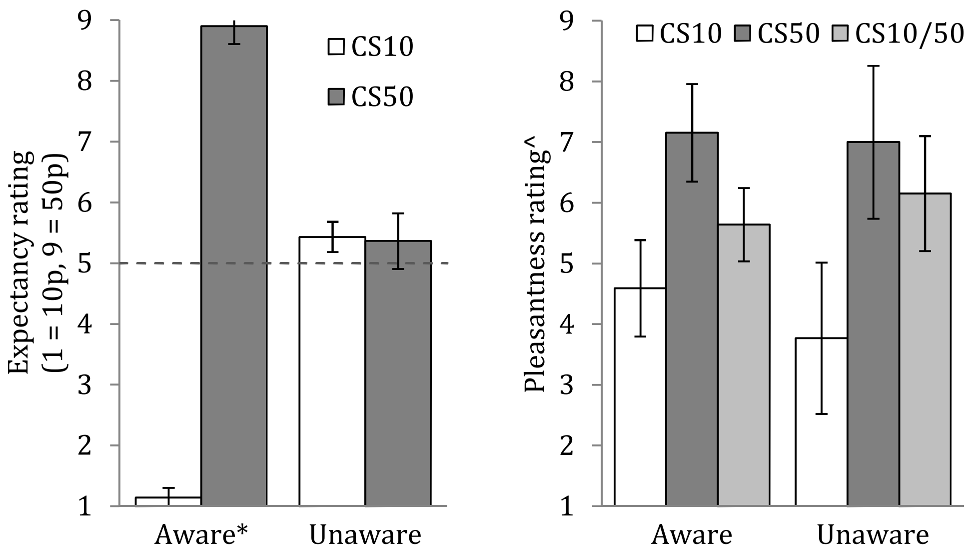

Figure 3.4.1.1. [left] Mean expectancy rating of winning either 10p or 50p after presentation of its respective CS for aware and unaware groups in the final block of the Pavlovian phase. Line at 5 indicates rating of 'don't know'; * $CS_{10}/CS_{50} \neq 5$ [p < .001].
[right] Mean pleasantness rating of Pavlovian stimuli following Pavlovian training for aware and unaware groups.
^ $CS_{50} > CS_{10/50} > CS_{10}$ [ps < .029]; CS_{10}, stimulus predictive of 10p; CS_{50}, stimulus predictive of 50p; $CS_{10/50}$, stimulus non-predictive; error bars represent 95%CI.

A mixed ANOVA of final block expectancy ratings, with CS and Awareness as factors revealed main effects of CS and Awareness [$Fs(1,43) > 5.72$, $ps < .025$], qualified by a significant interaction between CS and Awareness [$F(1,43) = 694$, $p < .001$]. Subsequent simple effects analyses confirmed that the aware group's mean expectancy rating for each CS was significantly different from 5 [$ts(31) > 56.6$, $ps < .001$], whereas the unaware group's ratings were either not in the correct direction (for CS_{10}) or did not differ significantly from 5 (for CS_{50}) [$p = .389$].

3.4.1.2 Evaluative conditioning

In contrast to the expectancy ratings, a mixed ANOVA of pleasantness ratings, with CS (CS_{10}, CS_{50}, $CS_{10/50}$) and Awareness as factors found that there was no dissociation between the aware versus unaware group's emotional evaluations of each CS. See Figure 3.4.1.1[right] for mean pleasantness ratings. There was a significant main effect of CS [$F(2,86) = 16.2$, $p < .001$], but no significant effect of Awareness, nor a significant interaction [$Fs < 1$]. Post-hoc comparisons revealed that the three CSs differed significantly from each other in a sequential manner ($CS_{50} > CS_{10/50} > CS_{10}$) [$ps < .029$]. There were no significant effects of either CS or Awareness on anxiety ratings [$Fs < 1$] (data not shown for brevity).

3.4.1.3 Instrumental training

During instrumental training all participants acquired declarative knowledge of the relationship between each button and their respective monetary outcomes, as assessed by post experiment interview. Figure 3.4.1.2 - Figure 3.4.1.4 present mean RI and RR for each Awareness group on each Button during each Block, as well as the total number of reinforced trials expressed as a percentage of the total possible.

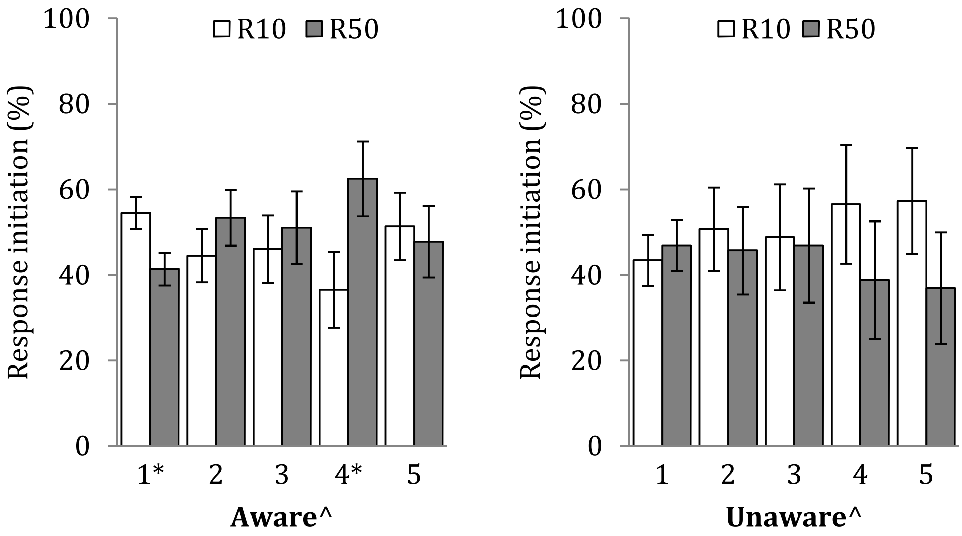

Figure 3.4.1.2. Mean response initiation during instrumental training for aware and unaware groups on either the 10p or 50p winning button during blocks 1-5.
**** $R_{10} \neq R_{50}$ [ps < .030]; ^ Aware > Unaware [p = .009]; error bars represent 95%CI.***

A mixed ANOVA of RI with Button (R_{10}, R_{50}) and Block (1-5) as within-subjects factors, and Awareness as the between subjects factor, showed main effects of Block and Awareness and a significant three-way interaction [*Fs* > 3.21, *ps* < .029]. The interaction was investigated with separate RM ANOVAs for each awareness group, which found a significant Block*Button interaction for the aware group [$F(4,124) = 6.63$, $p < .001$], but non-significant effects in the unaware group [*Fs* < 1.33, *ps* > .271]. The aware group interaction was followed with a series of t-tests comparing RI on each button at each block; they revealed significant differences at blocks 1 and 4 [*ts*(31) > 2.98, *ps* < .030, corrected].

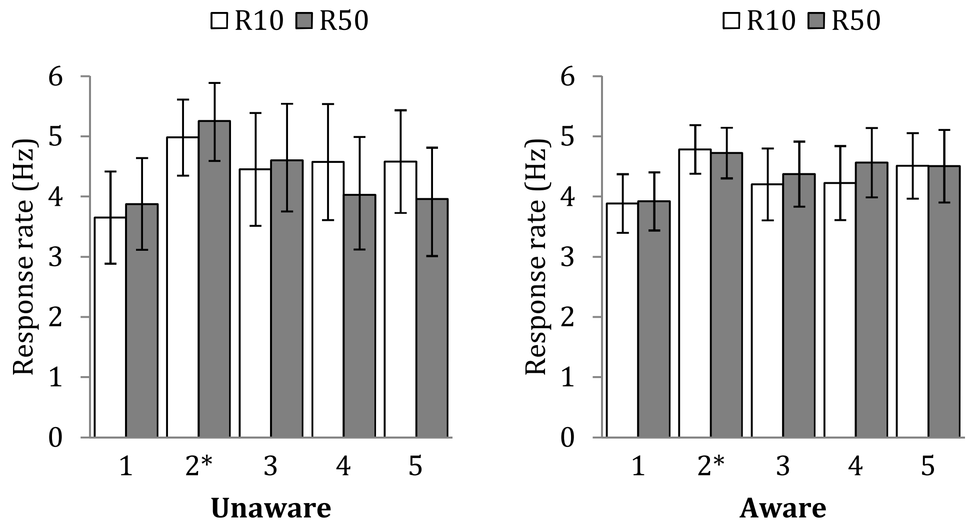

Figure 3.4.1.3. Mean response initiation during instrumental training for aware and unaware groups on either the 10p or 50p winning button during blocks 1-5.
**** block 2 > blocks 1/3/5 [ps < .047]; error bars represent 95%CI.***

The ANOVA of RR revealed a significant main of Block only [$F(2.44,105) = 5.88$, $p = .002$]. Post-hoc comparisons showed this effect to be due to block 2 RR being significantly higher than blocks 1/3/5 [$ps < .047$].

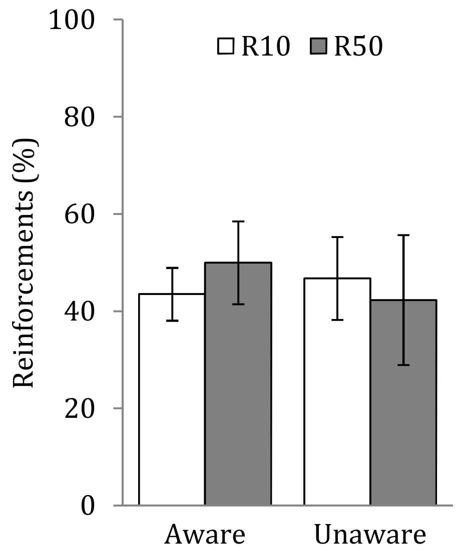

Figure 3.4.1.4. Mean number of reinforcements won during instrumental training, expressed as a percentage of the maximum possible (R_{10} max = 50, R_{50} max = 10).
Error bars represent 95%CI.

There were no significant effects involving Awareness or Button on the total percentage of reinforced trials [$Fs < 1$].

3.4.1.4 Transfer

3.4.1.4.1 Response initiation

A PIT effect on RI was seen only in aware participants, as illustrated in Figure 3.4.1.5. A mixed ANOVA of these RI data, with Stimulus (CS_{10}, CS_{50}, $S_{10/50}$), Button, Block (1,2), and Awareness as factors yielded a main effect of Awareness, qualified by Stimulus*Button*Awareness, and Stimulus*Button interactions [$Fs > 7.79$, $ps < .008$]. The Awareness interaction was investigated with separate ANOVAs for each awareness group, with Stimulus and Button as factors. For the aware group this revealed a significant Stimulus*Button interaction [$F(1.63,50.5) = 121$, $p < .001$], with further RM ANOVAs for each button revealing significant effects of Stimulus [$Fs(1.63,50.5) > 120$, $ps < .001$], located through post-hoc comparisons as being between all levels [$ps < .001$]. Effects in unaware participants were non-significant [$Fs < 1.50$, $ps > .244$].

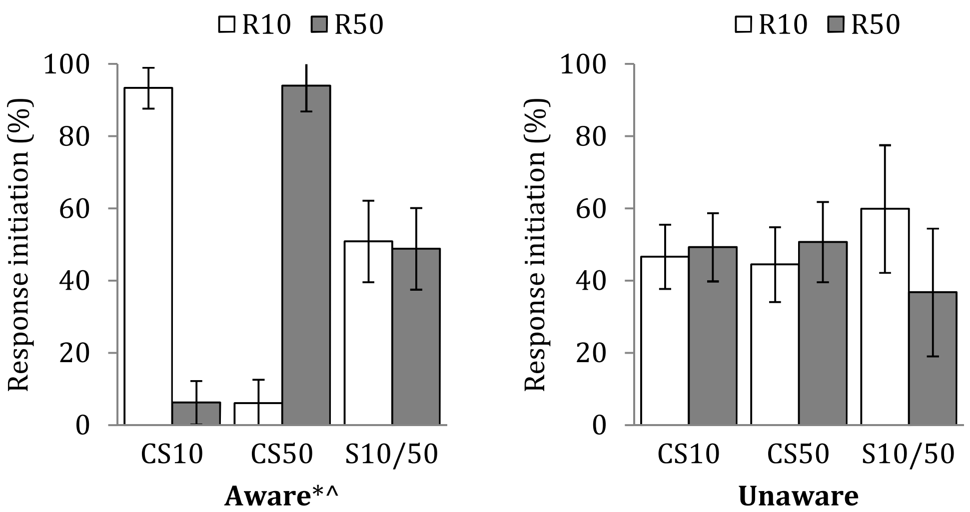

Figure 3.4.1.5. Mean response initiation across transfer phase on each button after presentation of Pavlovian or instrumental stimuli for aware and unaware groups.
**** R_{10}: $CS_{10} > S_{10/50} > CS_{50}$, R_{50}: $CS_{50} > S_{10/50} > CS_{10}$ [ps < .001]; ^ Aware > Unaware [p = .008]; CS_{10}, Pavlovian CS predictive of 10p; CS_{50}, Pavlovian CS predictive of 50p; $S_{10/50}$, grey squares from instrumental training; R_{10}, 10p button; R_{50}, 50p button; error bars represent 95% CI.***

3.4.1.4.2 Response rate

Similar to the RI analysis, a PIT effect on RR was seen only in aware participants (see Figure 3.4.1.6). A mixed ANOVA with Stimulus, Button, Block and Awareness as factors showed a main effect of Awareness [$F(1,43) = 4.50$, $p = .040$] and interactions between Stimulus*Awareness, Stimulus*Button, and Stimulus*Awareness*Button [$Fs(2,86) > 9.73$, $ps < .001$]. To investigate these interactions RM ANOVAs with Stimulus and Button as factors were run separately for aware and unaware groups, collapsing Block due to its non-significant effects. In the aware group these revealed a main effect of Stimulus and a significant Stimulus*Button interaction [$Fs(2,62) > 19.7$, $ps < .001$], with post-hoc comparisons of Stimulus finding $CS_{10} = CS_{50} < S_{10/50}$ [$ps < .001$]. Finally, post-hoc comparisons within the aware group, split by Button, confirmed linear effects of Stimulus on pressing, with $CS_{10} > S_{10/50} > CS_{50}$ on R_{10}, and $CS_{50} > S_{10/50} > CS_{10}$ on R_{50} [*ps* < .03]. Within the unaware group no effects were significant [*Fs* < 3.05, *ps* > .11].

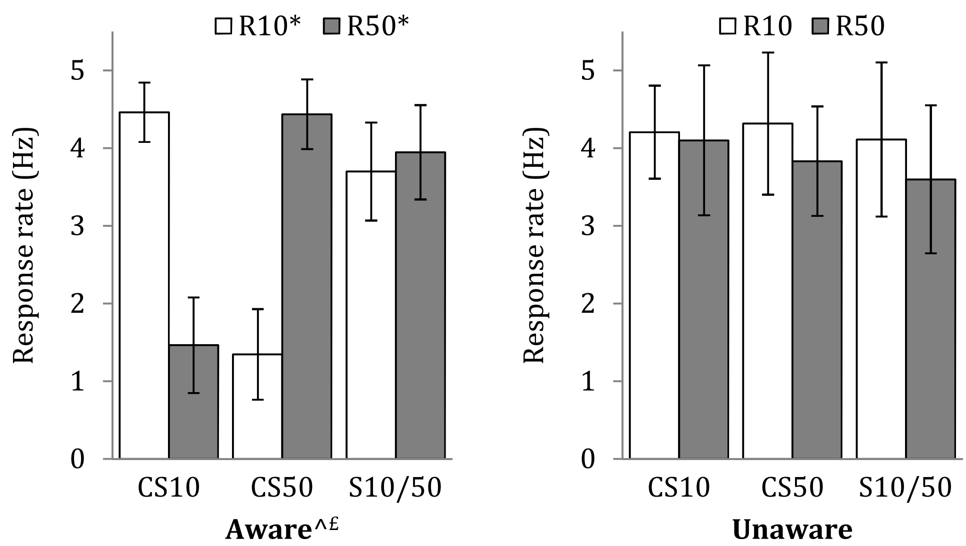

Figure 3.4.1.6. Mean response rate during transfer phase on each button after presentation of Pavlovian or instrumental stimuli for aware and unaware groups.
**** $CS_{10} \neq CS_{50} \neq S_{10/50}$ [ps < .03]; ^ $CS_{10} = CS_{50} < S_{10/50}$ [ps < .001]; £ Aware < Unaware [p = .040]; CS_{10}, Pavlovian CS predictive of 10p; CS_{50}, Pavlovian CS predictive of 50p; $S_{10/50}$, grey squares from instrumental training; R_{10}, 10p button; R_{50}, 50p button; error bars represent 95% CI.***

3.4.2 Role of personality in PIT

3.4.2.1 Awareness classification

To investigate whether awareness status could be predicted by stable personality traits, logistic regression analyses were conducted separately for the NEO and TCI, using their respective factors as predictors of awareness classification. For the NEO the model was non-significant [$\chi^2(5) = 4.53$, *p* = .44]. For the TCI, the initial model was also non-significant. However, after removal of two outliers (standardised residuals > 2) the omnibus test was significant [$\chi^2(4) = 13.3$, *p* = .010], correctly classifying 94% and 46% of aware and unaware participants, respectively, with HA the only significant contributor [*Exp(B)* = 0.83, *p* = .005]. Table 3.4.2.1 displays coefficients for each TCI predictor.

Table 3.4.2.1. Logistic regression coefficients of TCI domains predictive of awareness classification.

Predictor	*B*	*Exp(B)*	*p*
Novelty-Seeking	-0.03	0.97(0.12)	.622
Harm-Avoidance*	-0.19	0.83(0.12)	.005

Reward-Dependence	0.07	1.08(0.10)	.101
Persistence	-0.08	0.92(0.11)	.156
Constant	12.8		.050

Note: R^2 (Hosmer Jr & Lemeshow, 2004) = .27, model $\chi^2(4)$ = 13.3, p = .010; * p < .05; awareness coded higher.

3.4.2.2 Expectancy discrimination

As well as predicting awareness classification, personality traits were also assessed for their ability to predict the strength of expectancy discrimination in participants achieving awareness. Multiple-regression analyses were run separately for the NEO and TCI, with their respective factors as predictors and expectancy discrimination index (mean Pavlovian CS_{50} – CS_{10} expectancy score) as the outcome. The initial model for the NEO was non-significant [$F(2,26) = 2.01$, $p = .110$]. However, removing one outlier (standardised residual > 2) led to a significant model [$R^2 = .42$, $F(5,25) = 3.57$, $p = .014$], with N the only significant predictor [$\beta = .47$, $p = .021$] (see Table 3.4.2.2 for factor coefficients). The equivalent model for the TCI was non-significant [F < 1].

Table 3.4.2.2. Linear regression coefficients of NEO factors predicting expectancy discrimination in aware participants.

Predictor	*B*	*β*	*p*
Neuroticism*	0.07(0.06)	.47	.021
Extraversion	0.01(0.05)	.09	.584
Openness	-0.04(0.04)	-.33	.063
Agreeableness	0.03(0.05)	.28	.180
Conscientiousness	0.04(0.06)	.25	.190
Constant	0.62(6.35)		.843

Note: R^2 = .65, p = .014; * p < .05; expectancy discrimination = mean CS_{50} – CS_{10} expectancy rating; numbers in parentheses are 95%CI.

3.4.2.3 Evaluative conditioning

Similar to expectancy discrimination, the utility of personality traits in predicting emotional discrimination was tested with separate regression analyses for the NEO and TCI. Aware and unaware groups were combined due to their non-significant group differences in CS pleasantness ratings (see section 3.4.1.2 above). CS pleasantness discrimination (CS_{50} – CS_{10}) was the outcome, with the domains from either NEO or TCI as predictors. The NEO model was significant [$R^2 = .26$, $F(5,39) = 2.73$, $p = .033$], though none of its five factors was an individually significant predictor [*ps* > .066]. The removal of two outliers (standardised residuals > 2) retained a significant overall model [$R^2 = .39$, $F(5,37) = 4.70$, $p = .002$], and showed N and E to be significant predictors [*βs* = -.34 and .31, respectively, *ps* < .036]. The TCI model was initially non-significant [$F(4,40) = 1.52$, $p = .22$], however the removal of one outlier (standardised residual > 3) resulted in a significant model [$R^2 = .22$, $F(4,39) = 2.72$, $p = .043$] comprising HA as the only significant predictor [$\beta = -.46$, $p = .004$]. To compare the relative contributions of the NEO and TCI in predicting emotional discrimination their significant domains from the above analyses were entered into a further regression analysis. This resulted in a significant model [$R^2 = .22$, $F(3,41) = 3.78$, $p = .017$], although no one predictor was significant [*ps* > .112]. The removal of one outlier (std res > 3) improved the model in that it retained overall significance [$R^2 = .28$, $F(3,40) = 5.18$, $p = .004$] and revealed N to be its sole significant predictor [$\beta = -.44$, $p = .044$].

Table 3.4.2.3 displays coefficients for this final model.

Table 3.4.2.3. Regression coefficients of personality traits predictive of CS pleasantness discrimination.

Predictor	*B*	*β*	*p*
Neuroticism*	-0.12(0.12)	-0.44	.044
Extraversion	0.02(0.09)	0.08	.594
Harm-Avoidance	-.0.02(0.14)	-0.06	.781
Constant	8.36(7.66)		.033

Note: $R^2 = .28$, $p = .004$; * $p < .05$; CS pleasantness discrimination = $CS_{50} – CS_{10}$.

Because of the recurrent relationship between N and both expectancy and pleasantness discrimination, these latter two variables were correlated to assess the potential mediating role of N; neither correlations involving the whole sample, nor aware participants alone, were significant [*rs* > -.13, *ps* > .49].

3.4.2.4 Transfer effect

To explore the moderating influence of personality on transfer behaviour, regression analyses were run, separately for the two personality questionnaires, separately for RI and RR, and separately for aware and unaware participants (due to their quantitative differences in transfer performance). Two outcome variables were considered – the specific- and the general-transfer index (see section 3.3.4 above for detail). No model was significant [*Fs* < 1.93, *ps* > .135].

3.5 Discussion

The aims of the current experiment were twofold. The first was to test whether differential subjective emotional responses elicited by cues predictive of differentially valued rewards could transfer control onto separately trained reward-seeking behaviours, irrespective of the identity of the reward. The second was to investigate the moderating role of individual differences in personality on emotional and behavioural discrimination of the cues. The first test was not supported - participants who developed differential emotional responses to stimuli predictive of either 10p or 50p, regardless of explicit knowledge of these predictive relationships, did not display greater responding in the transfer task on CS_{50} than on CS_{10} trials. Instead, each stimulus selectively enhanced the response with which it shared an outcome, an effect seen only in the aware group. The secondary investigation of individual differences revealed that scores on negative-affect traits predicted awareness classification, the ability to associate each stimulus with its respective outcome, and the magnitude of differential emotional reaction to the cues.

The present behavioural results are in accord with previous studies that have supported the role of expectancy awareness in mediating PIT (Hogarth et al., 2007; Talmi et al., 2008; Trick et al., 2011). The current study strengthens this extant literature by finding that the emotional conditioned responses (ECRs) that accompany expectancy awareness do not by themselves elicit transfer. Thus knowledge of reward availability is a necessary criterion in the control of reward-seeking by separately trained Ss. Indeed, the magnitude of ECR was indistinguishable in aware and unaware cohorts, thus any differences in behaviour cannot be attributed to differences in emotional reactivity. Moreover, both groups pressed at a similar overall rate in the instrumental and transfer phases; the distinction lay in their allocation of pressing to each button in the presence of each S. Thus the lack of transfer in the unaware group was not due to floor or ceiling effects constraining their behaviour.

While the current data is supportive of the role of *awareness* in *specific*-PIT it is less supportive of the role of *emotion* in *general*-PIT. The specific version is argued to rely on the S activating the specific sensory features of the O, which in turn *biases* choice of R towards that which procures the same O (Colwill & Rescorla, 1988; de Wit & Dickinson, 2009; Estes, 1943). The general version is suggested to occur through the S activating the general emotional features of the O, which in turn *augments* any concurrent R, regardless of whether S and R share an O (Dickinson & Dawson, 1987). The current experiment found no general augmentation of R in the presence of the higher-reward CS_{50} compared to the lower-reward CS_{10}.

Yet results from Nadler et al and Prévost et al (2011; 2012) provide a possible demonstration of general transfer in humans, and so are at odds with the present study. As stated in the introduction, these experiments used a modified specific-PIT paradigm, where an S3 was paired with an O3 that had no corresponding R3, arguing that this precluded any specific transfer effect. Despite the apparent prevention of specific transfer these studies still demonstrated an augmentation of general responding on Rs 1&2 in the presence of S3. However, this reputed general transfer may have come from participants *generalising* across Ss or Os (McLaren & Mackintosh, 2002; Milton & Wills, 2004) and so selecting an R based on which brought about the O most comparable to that predicted by the unattached S. Thus any augmentation of responding when comparing pre-stimulus to stimulus conditions, as was the case with Nadler et al and Prévost et al, may contain elements of expectancy and so be a demonstration of specific, not general, PIT. To further test this suggestion it would be informative to assess the role of awareness in the reputed general transfer effect – if participants *unaware* of the S→O relationships still demonstrate PIT then a 'generalisation' explanation can be refuted, and an emotional explanation supported.

Although the development of evaluative conditioning (EC) in the absence of expectancy awareness was not the focus of the present investigation, the data provide support for the argument that emotional appreciation of a CS can occur in the absence of knowledge of its associated US (Hofmann et al., 2010). While it is difficult to confirm the absence of awareness, Lovibond and Shanks (2002) provide criteria for a robust study of awareness that the current procedure adhere to. CSs were abstract shapes that participants had not experienced before, therefore reducing external sources of emotion; a range of CSs were used and their relationship to either US was counterbalanced, therefore precluding the confound that any one CS was intrinsically more emotional; expectancy awareness was tested during learning, rather than during debriefing, thus reducing memory demands on the display of awareness.

Further information on the determinants of awareness and ECR was gleaned from exploration of the relationship between these variables and personality. The TCI's HA afforded a reduced likelihood of awareness classification, which accords with previous reports of a detrimental effect of negative-affect traits on task learning (Avila et al., 1999; Corr et al., 1995; Grillon, 2002; McLaughlin & Eysenck, 1967). Moreover, the NEO's N, a highly correlated construct (Cloninger et al., 1994), was negatively related to pleasantness discrimination, which again accords with extant literature asserting that the trait is involved in negative emotion processing (Canli et al., 2001; Costa & McCrae, 1992), and so may inhibit positive emotion processing. However, at odds with such findings is that N positively predicted expectancy discrimination. Furthermore, expectancy and emotion were unrelated themselves, suggesting independent effects of personality on each. Such a pattern of data will need to be replicated in subsequent studies before being scrutinised further.

The lack of an effect of CS emotional value in PIT shown here also requires further scrutiny. While the human literature to date has been unable to unequivocally demonstrate general PIT, results from rodent studies suggest a viable course for an alternative paradigm that may facilitate such an effect. Holland (2004) argues that transfer paradigms involving multiple Rs and Os bias the participating organism to adopt a transfer approach based on the sensory properties of the specific O predicted by its respective S, at the expense of the emotional properties afforded by the S. In contrast, paradigms involving a single R and O may allow greater modulation of the R by the emotional properties of the S. However, any increase in R elicited by a reward-paired S would be confounded by expectancy of the O in participants aware of the S→O contingency; on the other hand, if unaware participants demonstrate a transfer effect it should be due solely to the emotional properties of the S. Thus further studies should incorporate a single R and O to facilitate a general transfer effect, and include unaware participants to assess the effects of dissociated emotional aspects of reward-predictive Ss.

In conclusion, the current experiment demonstrated an enhancement of responding in the presence of a reward-paired cue, but such enhancement was specific to the response that gained the reward predicted by the cue; the magnitude of this enhancement was unaffected by the emotional value of the cue. Moreover, this specific-transfer effect was seen only in participants with knowledge of the cue-reward association; a group of participants who developed an emotional response to the cue in the absence of such knowledge showed no behavioural effects. Negative-affect traits predicted this knowledge acquisition, as well as the emotional response to the cue, but did not directly predict transfer performance. Further studies should incorporate a single response and reward to facilitate the effects of cue-elicited emotion on behaviour.

4 Single-response PIT

4.1 Abstract

Background – The results from the previous experiment suggested that outcome expectancy is sufficient to elicit reward-seeking. However, comparative research indicates that simplifying the PIT design to include only one reward and instrumental response may facilitate the influence of emotional processes on PIT.

Aims - Thus the aim of this second experiment was to investigate whether the ability of cue-elicited emotion to influence reward-seeking could be expressed using a single-outcome PIT paradigm. It also sought to measure the consistency of the effects of Neuroticism and Extraversion on propositional and emotional processes.

Methods – 62 participants completed the PIT task. The Pavlovian phase associated two visual CSs with either winning nothing or 50 pence, respectively; the instrumental phase trained participants to make a single button-pressing response to win 50p; the transfer phase tested the change in instrumental responding after presentation of either CS.

Results – 32 participants developed expectancy awareness, whereas 18 displayed a complete lack of awareness, after Pavlovian training. Despite this difference in awareness, both groups rated the 50p CS as more pleasant than the non-winning CS. Both groups responded similarly during instrumental training, but only the aware group demonstrated PIT in the transfer phase. This PIT effect was limited, however, to a reduction in response rate on non-winning CS trials. Neuroticism positively predicted the rate at which aware participants developed expectancy knowledge of the Pavlovian contingencies, but no personality domain predicted hedonic reactions to either CS.

Conclusions – Expectancy awareness is shown to be necessary for PIT, but the lack of a facilitatory effect of the 50p CS may have precluded the effect of appetitive emotional processes on responding. Subsequent studies should therefore manipulate the instrumental training schedule to encourage increases in responding in the presence of a reward-predictive cue.

4.2 Introduction

The previous experiment found no evidence that differential emotional responses elicited by two cues predictive of reward could influence two separately trained instrumental responses, i.e. no evidence of general PIT. However, PIT studies using non-human animals indicate that a simplified design including only one instrumental response may provide a situation in which general PIT can be expressed (Dickinson & Dawson, 1987; Holland, 2004). Such a possibility requires investigation by translating these non-human paradigms into one suitable for human participants, which will allow for better scrutiny of the relative contributions of propositional versus emotional responses to stimuli in purported examples of general PIT.

In a series of experiments, Holland (2004) demonstrated that the transfer effect of an S was facilitated by extended training of the R, but only when a single R was used. Extended training had little effect when two Rs were introduced. The effect of extended training was not due to stronger learning of the R, evidenced by comparable response-rates across training conditions, nor was it due to heightened O expectancy or valuation, evidenced by similar rates of O approach and consumption following transfer. This leaves open the possibility that the effect was due to an increase in the control of behaviour by emotional processes elicited by the S, though such a mechanism was not directly investigated by Holland.

A similar paradigm devised by Dickinson & Dawson (1987) supports the involvement of emotional processes in PIT using a single R. The pair trained rats to associated two different Ss with either pellets or sucrose, before reinforcing a single R with both pellets and sucrose. One or other O was then revalued through deprivation, before the effects of each S on the R were tested under extinction conditions. During test, transfer was shown only in the presence of the S predictive of the revalued O, which the authors interpreted as a general PIT effect. While this experimental manipulation was directed at the value of the O, rather than that of the S, emotional reactions to Ss have been shown to track O value (M. Field, Mogg, & Bradley, 2004). Thus, in concert, the paradigms of Holland (2004) and Dickinson & Dawson (1987) indicate a viable method for measuring general PIT.

Where both could be made more appropriate for the current experiment's purpose is through the addition of explicit falsification of the role of propositional learning. Such an end may be achieved by incorporating human participants who can be confidently classified as unaware of the S→O association, yet still demonstrate an emotional response to the S, as was the case in Experiment 1. Early reports of such unaware evaluative conditioning (EC) relied on using faces as both CS and US (Baeyens, Eelen, & van den Bergh, 1990), but were refuted on the grounds that any effect was more reliant on perceptual similarity of CS and US than genuine non-propositional learning (A. P. Field & Davey, 1999). However, more recent demonstration of unaware EC has successfully circumvented this and other flaws (Hofmann et al., 2010), through the use of novel CSs, counterbalanced CS-US pairings, and concurrent measures of awareness, design aspects argued to be necessary for the valid assessment of awareness (Lovibond & Shanks, 2002).

The Pavlovian phase from Experiment 1 already incorporated these necessary features for unaware EC, and so was relatively unchanged in the current study. The PIT procedure was amended, however, to ally it with the single R method of Holland (2004), such that the 10p O was replaced with a no-win O, and the 10p R removed entirely, such that the instrumental and transfer phases contained only one R. Here a general-PIT effect would be manifested as differential responding in the presence of either cue, though only in unaware participants. Any effect in aware participants would be confounded by differential expectancy of reward.

4.3 Method

4.3.1 Participants

Participants were 62 University of Sussex students (28 males and 34 females) with a mean age of 21.3 years (range 19-36). Other participant details were as General methods.

4.3.2 Design & Procedure

4.3.2.1 Instrumental training

Participants' experience of instrumental training was similar to that described in General Methods, save for the following details. The response window was 4s, as it had been in Experiment 1, rather than 18.5s. Thus reinforcement operated on the modified VI2.75 schedule rather than VI10. The "Press the button" prompt remained on screen for the full 4s, rather than being replaced by a blank screen, and omitted the question mark. The prompt was therefore written as an instruction rather than a choice. All other details were as General methods.

4.3.2.2 Transfer

As with Experiment 1, transfer conditions were in keeping with instrumental training. Thus the response window was maintained at 4s, rather than the 18.5s window described in General Methods. All other details were as General Methods.

4.3.3 Statistical analyses

RR was calculated using the same method as Experiment 1, removing the confound of response latency by dividing mean number of responses by response duration (4s – response latency). All other details were as General Methods.

4.4 Results

4.4.1 Group-level analyses

4.4.1.1 Expectancy awareness

32 (52%) participants were classified as aware (16 males and females, mean age 21.0, range 19-26), 18 (29%) unaware (6 males and 12 females, mean age 22.3, range 19-36), with 12 (19%) showing partial awareness. These 12 partially aware participants were excluded from further analysis. Aware and unaware groups did not differ significantly in terms of age [$t(48) = 1.56$, $p = .126$] or gender [$\chi^2(1) = 1.30$, $p = .365$].

In the final block of Pavlovian training the aware group correctly predicted the presence/absence of 50p after presentation of either CS, whereas the unaware group was unable to do so. Figure 4.4.1.1[left] presents each group's mean expectancy rating after seeing each predictive CS.

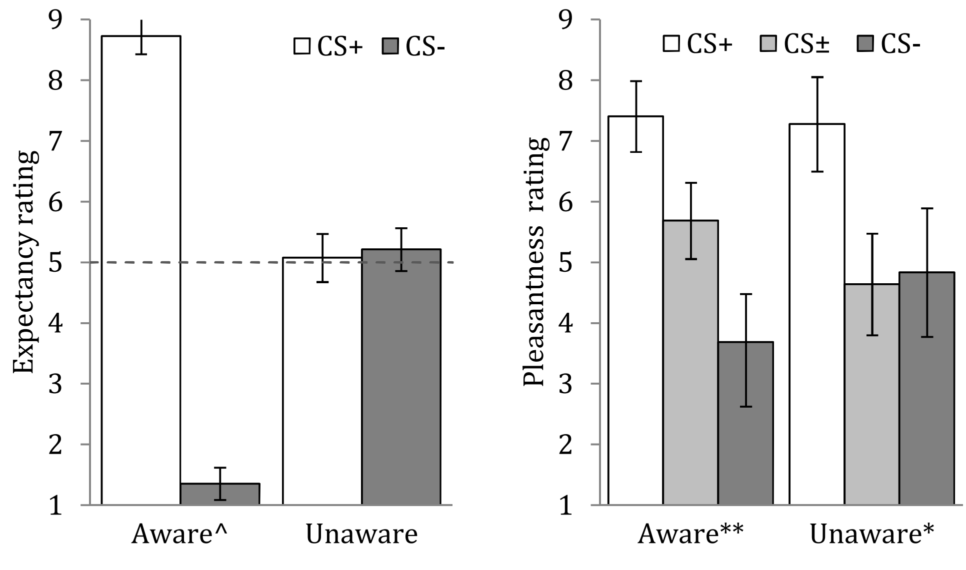

Figure 4.4.1.1. Mean expectancy [left] or pleasantness [right] rating from Pavlovian training for aware and unaware groups after presentation of each CS.
Line at 5 marks rating of 'don't know'; ^ $CS_+ > 5 >$ CS- [ps < .001], ** $CS_+ > CS_\pm >$ CS- [ps < .002], * $CS_+ > CS_\pm =$ CS- [ps < .009]; CS_+, Pavlovian CS predictive of 50p; $CS_\pm$, Pavlovian CS non-predictive; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95% CI.

A mixed ANOVA of final block expectancy ratings with CS and Awareness as factors showed a significant main effect of CS qualified by a significant interaction between

CS*Awareness [*Fs*(1,48) > 392, *ps* < .001]. Exploration of the interaction using one-sample t-tests verified that the aware group's expectancy ratings for both CSs were in the correct direction and significantly different from 5 [*ts*(31) > 31.5, *ps* < .001], whereas the unaware group's ratings were non-significantly different from 5 [*ts*(17) < 1.04, *ps* > .324].

4.4.1.2 Evaluative conditioning

Despite these differences in expectancy ratings both aware and unaware participants gave a similar pattern of pleasantness ratings for the various CSs (see Figure 4.4.1.1[right] for mean pleasantness ratings). A mixed ANOVA of pleasantness ratings with CS and Awareness as factors revealed a main effect of CS and a CS*Awareness interaction [*Fs*(2,96) > 3.69, *ps* < .027]. The interaction was investigated by separate RM ANOVAs for each awareness group. The main effect of CS was present in both groups [*Fs* > 12.8, *ps* < .002], but post-hoc comparisons explained the above interaction as being due to the aware group's ratings for each CS being significantly different from each other (CS+ > CS± > CS-) [*ps* < .002], whereas the unaware group showed significant differences for CS+ comparisons only (CS+ > CS± = CS-) [*ps* < .009].

For anxiety ratings, a mixed ANOVA as per pleasantness ratings found a significant main effect of CS [*F*(2,96) = 4.19, *p* = .023], with post-hoc comparisons showing the CS+ to evoke significantly less anxiety than the CS- [*p* = .038]. Table 4.4.1.1 presents the mean anxiety rating of each CS for each group.

Table 4.4.1.1. Mean (95%CI) anxiety ratings of each CS for each awareness group.

	CS_+*	$CS_\pm$	CS-
Aware	2.88 (.87)	2.75 (.65)	3.84 (.94)
Unaware	2.17 (1.16)	3.28 (.86)	3.28 (1.25)

Note: * CS_+ < CS- [p = .038]; CS_+, Pavlovian CS predictive of 50p; $CS_\pm$, Pavlovian CS non-predictive; CS-, Pavlovian CS predictive of winning nothing

4.4.1.3 Instrumental training

All participants learned to press at a rate sufficient to receive reinforcement within the first block of instrumental training. A series of mixed ANOVAs was conducted to compare the various behavioural indices of aware and unaware groups at each block of instrumental training. Results were non-significant [*Fs* < 1]. Table 4.4.1.2 contains means for the three behavioural indices displayed separately for each awareness group, with block collapsed due to its non-significant effects.

Table 4.4.1.2. Mean (95% CI) of each of the three behavioural measures taken during instrumental training, separated by awareness, averaged across blocks.

	Behavioural measure		
	RI	RR	Reinforcements
Aware	98.5 (.93)	5.21 (.71)	9.14 (.48)
Unaware	98.1 (1.24)	5.05 (.95)	8.63 (.64)

Note: RI, response initiation; RR, response rate; Reinforcements, number of times 50p won.

4.4.1.4 Transfer

Only aware participants displayed an effect of CS on behaviour, specifically RR, in the transfer phase.

RI was not significantly affected by CS (see Figure 4.4.1.2 for mean RI). A mixed ANOVA with Stimulus (CS+, S±, CS-) and Block as within-groups factors, and Awareness as the between-groups factor, revealed only an interaction between Block and Awareness [$F(1,48) = 4.14$, $p = .047$]. However, subsequent t-tests comparing mean RI during each block, separated by Awareness, showed a non-significant effect of Block for the two groups [$ts < 1.45$, $ps > .161$].

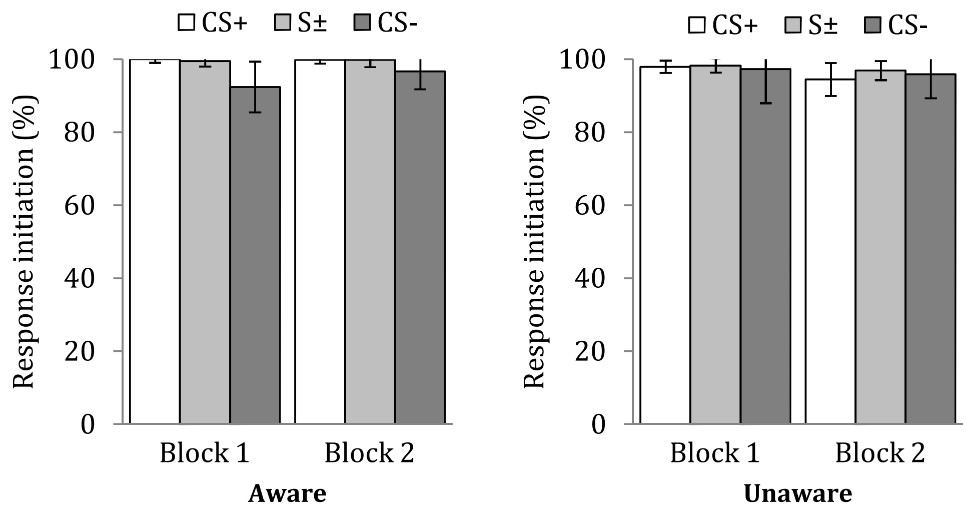

Figure 4.4.1.2. Mean response initiation for aware [left] and unaware [right] groups during blocks 1 and 2 of the transfer phase.
CS_+, Pavlovian CS predictive of 50p; $S_\pm$, grey squares from instrumental training; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95% CI.

A similar pattern of data were found for RR (Figure 4.4.1.3 shows mean RR for each group after each Stimulus). The mixed ANOVA showed a significant Stimulus main effect and Stimulus*Awareness interaction [$Fs > 3.95$, $ps > .030$]. The Stimulus*Awareness interaction was investigated by re-running the ANOVA separately for each awareness group. These second analyses revealed only a significant main effect of Stimulus in aware participants [$F(1.37,42.6) = 8.38$, $p = .003$], with post-hoc comparisons specifying this effect as being due to a higher RR for CS+ and S± trials than CS- trials ($ps < .014$).

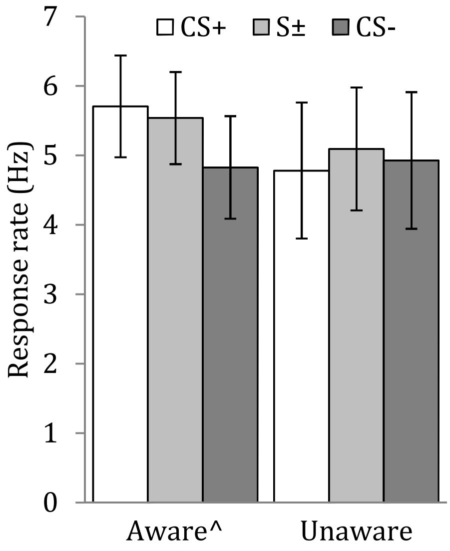

Figure 4.4.1.3. Mean response rate for aware and unaware groups at each level of Stimulus, Block collapsed.
^ $CS_+ = S_\pm > CS-$ [ps < .014]; CS_+, Pavlovian CS predictive of 50p; $S_\pm$, grey squares from instrumental training; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95% CI.

4.4.1.5 Transfer expectancy

Expectancy ratings pertaining to transfer were not obtained from 4 aware and 1 unaware participants due to technical malfunction. Data obtained from the remaining participants was in keeping with their earlier expectancy ratings taken during the Pavlovian phase. A mixed ANOVA with Stimulus and Awareness as factors found a significant main effect of Stimulus and a significant Stimulus*Awareness interaction [$Fs(2,86) > 16.6$, $ps < .001$]. The interaction was explored by further RM ANOVAs for each awareness group which found significant and marginal main effects of Stimulus in the aware and unaware groups, respectively [$Fs > 3.16$, $ps < .056$]. However, post-hoc comparisons explained the previous interaction as being due to the aware group showing significant differences for all comparisons (thus CS+ > S± > CS-; $ps < .001$), whereas unaware participants showed non-significant differences throughout [$ps > .126$]. See

Table 4.4.1.3 for mean transfer expectancy ratings.

Table 4.4.1.3. Mean (95%CI) ratings for expectancy of winning during transfer phase after presentation of each stimulus (scale range 0-100).

	CS_+	$S_\pm$	CS-
Aware*	84.1 (6.90)	52.9 (7.00)	13.6 (7.58)
Unaware	62.4 (8.86)	51.4 (8.98)	40.1 (9.72)

Note: * $CS_+ > S_\pm >$ CS- [ps < .001]; CS_+, Pavlovian CS predictive of 50p; $S_\pm$, grey squares from instrumental training; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95% CI.

4.4.2 Role of personality in PIT

4.4.2.1 Awareness classification

Separate logistic regressions were conducted with the domains of either the NEO or TCI as predictors of awareness categorisation. Neither model was significant [$\chi^2s < 6.99$, $ps > .22$].

4.4.2.2 Expectancy discrimination

Although personality traits were not able to *classify* participants as aware or unaware, NEO factors predicted the magnitude of expectancy discrimination in participants ultimately defined as aware. Separate linear regression analyses were employed for the NEO and TCI, using their respective factors as predictors. The initial NEO model was non-significant [$F = 1.80$, $p = .15$], but the removal of one outlier (std res > 2) led to a significant model [$R^2 = .43$, $F(5,25) = 3.79$, $p = .011$] comprising N and O as significant predictors [$\beta = .57$, $p = .004$; $\beta = -.44$, $p = .026$, respectively] (see Table 4.4.2.1 for full model coefficients). The equivalent model for the TCI was non-significant [$F = 2.62$, $p = .057$].

Table 4.4.2.1. Linear regression coefficients of NEO factors predicting expectancy discrimination in aware participants.

Predictor	*B*	*β*	*p*
Neuroticism*	0.12(0.08)	.57	.004
Extraversion	-0.00(0.08)	-.02	.916
Openness*	-0.09(0.08)	-.44	.026
Agreeableness	0.03(0.05)	.21	.233
Conscientiousness	0.03(0.06)	.22	.280
Constant	1.75(6.98)		.610

Note: $R^2 = .43$, $p = .011$; * $p < .05$; expectancy discrimination = mean CS_+ – CS- expectancy rating; numbers in parentheses are 95%CI.

4.4.2.3 Evaluative conditioning

Regression analyses using the domains of either the NEO or TCI as predictors of CS pleasantness discrimination were non-significant [*Fs* < 1.32, *ps* > .28]. Due to the significant difference between anxiety ratings of the CS_+ and CS-, analyses were also conducted with CS anxiety discrimination as the outcome; neither was significant [*Fs* < 1].

4.4.2.4 Transfer discrimination

Regression analyses were run for each permutation of questionnaire, awareness group, and response variable (RI, RR) with the respective domains of each questionnaire as predictors of transfer discrimination (CS_+ - CS_-). None were significant [*Fs* < 1.85, *ps* > .15].

4.5 Discussion

The current experiment was designed to test whether a PIT paradigm with a single instrumental response would allow the emotional responses elicited by Pavlovian stimuli to transfer control onto the separately trained behavioural response. No evidence was found in favour of this process. Participants rated the reward-presence cue as more pleasant, and the reward-absence cue as more anxious, regardless of propositional knowledge of the cue-outcome association, yet only those participants who correctly expected either outcome after viewing its cue displayed a transfer effect. Thus dissociated emotional responses to stimuli did not elicit general PIT. Additionally, the degree to which aware participants' expectancy ratings discriminated between either stimulus was predicted by their level of trait Neuroticism and Openness.

The necessary status of propositional knowledge in mediating a PIT effect here is in accordance with the previous experiment, as well as studies from other researchers (Hogarth et al., 2007; Talmi et al., 2008; Trick et al., 2011). The lack of general PIT in a group of participants who displayed isolated emotional responses to Ss is again at odds with the assertions of Nadler et al and Prévost et al (2011; 2012), who argue that such a response is sufficient to elicit transfer. As the paradigm used by those researchers cannot rule out the role of propositional knowledge in their general transfer effect, the mechanism by which a general transfer effect occurs may instead require an S to activate both propositional and emotional processes. Indeed, the investigations of Dickinson & Dawson and Holland (1987; 2004) suggest that emotional responses to Ss can play some role, but the current data add to their results by finding that activation of a propositional mechanism may be necessary for such ECRs to influence behavioural Rs.

However, whereas these published claims of general PIT have been predicated on a *facilitation* of R above some baseline level, the current study shows only inhibition. The transfer effect was limited to a reduction in RR under CS_- conditions, compared to $S_\pm$, rather than an increase under CS_+ conditions. Thus it is possible that detection of a general PIT effect in unaware participants was hampered by a ceiling effect, with participants unable to increase their RR above baseline due to motoric, rather than motivational, constraints. In support of this possibility, Lovibond (1983) reported that a facilitatory effect of a CS_+ on performing rabbits was only demonstrated when baseline response rate was low. Moreover, Nadler et al and Prévost et al (2011; 2012) used VR5 and VR10 reinforcement schedules, respectively, thus higher than the VR2 used here, with concomitant response rates of 2 and 3Hz, respectively, thus lower than the 5Hz displayed here.

Moreover, the "Press the button" prompt that remained on screen while participants responded may have been interpreted as a mandatory instruction, rather than a reminder of possible options. This may have artificially elevated RI, due to participants wishing to comply with instructions, rather than seek reward of their own volition. Subsequent investigation should, therefore, employ instrumental schedules that produce a comparatively low level of baseline responding. Additionally, instructions should emphasise that participants may [not] initiate a response depending on their own free will. These methodological alterations will provide more suitable conditions within which to allow for an increase in RR and RI upon CS_+ presentation.

Regardless of the direction of transfer effect, any demonstration of PIT in the unaware group of the current study could be questioned on the grounds that they showed a degree of re-consolidation of CS→US knowledge (Alberini, 2005). Although no unaware participant was consistently able to predict the occurrence of each US after presentation of its CS by the end of the Pavlovian phase, their expectancy ratings showed a marginal effect at the end of transfer. However, such post-hoc assessments of awareness have been shown to be unreliable (Lovibond & Shanks, 2002), introducing confounding factors such as retrospective justification of behaviour (Festinger, 1962), and so should not be used to undermine the case for unaware EC shown here. Evaluative ratings were taken immediately after Pavlovian conditioning, thus giving little time for delayed consolidation to influence awareness.

As well as replicating the unaware EC effect of the first study, the current experiment also replicated the facilitatory effect of Neuroticism on propositional learning. While consistent within the current series, such a replication presents a potential contradiction to extant findings of an inhibitory effect of negative-affect traits on task learning (Avila et al., 1999; Corr et al., 1995; Grillon, 2002; McLaughlin & Eysenck, 1967). However, these published reports did not use N as defined in the NEO-PI-R (Costa & McCrae, 1992), rather traits correlated with N. Thus one explanation for this discordant finding is that a facet unique to N may explain its influence on learning better than its membership of the nebulous construct of negative-affect. Alternatively, the failure to replicate the negative relationship between N and pleasantness discrimination implies a tenuous relationships between personality and learning, thus conclusions on the role of N in propositional learning should be withheld until further replication is obtained.

In summary, a group of participants who developed an emotional response to reward-predictive cues, despite an absence of awareness of the cue-reward association, did not display any influence of the cues on a separately trained instrumental response. Only participants who correctly expected to receive reward after presentation of the cue demonstrated a transfer effect. However, this effect was confined to an inhibitory influence of a reward-absence cue, leaving open the possibility that a lack of transfer in the unaware group was due to response-rate ceiling effects. Such a possibility should be explored using a task that reduces baseline levels of responding. Trait Neuroticism positively predicted propositional learning, thus the consistency of this association should be tested further.

5 Single-response PIT with VI10 schedule

5.1 Abstract

Background – The results from experiment two further supported the notion that outcome expectancy is sufficient to elicit reward-seeking. However, any facilitatory effect of CS hedonic value on responding may have been impeded by high baseline responding.

Aims - The aim of this third experiment was to develop instrumental training conditions that would provide a lower level of baseline responding, in order to allow for an increase in the presence of a CS paired with reward.

Methods – 75 participants completed a PIT task. The Pavlovian phase associated two visual CSs with either winning nothing or 50 pence, respectively, as per the previous study. The instrumental phase used a button-pressing response to win 50p, and introduced a variable interval 10 reinforcement schedule. Additionally, half of participants won or lost 50p during instrumental training, whereas the other half won 50p or won nothing. The transfer phase presented participants with the Pavlovian CSs, while they pressed the button in extinction.

Results – 29 participants were classified as aware, whereas 23 were classified as unaware, after Pavlovian training. Both aware and unaware groups showed an increase in 50p CS liking from pre- to post-Pavlovian emotional rating sessions. Both awareness groups responded similarly during instrumental training, but groups experiencing monetary loss showed a reduction in response rate compared to groups not experiencing loss. In transfer, a facilitatory effect of the 50p CS was manifest in response initiation, but only an inhibitory effect was seen in response rate. Furthermore, any transfer effect was limited to groups demonstrating expectancy awareness. Personality data suggested that Extraversion was related to CS hedonic discrimination in unaware participants.

Conclusions – The VI10 schedule was successful in allowing for cue-potentiation of instrumental responding during the transfer phase, but the aversive training manipulation served to depress responding regardless of cue. Expectancy awareness was confirmed as necessary for PIT, but further study should investigate its sufficiency by manipulating cue-elicited hedonic value.

5.2 Introduction

Experiment 2 found that only a group of participants who correctly expected an O after viewing its associated S displayed PIT. While this group also rated the S as more emotionally salient, the direct influence of S-induced emotionality could not be dissociated from S-induced expectancy, as a group of participants without O expectancies did not display PIT. However, the PIT effect demonstrated by the aware group was solely an inhibitory one – their responding was reduced after a reward-absence cue, but not increased after a reward-presence cue. Thus the lack of transfer in the unaware group may have been because the task did not allow for any increase in responding that an isolated emotional response to an appetitive cue may otherwise have brought.

Indeed, a series of experiments by Lovibond (1981, 1983) showed that the presentation of an S interfered with the ongoing R to the extent that response rates were reduced, and increased only when baseline levels were especially low. Similarly, on closer inspection of the data used to support the demonstration of general PIT by Dickinson & Dawson (1987), where *facilitation* of responding to an appetitive S was claimed, *suppression* of responding to a *non-appetitive* S was in fact more apparent. Moreover, Wyvell and Berridge (2000, 2001) showed only marginally significant appetitive PIT effects in control rats, with reliable response elevation only coming after experience with amphetamine. Thus an appetitive PIT effect may be less likely to occur in non-clinical samples without suitable methodology designed to reduce baseline response rates.

Methodological precedents for achieving such ends have been set in two forms. The first is the use of effortful instrumental schedules, under which the number of responses required to receive reinforcement is high. Such a technique has been used to successfully demonstrate facilitatory PIT in multiple studies (Corbit & Balleine, 2005; Nadler et al., 2011; Prévost et al., 2012), with a ratio of responses to reinforcements no lower than 5:1. However, PIT has been shown to be less stable when using ratio schedules compared to interval schedules (Lovibond, 1981, 1983), potentially explained by the greater ability of interval schedules to engender habitual responding (Yin & Knowlton, 2006), and the greater ability of habitual responding to show PIT (Holland, 2004). Thus the second, more effective, precedent is the use of long instrumental schedules, under which the duration of response required to receive reinforcement is high. Such interval schedules have also shown facilitatory PIT (Colwill & Rescorla, 1988, 1990; Talmi et al., 2008; Trick et al., 2011), with a ratio of interval to response no lower than 5:1. A third technique to lower baseline responding may be to introduce intermittent aversive consequences to instrumental performance. This holds face-validity when investigating addictive processes, in that drug-seeking may occasionally be punished through negative health effects, arrests, social disapproval, but the effects of such a manipulation on PIT performance in humans is not known.

Along with alterations to the instrumental schedule to facilitate PIT, the previous experiment may also be improved through changes to the measurement of EC. Although the current method of associating novel CSs with appetitive USs in a counterbalanced manner accords with criteria for valid assessment (Hofmann et al., 2010; Lovibond & Shanks, 2002), demonstrating a change in rating across time, from pre- to post-conditioning, would provide strong evidence that any EC was genuinely associative in nature, rather than being an artefact of stimulus pairings.

Thus the current study was devised to test whether reducing baseline response rates, via increased response duration or partial punishment, would allow an increase in responding in the presence of a separately trained appetitive stimulus. It was also designed to scrutinise the associative basis of the evaluative conditioning effects seen in the previous two studies.

5.3 Method

5.3.1 Participants

Participants were 75 University of Sussex students (36 males and 39 females) with a mean age of 20.61 years (range 18-30). Other participant details were as General Methods.

5.3.2 Design & Procedure

5.3.2.1 Emotional evaluations – pre-Pavlovian

A baseline CS emotional ratings session was inserted prior to Pavlovian training, in order to measure the change in rating across conditioning. This pre-Pavlovian session was introduced with the phrase: "You will first be asked some questions about a set of pictures." All other details were as General Methods.

5.3.2.2 Instrumental training

The change of instrumental training conditions introduced for this experiment was predicated on a pilot study conducted to ascertain appropriate reinforcement schedules for the purposes of reducing baseline responding. Details of this pilot study can be found in Appendices, section 10.1.1 below.

Prior to instrumental training participants were allocated to either an appetitive or an aversive version of the task. The appetitive version was as described in General Methods. The aversive version was similar except that the VR2 schedule was modified such that participants would either win 50p *or lose 50p* with 50% contingency, rather than winning 50p or nothing. Thus successful pressing under the VI10 schedule was met with either "You win 50p" or "You lose 50p". Unsuccessful pressing was still signalled by "You win nothing", and no response at all was still signalled by a blank screen.

5.3.3 Statistical analyses

Although data were collected until 32 participants displayed expectancy awareness, analysis of the full 75 participants' instrumental training data found that 7 failed to receive positive reinforcement. These 7 participants were excluded from all analyses. All participants completing the aversive version experienced punishment.

5.4 Results

5.4.1 Group-level analyses

5.4.1.1 Expectancy awareness

Of the remaining 68 participants, 29 (43%) participants were classified as aware (14 males, 15 females), 23 (34%) unaware (11 males and 12 females), with 16 (23%) falling outside either category. These 16 non-classified participants were excluded from further analysis, leaving 52. Aware and unaware groups did not differ significantly in terms of age [$t(50) < 1$] or gender [$\chi^2(1) = .001$, $p = .974$].

The aware group was able to correctly identify the predictive validity of both CSs in the final block of Pavlovian training; unaware participants were, as per their classification, unaware of either CS-US relationship. The two groups' mean expectancy rating for each CS in the final block of the Pavlovian phase is depicted in Figure 5.4.1.1.

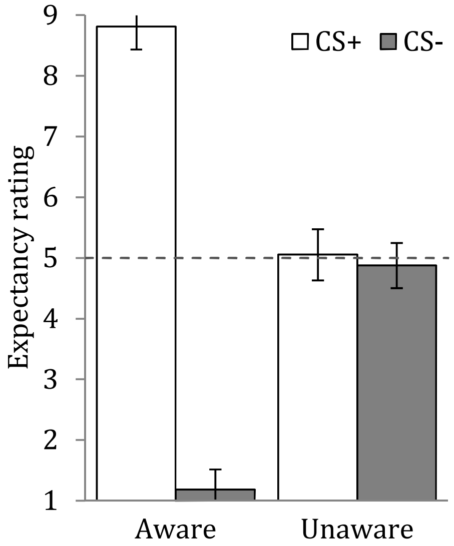

Figure 5.4.1.1. Mean expectancy rating of winning 50p after presentation of each CS for aware and unaware groups.
Line at 5 indicates rating of 'don't know'; CS_+, Pavlovian CS predictive of 50p; $CS_\pm$, Pavlovian CS non-predictive; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95%CI.

A mixed ANOVA of expectancy ratings, with CS and Awareness as factors, revealed a main effect of CS and a CS*Awareness interaction [$Fs(1,50) > 356$, $ps < .001$]. The interaction was investigated using one-tailed t-tests comparing each CS rating from each group to 5; the aware group's ratings for each CS differed significantly from 5 [$ts(28) > 39.0$, $ps < .001$], whereas the unaware group's ratings did not differ from 5 [$ts < 1$].

5.4.1.2 Evaluative conditioning

Pleasantness ratings at the start of Pavlovian training were similar across CSs and awareness groups, but after association with reward the CS+ was rated more pleasant, and the CS- less pleasant, than the CS± in the aware group (see Figure 5.4.1.2 for mean pleasantness rating of each CS before and after Pavlovian training in aware and unaware groups).

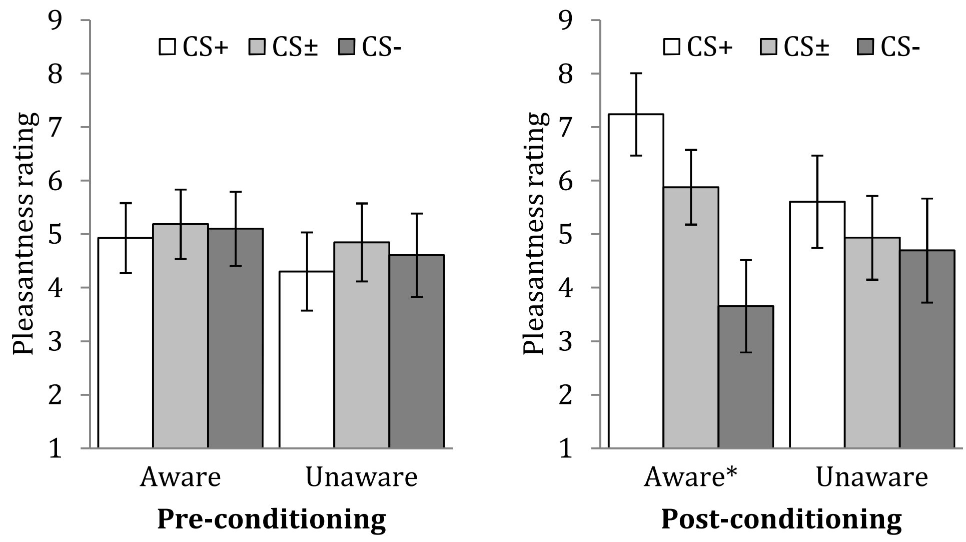

Figure 5.4.1.2. Mean pleasantness rating for each CS pre- and post-Pavlovian conditioning for each awareness group.
**** = CS_+ > $CS_\pm$ > CS- [ps < .008]; CS_+, Pavlovian CS predictive of 50p; $CS_\pm$, Pavlovian CS non-predictive; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95% CI.***

A mixed ANOVA with CS, Time (pre- vs post-conditioning) and Awareness as factors revealed significant main effects of CS and Time [*Fs* > 6.11, *ps* < .006], and significant interactions for CS*Time and CS*Time*Awareness [*Fs* > 5.55, *ps* < .008]. The three-way interaction was followed by RM ANOVAs split by Awareness and Time, which found non-significant effects of CS pre-conditioning [Fs < 1], but a significant effect post-conditioning in the aware group [$F(1.38,38.6) = 21.3$, $p < .001$]. Post-hoc comparisons located this effect as being between all three levels of CS (CS+ > CS± > CS-) [*ps* < .008].

Although the main analysis found no differential effect of CS on pleasantness rating in the unaware group, exploratory analysis found an increase in CS+ rating over time. Student's t-tests comparing the unaware group's pleasantness ratings before vs after conditioning showed a significant increase for the CS+ [$t(22) = 2.22$, $p = .037$, uncorrected], yet non-significant changes for the other two CSs [*ts* < 1].

As with pleasantness ratings, anxiety ratings were similar across CSs and groups before Pavlovian training, but after conditioning the CS- generated more anxiety than the other CSs in both groups.

Table 5.4.1.1 presents mean anxiety ratings at each time-point for each CS separately for aware and unaware groups.

Table 5.4.1.1. Mean (95%CI) anxiety ratings of each CS pre- and post-Pavlovian conditioning for aware and unaware groups.

	Pre-conditioning			Post-conditioning		
	CS_+	$CS_\pm$	CS-	CS_+	$CS_\pm$	CS-*
Aware	2.21(.58)	1.85(.44)	1.90(.42)	1.86(.70)	2.12(.53)	4.14(.99)
Unaware	1.78(.66)	1.59(.49)	1.52(.48)	2.78(.79)	2.52(.60)	3.52(1.11)

Note: * = CS- > CS_+ = $CS_\pm$ [ps < .001]; CS_+, Pavlovian CS predictive of 50p; $CS_\pm$, Pavlovian CS non-predictive; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95% CI.

A mixed ANOVA with CS, Time and Awareness as factors revealed significant main effects of CS and Time [*Fs* < 8.20, *ps* < .001], and a significant interaction of CS*Time [$F(1,100) = 13.3$, $p < .001$]. The interaction was investigated using separate RM ANOVAs at each time-point, with CS as the only factor. These confirmed that there were non-significant differences between CSs pre-conditioning [$F(1.68,85.6) = 1.72$, $p = .189$], but significant differences post-conditioning [$F(1.68,85.6) = 14.3$, $p < .001$]. Post-hoc comparisons revealed this post-conditioning CS effect to be due to a higher anxiety rating for the CS- compared to CS+ or CS± [*ps* < .001].

5.4.1.3 Instrumental training

After removing the 7 participants who failed to receive positive reinforcement during the instrumental phase the appetitive and aversive versions of the task contained 14 and 15 aware participants, respectively, with 15 and 8 unaware participants, respectively. These differences in frequencies were non-significant [$\chi^2(1) = 1.49$, $p = .222$]. All participants completing the aversive version experienced punishment.

To investigate the relative number of reinforcements received by aware and unaware participants in each version of training, separate analyses were run for the appetitive and aversive tasks due to there necessarily being zero punishments in the appetitive version. A t-test of positive reinforcements revealed a non-significant effect of Awareness in the appetitive task [$t(27) = 1.60$, $p = .120$]. Similarly, a mixed ANOVA with Reinforcement type (positive, punishment) as the within-subjects factor and Awareness as the between-subjects factor found no significant effects [$Fs(1,21) < 1$]. Figure 5.4.1.3 - Figure 5.4.1.5 display reinforcements, RI, and RR separated by awareness and training groups.

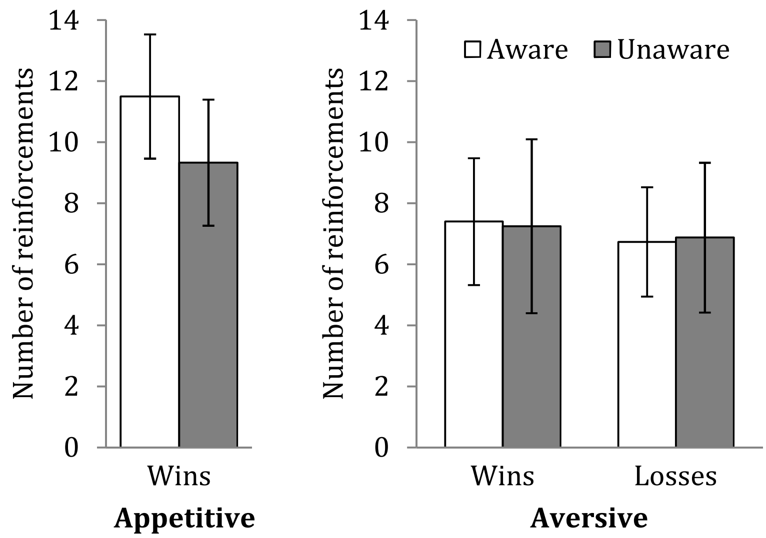

Figure 5.4.1.3. Number of reinforcements experienced by aware and unaware groups given appetitive or aversive instrumental training.
Error bars represent 95%CI.

A series of mixed ANOVAs were run for each of the two remaining behavioural variables with Training (appetitive, aversive) and Awareness as between-subjects factors, and Block (1-4) as the within-subjects factor. For RI these revealed non-significant effects [*Fs* < 3.32, *ps* > .075].

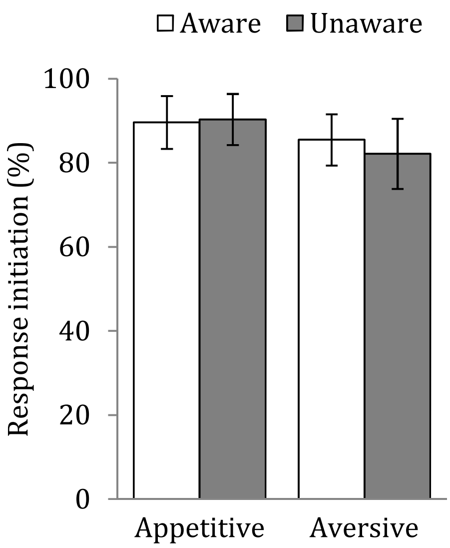

Figure 5.4.1.4. Response initiation for aware and unaware groups given appetitive or aversive instrumental training.
Error bars represent 95%CI.

For RR there were main effects of Block and Training [*Fs* > 9.10, *ps* < .004]; post-hoc comparisons explained the Block effect as being due to lower rates for block 1 compared to all others [*ps* < .001].

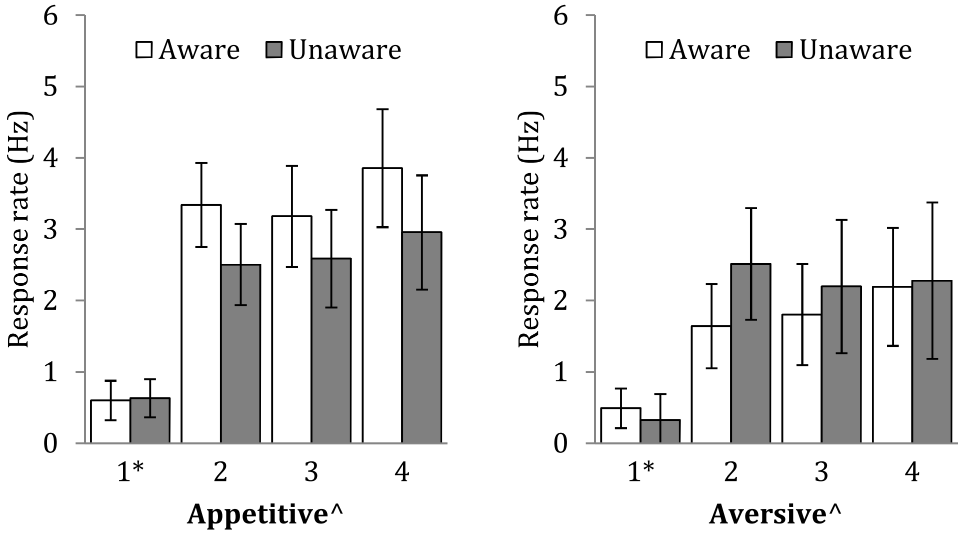

Figure 5.4.1.5. Response rate for aware and unaware groups during each block of instrumental training under appetitive or aversive conditions.
^ appetitive > aversive [p = .004]; * block 1 < blocks 2-4 [ps < .001]; error bars represent 95%CI.

5.4.1.4 Transfer

Aware participants demonstrated transfer regardless of instrumental version. Despite not developing differential outcome expectancies in the Pavlovian phase, unaware participants experiencing aversive instrumental conditions also displayed transfer, although to a lesser extent than their aware counterparts.

5.4.1.4.1 Response initiation

Separate mixed ANOVAs were run for each of the two behavioural variables (RI, RR) with Stimulus (CS+, S±, CS-) and Block (1,2) as within-subjects factors, and Awareness and Training as between-subjects factors. For RI this revealed significant main effects of Stimulus, Block, and Training [*Fs* > 5.20, *ps* < .028], and a significant Stimulus*Awareness interaction [$F(2,96) = 3.69$, $p = .029$]. The interaction was followed by mixed ANOVA with Stimulus, Block and Training as factors, separated by Awareness. In aware participants this found significant main effects of Stimulus and Block [*Fs* > 5.47, *ps* < .027], with post-hoc comparisons showing all Stimulus comparisons to differ (CS+ > S± > CS-; *ps* < .004). In unaware participants there were significant main effects of Stimulus, Block, and Training [*Fs* > 4.51, *ps* < .046], and a significant Stimulus*Training interaction [$F(2,42) = 4.74$, $p = .014$]. This interaction in the unaware group was investigated by separate RM ANOVAs for each training group, with Stimulus and Block as factors. Effects were non-significant for the appetitive group [*Fs* < 2.21, *ps* > .160], but there was a main effect of Stimulus in the aversive group [$F(2,14) = 5.08$, $p = .022$], albeit explained by post-hoc comparisons as being due to a trend-level difference between CS+ and CS- [$p = .062$]. Figure 5.4.1.6

contains mean RI separated by Awareness [left/right], Training [top/bottom], Stimulus, and Block.

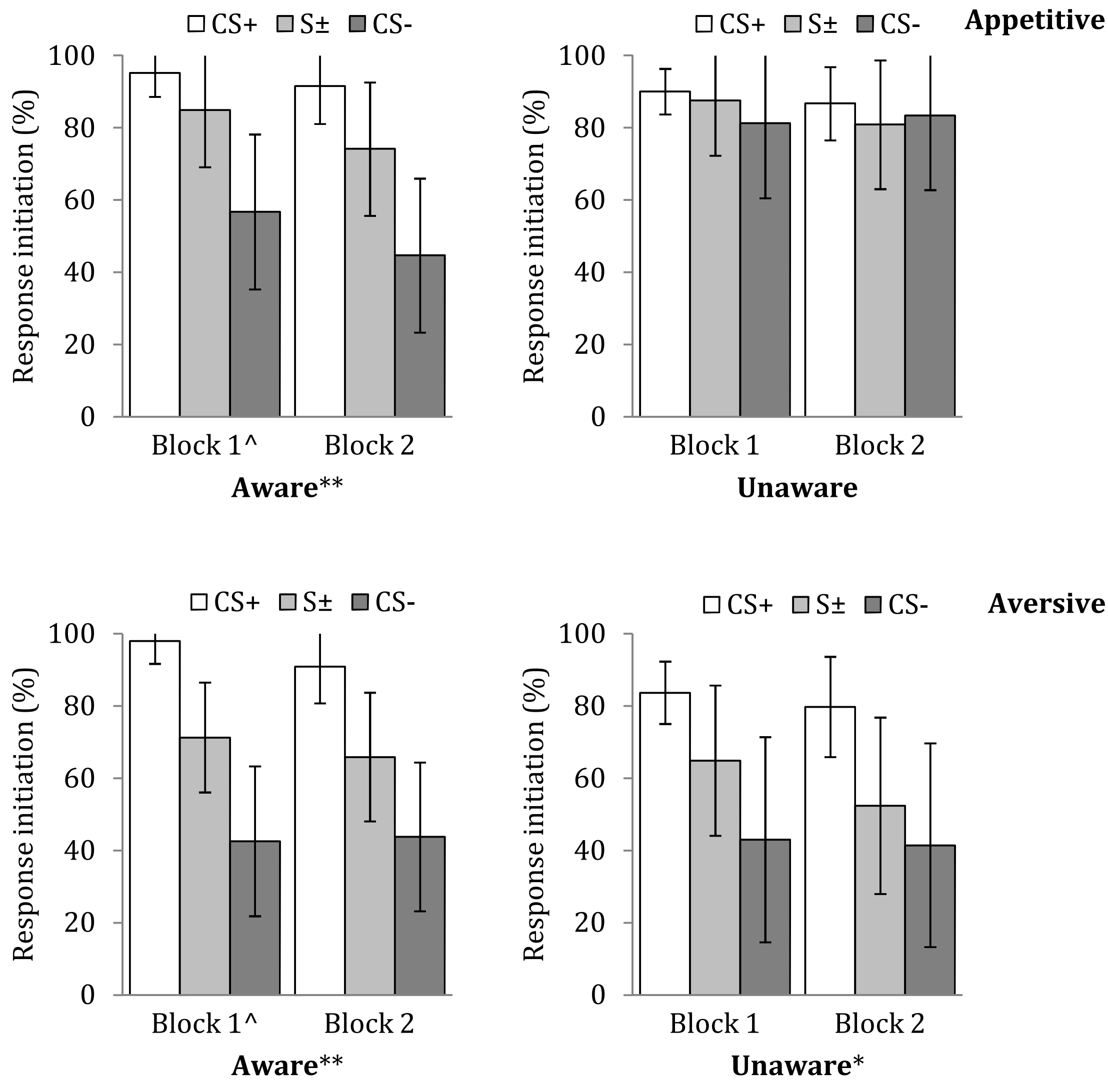

Figure 5.4.1.6. Mean response initiation (%) according to stimulus type and block, aware groups shown left, unaware groups shown right, appetitive training shown top, aversive training shown bottom.
**** = CS_+ > CS- [p = .062], ** = CS_+ > $S_\pm$ > CS- [ps < .004], ^ = block 1 > block 2 [p = .027]; CS_+, Pavlovian CS predictive of 50p; $S_\pm$, grey squares from instrumental training; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95% CI.***

5.4.1.4.2 Response rate
The pattern of RR data was similar to that of RI, though rates did not diminish over time (see Figure 5.4.1.7 for mean RR). The mixed ANOVA revealed main effects of Stimulus and Training [Fs > 16.4, ps < .001], and a Stimulus*Training*Awareness interaction [F(1.50,72.1) = 6.98, p = .004]. The three-way interaction was investigated with further mixed ANOVAs split by Awareness, with Stimulus and Training as factors. In the aware

group this showed main effects of Stimulus and Training [*Fs* > 16.3, *ps* < .001], with post-hoc comparisons finding CS- to be significantly lower than CS+ or S±, which themselves did not differ significantly [*ps* < .002]. In the unaware group there were significant effects of Stimulus and Stimulus*Training [*Fs*(2,42) > 5.12, *ps* < .011]. This interaction was followed by separate RM ANOVAs for each training condition, which found a non-significant Stimulus effect in the appetitive condition [*F* < 1], compared to a trend-level Stimulus effect in the aversive condition [*F*(2,14) = 3.41, *p* = .062], driven by CS- RR being lower than CS+, though non-significantly so after Bonferroni-corrected comparisons [*p* = .184].

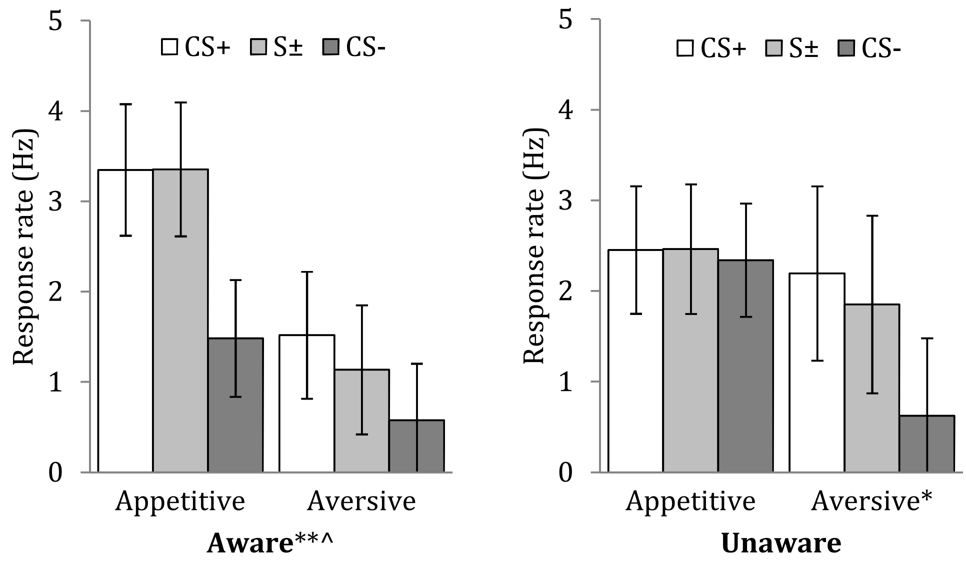

Figure 5.4.1.7. Mean response rate (Hz) as a function of stimulus type and instrumental training conditions, separately for aware [left] and unaware [right] groups.
Error bars represent 95%CI. * = CS- < CS+ [p = .184], ** = CS- < S± = CS+ [ps < .002], ^ = aversive < appetitive [p < .001]; CS+, Pavlovian CS predictive of 50p; S±, grey squares from instrumental training; CS-, Pavlovian CS predictive of winning nothing.

5.4.1.5 Transfer expectancy

The aware group's expectancy of winning during transfer accurately ranked the reward contingencies of the three stimuli (CS+ > S± > CS-). The unaware group, despite their classification, reported higher reward expectancies for the CS+ than either S± or CS-. Figure 5.4.1.8 presents mean transfer expectancy ratings for each stimulus, separated by Training and Awareness.

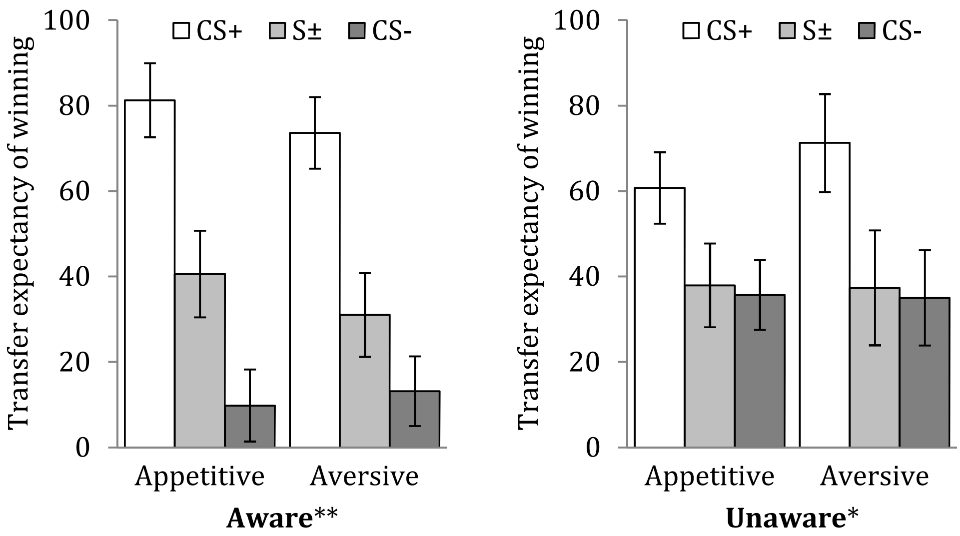

Figure 5.4.1.8. Mean expectancy of winning during transfer according to stimulus, separated by instrumental training conditions and awareness group. Error bars represent 95%CI. * CS+ > S± = CS- [ps < .001], ** CS+ > S± > CS- [ps < .001]; CS_+, Pavlovian CS predictive of 50p; $S_\pm$, grey squares from instrumental training; CS-, Pavlovian CS predictive of winning nothing

A mixed ANOVA of transfer expectancy ratings with Stimulus, Awareness and Training as factors found significant effects of Stimulus and Stimulus*Awareness [$Fs(2,96) > 15.6$, $ps < .001$]. The interaction was followed by separate RM ANOVAs for each awareness group with Stimulus as the only factor. These revealed a significant effect of Stimulus in the aware group [$F(2,56) = 146$, $p < .001$] due to all three levels differing significantly from one another [$ps < .001$], compared to a significant effect of Stimulus in the unaware group [$F(2,44) = 20.9$, $p < .001$] due to CS+ differing from S± and CS- [$ps < .001$].

5.4.2 Role of personality in PIT

5.4.2.1 Awareness classification

Logistic regression analyses with the domains from the NEO or TCI were inputted as predictors of awareness classification. Neither questionnaire model was significant [$\chi s^2 < 4.0$, $ps > .40$].

5.4.2.2 Expectancy discrimination

Treating awareness as a continuous variable, linear regressions were run with either the NEO or TCI domains as predictors and expectancy discrimination index as the outcome, for aware participants only. Neither model was significant [$Fs < 1.04$, $ps > .42$].

5.4.2.3 Evaluative conditioning

The influence of personality on evaluative conditioning was measured by regressing CS emotional discrimination scores on NEO or TCI personality domains. Pleasantness analyses were separated by Awareness, due to the significant effects of Awareness in section 5.4.1.2 above, whereas anxiety analyses were conducted on the entire cohort. For aware participants neither the NEO nor TCI models were significant [*Fs* < 1.33, *ps* > .33]. Similarly for unaware participants, neither model was significant overall [*Fs* < 1.66, *ps* > .20], but E was a significant individual predictor of pleasantness discrimination within the main NEO model [β = .58, *p* = .018].

Although the unaware group showed a non-significant post-Pavlovian pleasantness discrimination, their evaluative conditioning was manifest in a significant increase in CS+ rating over time (see section 5.4.1.2 above). Thus the change in rating from pre- to post-Pavlovian conditioning was entered as the dependent variable in regressions using the two sets of personality domains as predictors, targeted only at unaware participants. However, neither model was significant [*Fs* < 1.8, *ps* > .17].

Models containing anxiety ratings were also non-significant [*Fs* < 1].

5.4.2.4 Transfer discrimination

Regression models were computed separately for RI and RR discrimination index (CS_+ - CS_-), and split by Awareness and Training due to their significant effects at the group level (see section 5.4.1.4 above). No model was significant [*Fs* < 3.0, *ps* > .07].

However, due to the success of the VI10 schedule in producing a significant facilitation of CS_+ RI above $S_\pm$, appetitive RI transfer-effect scores (CS_+ - $S_\pm$) were used as the dependent variable in a further set of regression analyses. Models were again non-significant [*Fs* < 1.3, *ps* > .35]. In contrast, comparable analyses using appetitive RR transfer-effect scores found, in aware appetitively trained participants, that a model containing the four TCI domains was significant [R^2 = .87, $F(4,8)$ = 6.26, *p* = .014], after the removal of one outlier (std res > 2; model was non-significant before removal [$F(4,9)$ = 1.97, *p* = .18]), with NS the sole significant contributor [β = -.70, *p* = .016]. Exploration of this result by regressing either CS_+ or $S_\pm$ RR on NS found neither model to be significant [*Fs* < 1].

5.5 Discussion

The primary aim of the current experiment was to test whether an appetitive stimulus could increase a separately trained response, if the task engendered sufficiently low levels of baseline responding, rather than simply allowing a non-appetitive stimulus to decrease the response. Such a positive transfer effect was achieved, in that there was a significant increase in the number of trials where a response was initiated in the presence of a reward-predictive stimulus compared to a non-predictive stimulus. In the group of participants aware of the CS-US contingency, this result was obtained regardless of whether the instrumental response was partially punished. In contrast, the unaware group displayed positive transfer only when aversive training conditions had been experienced. To describe this effect as general transfer may, however, be premature, as the same group of unaware participants also showed increased expectancy of winning under reward-predictive cue conditions, thus questioning their categorisation as unaware.

The experiment was also designed to scrutinise the evaluative conditioning effect seen in the previous studies, by measuring stimulus valence prior to conditioning. EC was robust in the aware group, showing change over time as well as stimulus differences post-conditioning. Tentative support for EC in the unaware group was obtained, in that an increase in CS_+ rating was observed over time, but differences between the CS_+ and the other CSs after conditioning was less strong than in the previous experiments.

The study also sought to replicate the positive relationship between Neuroticism and propositional discriminative learning found in the previous two experiments. No evidence was found for such a relationship in the current cohort. However, an exploratory investigation discovered that Novelty-Seeking negatively predicted the facilitatory transfer effect, albeit only in aware participants trained under appetitive conditions.

The success of the VI10 schedule in eliciting a positive transfer effect in aware participants accords with previous studies that have used similar interval schedules to similar effect (Colwill & Rescorla, 1988, 1990; Holland, 2004; Lovibond, 1983; Talmi et al., 2008; Trick et al., 2011). The finding that manipulation of a VR schedule had no effect on transfer also accords with the unstable PIT effects demonstrated when using ratio schedules (Lovibond, 1981, 1983). The lack of effect on PIT of aversive training also supplements an experiment by Lovibond (1981) that found a PIT effect despite the transfer phase being conducted under signalled extinction. In the current experiment the transfer phase was conducted under signalled punishment, for half the cohort, yet an appetitive PIT effect was still observed. Thus despite potential response futility, as was the case for Lovibond, or risk, as was the case here, an appetitive stimulus was still able to increase responding.

Such concordance lends support to the notion of the S having its effect on behaviour via an expectation of the O (Colwill & Rescorla, 1988; de Wit & Dickinson, 2009; Hogarth et al., 2007), in that an S carrying an expectancy of an appetitive O was able to override an R engendering expectancies of a neutral or negative O. This interpretation is made more complicated by the similarity of results, in the aware group, for pleasantness ratings and response initiation, in that both follow a linear pattern through CS_+, $S_\pm$, CS_-, thus any attribution of behavioural results to expectancy could be confounded by emotion. However, the RI PIT effect demonstrated by the ostensibly unaware group experiencing aversive training is in better accord with their transfer expectancy ratings than their CS pleasantness ratings, in that there was a significant and marginal effect of S for RI and transfer expectancy, respectively, yet a non-significant effect of CS for pleasantness. Thus the overall pattern of data better support an explanation of appetitive PIT here in terms of expectancy than emotion. Such a summation is tentative, however, due to the quasi-experimental nature of these findings.

However, facilitatory PIT was confined to RI; only inhibitory PIT was seen in RR. This provides an intriguing dissociation between the two assays. While the pattern of RI behaviour better fits expectancy ratings, the pattern of RR is in better agreement with anxiety ratings, in that the CS_- was rated as more anxiety-provoking than the other CSs, and provoked fewer responses per trial than the other CSs. Thus the anxiety-laden CS_- elicited an avoidance response, manifested primarily in RR. The dissociation of these two behavioural variables is corroborated by experiments that have explicitly parsed reward-seeking into distal and proximal responses by using an instrumental response chain, where pressing one lever gives rise to a second lever, and pressing this second lever gives rise to a reward (Balleine, 1992; Balleine, Garner, Gonzalez, & Dickinson, 1995; Corbit & Balleine, 2003). These studies showed that distal responses were sensitive to changes in O expectancy, whereas proximal responses were sensitive to changes in S value. To the extent that the variables of RI and RR used in the current experiment can be considered distal and proximal to reward, their differential reactions to CSs may therefore be attributable to their differing sensitivity to O expectancy versus S emotional value.

Such an assertion would predict, however, that a facilitatory effect should be seen in RR as well as RI, which was not the case here. On the one hand this may be due to the comparatively weak influence of evoked pleasantness, compared to anxiety, on behaviour, allowing only CS_- anxiety to influence responding. Indeed, the purported general PIT described by Nadler et al (2011) was seen only when using aversive Ss, which the authors attribute to the greater emotional significance attributed to aversive rather than appetitive outcomes. Alternatively, participants may have tried to 'maximise', that is press consistently to ensure reward, rather than 'match', that is press in line with perceived instrumental contingencies (Hinson & Staddon, 1983; Wolford, Newman, Miller, & Wig, 2004). Thus if participants had initiated a response to the $S_\pm$ they would execute that response in the same manner as their response to the CS_+, as such a strategy would maximise the number of rewards gained.

If the emotional explanation is correct then introducing an objectively aversive element to Pavlovian training may further encourage differential responding; if the maximising explanation is correct then ensuring that participants have sufficient experience of the 50% instrumental contingency may encourage matching, as maximising is no more optimal than matching when contingency equals 50% (Wolford et al., 2004). This latter end may be better served by reverting to a purely appetitive instrumental contingency, as the partially aversive contingency introduced here caused a reduction in transfer expectancy ratings to below 50%. Additionally, more participants were excluded from the aversive group than the appetitive group due to lack of reward during instrumental training, thus the aversive manipulation should be removed from future studies.

The introduction of pre-conditioning evaluative ratings may also have been problematic. Differentiation between each CS was reduced in both aware and unaware groups, compared to Experiment 2, to the extent that the CS effect became non-significant in the unaware group. While this baseline rating session was intended to clarify unaware EC, its influence on aware participants' ratings suggests that it may have confounded it instead. Presentation of the CSs prior to conditioning may have caused latent inhibition (Lubow & Moore, 1959), and although the two presentations of each CS would ordinarily be too low to elicit such an effect (Lubow, 1973), the addition of the rating questions may have caused each CS's emotional value to be consolidated at a neutral point. Whereas aware participants may be able to re-consolidate their judgements with propositional knowledge of the CS→US association, unaware participants' EC may be insufficiently intense to manipulate their ratings (Alberini, 2005). The fact that the unaware group showed a change in CS_+ rating over time suggests that some degree of EC did occur, but that the baseline rating phase changed the manner in which such EC was expressed. Moreover, the fact that the various CSs were rated as non-significantly different before conditioning supports the demonstration of unaware EC in the previous two experiments by removing the confound of pre-conditioning differences.

Less consistent across studies has been the association of Neuroticism with discriminative learning; positive correlations in the first two experiments were not repeated in this third experiment. This may also have been due to the baseline evaluative rating session interfering with learning, but could also be explained as being due to the multifaceted nature of the N factor. It may be that one of its six facets is primarily responsible for N's relationship with learning, but that the facet's relationship with N has differed across different cohorts. Indeed, the relationship between NEO factors and addiction contains nuanced information at the facet level that is lost at the factor level (Ruiz et al., 2003; Terracciano & Costa, 2004), thus future analysis at the lower-order level may elucidate the influence of N on discriminative learning. Further studies may also investigate the consistency of the suppressive effect of Novelty-Seeking on cue-potentiated RR found in the current study. The direction of the relationship runs contrary to that predicted by Cloninger (1987; Cloninger et al., 1994), who attributes NS with a role in approach to reward cues, whereas the reduction in RR here is more in keeping with an avoidance response.

Finally, although the current experiment finds again that expectancy awareness is *necessary* for the control of behaviour by separately trained reward-paired cues, it does not attest to whether it is *sufficient*. It may be that knowledge of the O coupled with an ECR is required, alternatively an expectancy representation alone may be all that is needed to influence reward-seeking. Future research should attempt to isolate the sensory aspects of an O by manipulating the level of emotional response elicited by an S in order to address these propositions.

In conclusion, it was found that a stimulus paired with reward was able to increase, and a stimulus paired with non-reward was able to decrease, a separately trained instrumental response. Effects of the stimuli on behaviour, whether facilitatory or inhibitory, only occurred in groups showing an expectancy of the relevant outcome. Facilitation was only apparent in the frequency of response initiation, rather than response rate, which attests to the dissociable effects of a cue's predictive versus emotional properties. Inter-individual variation in the facilitation of response rate was negatively predicted by Novelty-Seeking, a result which runs contrary to the domain's theoretical grounding and so will require further investigation. The use of a partially aversive instrumental training schedule did not influence the stimulus effect on responding, but instead had a more general suppressive effect on response rate, to the extent that it reduced the number of rewards earned during training. Subsequent investigation should attempt to experimentally manipulate CS emotional value to dissociate its effects on behaviour from outcome expectancy.

6 Single-response PIT with counter-conditioning

6.1 Abstract

Background – Experiment three provided further support for the necessary status of reward expectation in mediating PIT. But whether expectancy is sufficient, or whether it interacts with emotion, requires experimental manipulation.

Aims - Thus the aim of this fourth experiment was to investigate whether reducing the hedonic value of a reward-paired cue would bring about changes in PIT. It also sought to understand the inconsistent effect of personality on aspects of the PIT paradigm by targeting analyses at lower-order traits.

Methods – 68 participants completed a PIT task with a counter-conditioning procedure. The Pavlovian phase associated two visual CSs with either winning nothing or 50 pence, respectively. Then one group underwent a counter-conditioning manipulation where the reward-predictive cue was paired with unpleasant pictures, whereas another group served as control. An instrumental phase trained participants to make a single button-pressing response to win 50p. The transfer phase measured the change in instrumental responding after presentation of either CS, and whether any influence on responding was imparted by the counter-conditioning phase.

Results – 28 participants developed expectancy awareness after Pavlovian training. All groups liked the 50p CS more than the other CSs after Pavlovian training, but counter-conditioning reduced this 50p CS liking. In transfer, the aware group experiencing aversive counter-conditioning showed an abolition of facilitatory PIT in the presence of the 50p CS, while the control group showed maintenance of such facilitatory PIT. Facet-level personality regression models found that negative-affect traits predicted levels of expectancy awareness, whereas positive-affect traits predicted the magnitude of CS hedonic value attribution and reward-cue potentiation of response rate.

Conclusions – Both expectancy and emotion are necessary for cue-potentiated instrumental responding. Hedonic value of a reward-paired cue influences instrumental responses that are closest to reward delivery, but not those that are further away from reward delivery. Predispositions to negative-affect facilitate the development of reward expectation, whereas predispositions to positive-affect facilitate hedonic reactions, when encountering reward-paired cues.

6.2 Introduction

Experiment 3 confirmed that an expectation of reward is necessary for conditioned stimuli to moderate a separately trained instrumental response. This is consistent with experiments 1 & 2, as well as a large body of extant literature arguing for the necessary status of such cognitive processes in reward-seeking (Bolles, 1972; de Wit & Dickinson, 2009; Hogarth et al., 2007; Hogarth & Duka, 2006). However, complementary theories of the role of conditioned stimuli in reward-seeking propose that the emotional and motivational responses elicited by such stimuli exert an additional influence on behaviour (Berridge, 2000; Bindra, 1974; Robinson & Berridge, 1993; Toates, 1986). In support, the present set of experiments has found indirect evidence for the moderation of cue-potentiated behaviour by emotional conditioned responses, but have been unable to dissociate expectancy from emotion. The interactive effects of these two psychological processes on cue-potentiated reward-seeking therefore remain unclear.

The majority of investigations into the moderating role of conditioned responses on stimulus-elicited reward-seeking have manipulated the hedonic value of the reward itself, rather than that of its conditioned stimulus (Colwill & Rescorla, 1990; Hogarth, 2012; Holland, 2004). While changes in O value can be reflected in changes in S value (Berridge, 2000; M. Field et al., 2004; Toates, 1986), different behavioural paradigms are differentially sensitive to such changes. For example, Dickinson & Dawson (1987) trained rats to associate one S with sucrose and another S with pellets, before the rats learned that pressing a single lever earned both sucrose and pellets. Following devaluation of pellets through satiety the authors found that instrumental responding was reduced in the presence of the pellet S compared to the sucrose S, arguing that such an effect demonstrated sensitivity to the changed O value.

However, in a series of similar experiments, Holland (2004) showed that although baseline instrumental responding was sensitive to O value, facilitation of the R by separately trained Ss was unaffected by O devaluation. Holland also showed that as O value became less influential on baseline responding, S effects became more influential, suggestive of a shift in behavioural control from O value to S value. Thus the disparate findings of Dickinson & Dawson and Holland may be explained by their two paradigms being differentially sensitive to S value.

Such a hypothesis may be tested by directly altering the hedonic value of the reward-paired S through the process of counter-conditioning (CC, Baeyens et al., 1989; Dickinson & Pearce, 1977). After pairing an initially neutral CS with an appetitive US, the CS is then paired with a US of opposite valence to the original. Although the initial appetitive pairing is successful in increasing the liking attributed to the CS, the subsequent aversive pairing is able to abolish or even reverse this emotional conditioned response (Hollands, Prestwich, & Marteau, 2011; Kerkhof, Vansteenwegen, Baeyens, & Hermans, 2011; Van Gucht et al., 2010). CC has a lasting effect on evaluative ratings of CSs (Kerkhof et al., 2011), and has been shown to reduce consumption of appetitive food (Hollands et al., 2011; Van Gucht et al., 2010).

However, the mediation of the effects of CC on behaviour by CS hedonic value may be confounded by the effects of CC on US expectancy, in that CC studies so far either confirm that US expectancy tracks CS emotional value (Van Gucht et al., 2010), or are unable to falsify such a claim (Baeyens et al., 1989; Kerkhof et al., 2011). Thus a technique to deliver CC while dissociating its effects on expectancy from emotion is required. Such a technique may be informed by the finding that changes in context have dissociable effects on cue-elicited expectancy and emotion (Van Gucht et al., 2013). Using an ABA context shift design, where appetitive conditioning occurred in context A, followed by CC in context B, it was demonstrated that a return to context A renewed US expectancy but did not renew CS liking. Thus expectancy appears sensitive to contextual changes, whereas ECRs are less sensitive to such shifts. Conducting any CC in a session distinct from that of the rest of an experiment may therefore allow for changes in CS liking that are dissociated from changes in US expectancy.

While the context in which CC is conducted appears less influential on its success, the direction of valence change may be more influential in whether changes in EC are expressed. Greater consistency of effect has been shown when reversing an originally appetitive CS compared to an originally aversive CS (Baeyens et al., 1989; Dickinson & Pearce, 1977; Stevenson, Boakes, & Wilson, 2000), thus attempting to reduce the pleasantness of a reward-predictive CS may be more effective than reducing the anxiety attributed to a reward-absence predictive CS. Additionally, indirect evidence suggests that any behavioural effect of manipulating CS pleasantness may manifest itself in responses proximal rather than distal to reward (Balleine, 1992; Balleine et al., 1995; Corbit & Balleine, 2003). Using instrumental response chains, where a series of separate responses is required for reward, Balleine and colleagues showed that presentation of a reward-paired CS only influenced responses closer to the end of the instrumental chain. Thus CC effects on instrumental responding would be expected to be detected in response rate more than response initiation.

Moreover, personality factors associated with addiction risk have been shown to have a greater effect on proximal rather than distal drug-seeking. A relationship between positive-affective traits and substance misuse has been documented for multiple drugs (Cloninger, 1987; Ruiz et al., 2003; Terracciano & Costa, 2004). A possible explanation for this association is provided by Hogarth (Hogarth, 2011) who finds that non-planning impulsivity influences nicotine consumption, a proximal response, but does not alter nicotine seeking, a distal response. This corroborates the finding of a relationship between Novelty-Seeking and cue-potentiated response rate in the previous experiment, as NS contains facets pertaining to aspects of impulsivity (Cloninger et al., 1994), warranting detailed examination of the influence of NS on cue-potentiated instrumental responding.

In light of these converging data, the present experiment was devised to test whether reducing the positive emotional value of a reward-predictive stimulus would bring about concomitant reductions in response rate under conditions of cue-potentiated instrumental behaviour. It also sought to replicate the association between Novelty-Seeking and cue-potentiated response rate found in the previous experiment, and to obtain a more detailed understanding of this relationship at the facet level.

6.3 Method

6.3.1 Participants

Participants were 68 University of Sussex students (23 males and 45 females) with a mean age of 19.3 years (range 18-27). Other participant details were as General Methods.

6.3.2 Materials

All phases used the same materials as described in General Methods. The addition of the CC phase brought with it 12 aversive and 36 neutral images taken from the International Affective Picture System Database (IAPS, Lang, Bradley, & Cuthbert, 2008). Pictures were selected to ensure a balance of images depicting humans, due to the potential for human scenes to elicit greater attention. Figure 6.3.2.1 displays exemplar images; list of full set can be found in Appendices, section 10.1.2. According to the IAPS database, which rated valence (unpleasant – pleasant) and arousal (unarousing – arousing) on a 9-point Likert scale, the aversive set had a mean valence of 1.97 (SD = .034) and arousal of 5.83 (SD = 0.82), whereas the neutral set had a mean valence of 5.01 (SD = .036) and arousal of 2.82 (SD = 0.56). Aversive and neutral sets differed significantly on both valence and arousal [$ps < .001$].

Figure 6.3.2.1. Images used during counter-conditioning manipulation, showing aversive [left] and neutral [right] exemplars.
Note that images were displayed in colour to participants.

Images were displayed at the same size and resolution as Pavlovian CSs, 10.2 cm^2 at a resolution of 1280 x 1024 pixels, as specified in General Methods. Responses during the CC task used the left and right arrow keys, of a different keyboard from that used in Pavlovian training, labelled yellow to highlight their activation.

6.3.3 Design & Procedure

6.3.3.1 Counter-conditioning

After giving their post-Pavlovian emotion ratings, participants took a 1min break before they experienced the counter-conditioning phase. They were randomly allocated to either neutral or aversive conditions, though allocation was constrained to ensure gender balance. The phase began with the following instructions:

> In this task you will see pairs of pictures. After each pair has been presented you will be asked to press an arrow key to indicate which picture you recognise. Press the left arrow if you have seen the picture on the left before. Press the right arrow if you have seen the picture on the right before. You should respond as quickly as possible after the question has appeared. Press the spacebar to start.

Trials then started with a black fixation cross, positioned centrally on a grey screen, for 1s, followed by a stimulus pair of duration 5s. One image was always a Pavlovian CS, the other was an IAPS picture. Stimuli were presented side-by-side, in the vertical centre of the screen, with a gap of 1cm between them. These differences in presentation compared to the Pavlovian phase were designed to emphasise the change in context from Pavlovian to

CC. The question "Which picture have you seen before?" then appeared below the stimuli for 2.5s, during which time participants responded using the labelled arrow keys. This response requirement was designed to encourage participants to view both images, rather than avoiding any potentially aversive pictures. Trials ended with a grey screen of duration 1s before the next began.

There were 36 trials in total, thus 12 trials each of CS_+, $CS_\pm$, CS- (the two $CS_\pm$ were presented 6 times each). A different IAPS picture was used in each trial, though this was not communicated to participants. Order of presentation was random, horizontal position of CS, and association of CS category (CS_+, $CS_\pm$, CS-) with specific neutral images, was counterbalanced. Those assigned to the neutral condition saw all CSs paired with neutral photographs, those in the aversive condition saw the CS_+ paired with aversive images, yet the other CSs were paired with neutral images.

Upon completion of the final trial participants took a further 1min break, before completing a second evaluative rating session. This second session began with the instruction:

> In a moment you will perform a different task where you can win money. But first please answer some questions about the pictures you have seen. Press the spacebar to start.

The purpose of the break between CC and second rating session, and making reference to winning money, was to change the context again to better match the transfer phase, to ensure that participants' responses were not specific to the CC context. The rest of the rating session continued as had that of the first, described in General Methods.

6.3.4 Statistical analyses

The CC procedure was piloted in a small sample before use in the main study to test its effectiveness. This pilot confirmed the method's suitability by showing a complete abolition of differential pleasantness ratings, between all CSs (see Appendices, section 10.1.2 for details).

Data were collected until 32 participants displayed expectancy awareness, as per General Methods, but analysis of the full 68 participants' instrumental training data found that 6 failed to receive positive reinforcement in training. These 6 participants were excluded from all analyses.

To quantify the effectiveness of the CC procedure a 'CC-effect' score was calculated as the change in CS_+ pleasantness rating from post-Pavlovian to post-CC (Pavlovian – CC). This measure was used as the outcome variable in a regression model to investigate the moderating role of personality in the CC procedure.

6.4 Results

6.4.1 Group-level analyses

6.4.1.1 Expectancy awareness

Of the remaining 62 participants, 28 (45%) were classified as aware (14 males and females), 19 (31%) unaware (5 males and 14 females), with 15 (24%) falling outside either category. These 15 non-classified participants were excluded from further analysis, leaving 47. Aware and unaware groups did not differ significantly in terms of age [$t < 1$] or gender [$\chi^2(1) = 2.64$, $p = .104$].

Both groups' expectancy data from the final block of Pavlovian training were in keeping with their individual classifications. Mean expectancy rating from the final block of the Pavlovian phase are presented in Figure 6.4.1.1.

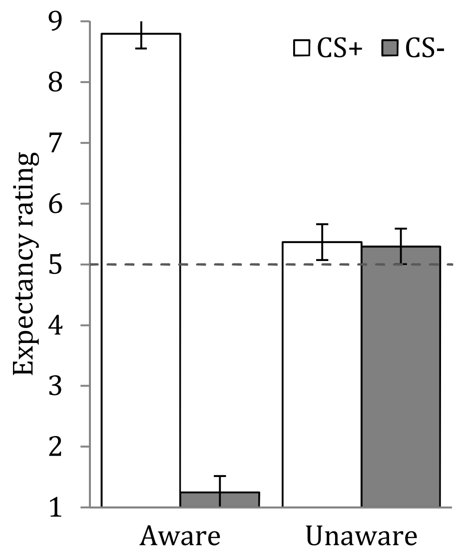

Figure 6.4.1.1. Mean expectancy rating of winning 50p after presentation of each CS for aware and unaware groups in the final block of the Pavlovian phase.
Line at 5 indicates rating of 'don't know'; error bars represent 95%CI; CS_+, Pavlovian CS predictive of 50p; CS-, Pavlovian CS predictive of winning nothing

A mixed ANOVA of final block expectancy ratings with CS and Awareness as factors showed significant CS and CS*Awareness effects [$Fs(1,45) > 849$, $ps < .001$]. The interaction was followed with separate t-tests for each group, comparing each CS rating to 5; the aware group's ratings differed significantly from 5 [$ts(27) > 38.6$, $ps < .001$] while the unaware group's did not [$ts(18) < 1.93$, $ps > .069$].

6.4.1.2 Evaluative conditioning

After removing the 6 participants excluded for later non-reinforcement of instrumental responding, the neutral and aversive CC group contained 12 and 16 aware participants, respectively, with 10 and 9 unaware participants, respectively. These differences in group numbers were non-significant [$\chi^2(1) = .434$, $p = .510$].

While there was little effect on pleasantness ratings of neutral CC, aware participants in the aversive CC group showed a reduction of CS+ ratings to levels comparable to the CS±. Figure 6.4.1.2 shows mean pleasantness ratings for each group at each time-point.

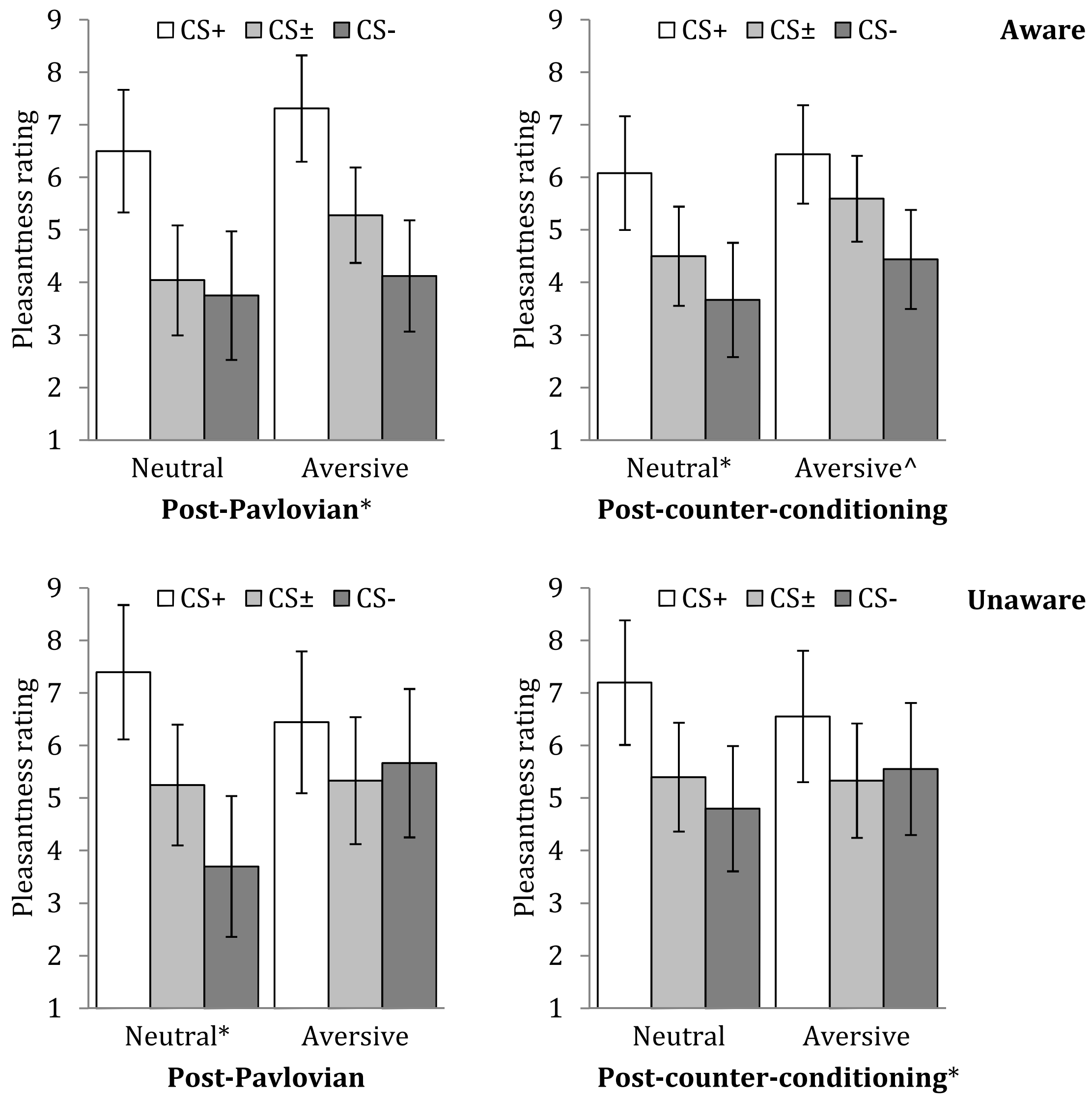

Figure 6.4.1.2. Mean pleasantness rating for each Pavlovian CS according to valence of counter-conditioning stimuli encountered, separated by timepoint [left/right] and awareness [top/bottom].
Error bars represent 95%CI. * CS_+ > $CS_\pm$ [ps < .039, uncorrected], ^ CS_+ = $CS_\pm$ [p = .253, uncorrected]; CS_+, Pavlovian CS predictive of 50p; $CS_\pm$, Pavlovian CS non-predictive; CS-, Pavlovian CS predictive of winning nothing.

A mixed ANOVA of pleasantness ratings, with CS, Time (post-Pavlovian, post-CC), Awareness and CC (neutral, aversive) as factors, found only a main effect of CS [$F(2,86) = 22.8$, $p < .001$], with post-hoc comparisons finding CS+ ratings to be significantly higher than CS± and CS- ratings (CS+ > CS± = CS-; *ps* < .001).

However, to provide a more powerful analysis of the effects of CC, RM t-tests targeting the difference between CS+ and CS± at each level of Awareness, CC, and Time were run. Post-Pavlovian CS+ ratings were significantly higher than CS± for aware groups regardless of subsequent CC allocation, and for the unaware group in the neutral CC allocation [*ts* > 2.72, *ps* < .018, uncorrected] (for the unaware group in the aversive CC allocation $t(8) = 1.60$, $p = .149$). In contrast, post-CC ratings were significantly higher for CS+ than CS± in unaware groups regardless of CC experience, and for the aware group experiencing neutral CC [*ts* > 2.47, *ps* < .038, uncorrected]. The aware group experiencing aversive CC was the only group to show a non-significant difference between CS_+ and $CS_\pm$ at this final rating session [$t(15) = 1.19$, $p = .253$].

Due to the aversive nature of the CC manipulation, CS anxiety ratings were scrutinised in the same manner as pleasantness ratings. The ANOVA, with CS, Time, Awareness and CC as factors, reported only an interaction between Time and CC [$F(1,43) = 4.68$, $p = .036$]. This was followed by independent-groups t-tests on overall anxiety ratings (collapsing CS and Awareness) comparing each CC group, separately for each time-point. These revealed non-significant differences between CC groups at both timepoints [*ts*(45) < 1.24, *ps* > .22]. When conducting the same targeted contrasts as per pleasantness ratings, comparing CS_+ to $CS_\pm$ anxiety rating, all tests were non-significant [*ts* < 1.05, *ps* > .324].

6.4.1.3 Instrumental training

Participants learned the instrumental response regardless of Awareness or CC allocation.

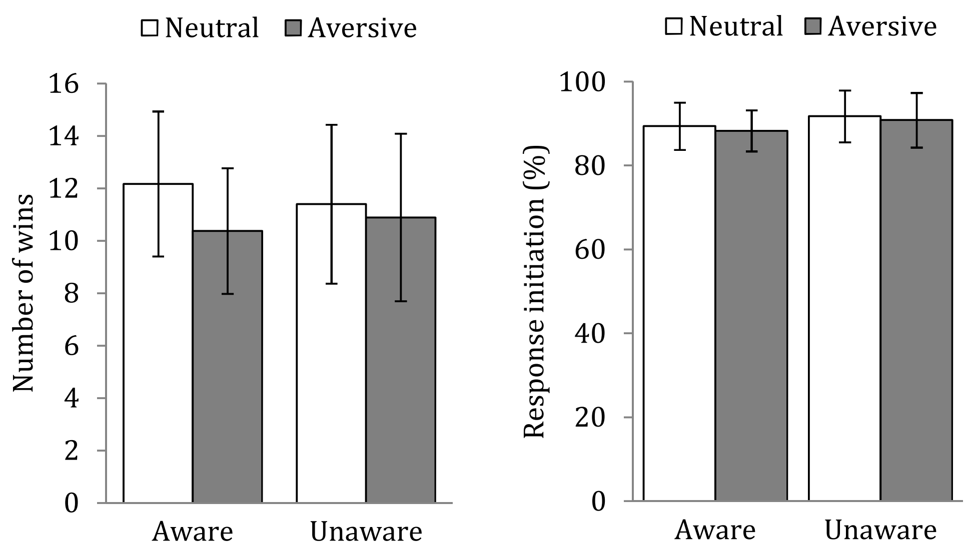

Figure 6.4.1.3. Number of wins and response initiation during instrumental training for aware and unaware groups experiencing either neutral or aversive counter-conditioning. Error bars represent 95%CI.

Figure 6.4.1.3 & Figure 6.4.1.4 contain mean values of reinforcements, RI, and RR during instrumental training according to CC and Awareness groups.

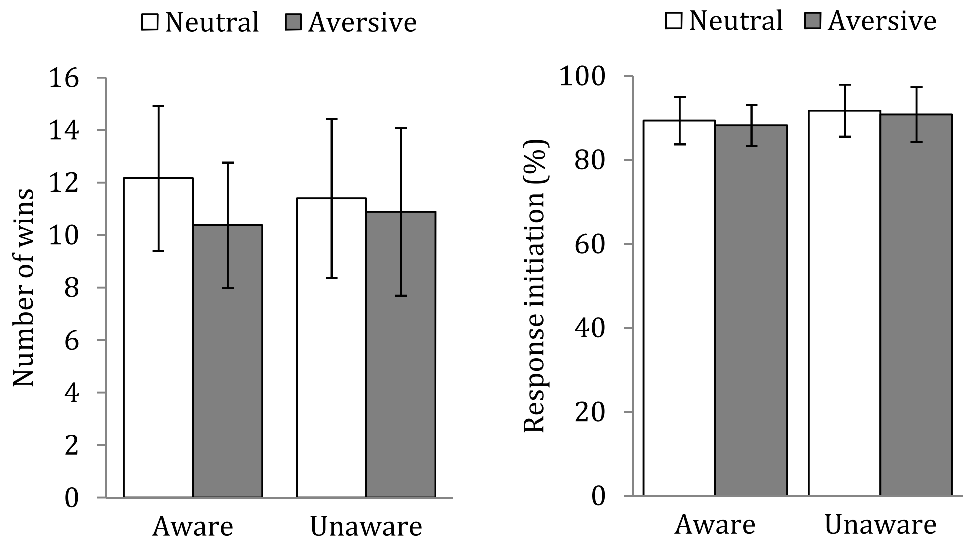

Figure 6.4.1.3. Number of wins and response initiation during instrumental training for aware and unaware groups experiencing either neutral or aversive counter-conditioning.
Error bars represent 95%CI.

A factorial ANOVA of number of reinforcements gained was conducted, with Awareness and CC as factors, and found non-significant differences throughout [*Fs* < 1]. Mixed ANOVAs were run with Awareness, CC, and Block (1-4) as factors, separately for RI and RR. For RI these revealed non-significant effects [*Fs* < 1]. For RR there was again an effect of Block [$F(2.03,87.1) = 107$, $p < .001$] explained by block 1 having a lower RR than 2—4 [*ps* < .001]; no other effects attained statistical significance [*Fs* < 2.85, *ps* > .074].

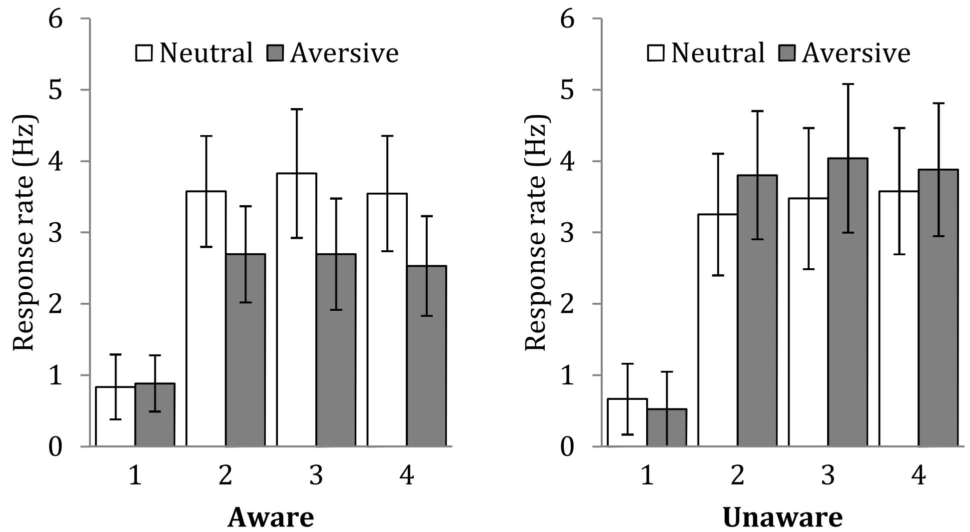

Figure 6.4.1.4. Response rate for aware [left] and unaware [right] groups experiencing either neutral or aversive counter-conditioning during each block of instrumental training.
**** block 1 < blocks 2—4 [ps < .001]; error bars represent 95%CI.***

6.4.1.4 Transfer

Transfer of conditioned responses from the Pavlovian stimuli onto the instrumental response was seen only in the aware group. However, this transfer effect was reduced in the RR of aware participants in the aversive CC group.

A series of mixed ANOVAs was run for RI and RR, with Awareness, CC, Stimulus (CS+, S±, CS-) and Block (1, 2) as factors.

6.4.1.4.1 Response initiation

The omnibus ANOVA revealed significant effects of Stimulus, Block, and the Stimulus*Awareness interaction [*Fs* > 13.3, *ps* < .001]. The interaction was followed by separate RM ANOVAs for each awareness group, with Stimulus and Block as factors. These showed main effects of Stimulus and Block in the aware group [*Fs* > 8.58, *ps* < .007], with post-hoc comparisons finding all levels of Stimulus to differ significantly (CS+ > S± > CS-, *ps* < .007), and an effect of Block in the unaware group [$F(1,18) = 7.74$, $p = .012$]. See Figure 6.4.1.5 for mean RI. Planned contrasts of CS_+ versus $S_\pm$ RI for each of the four group permutations, Block collapsed, confirmed significant differences for both aware groups [*ts* > 2.94, *ps* < .011], and non-significant differences for both unaware groups [*ts* < 1].

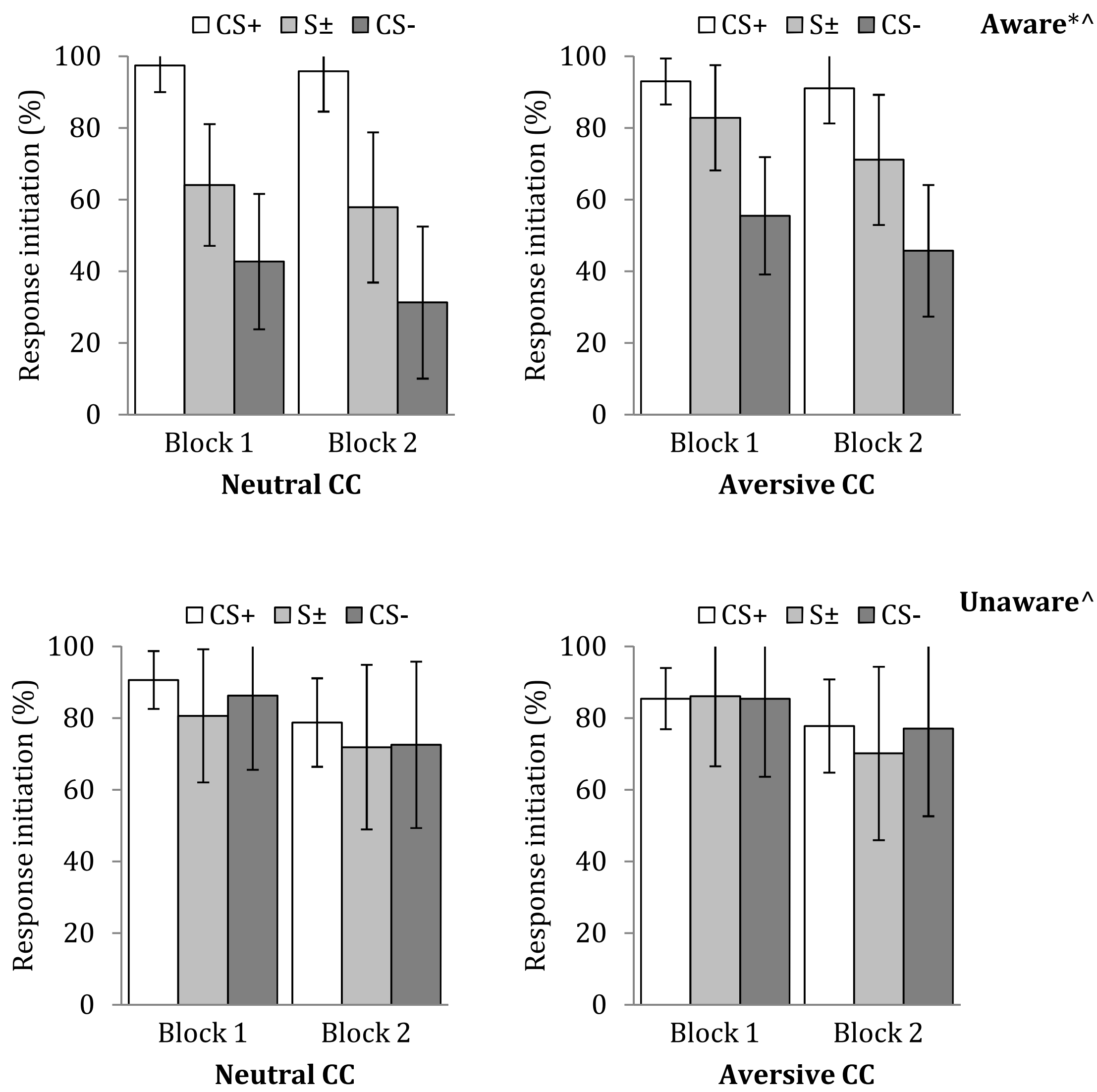

Figure 6.4.1.5. Mean response initiation (%) during transfer for each stimulus, separated by block, counter-conditioning group[left/right], and awareness[top/bottom].
**** $CS_+ > S_\pm >$ CS- [ps < .007]; ^ block 1 > block 2 [ps < .012]; CS_+, Pavlovian CS predictive of 50p; $S_\pm$, grey squares from instrumental training; CS-, Pavlovian CS predictive of winning nothing; error bars represent 95% CI.***

6.4.1.4.2 Response rate

The omnibus ANOVA revealed significant main effects of Stimulus and Block, and interactions of Stimulus*Awareness and CC*Awareness. The interactions were explored with mixed ANOVAs, containing CC, Stimulus and Block as factors, separately for each awareness group. These revealed, in the aware group only, main effects of all three factors [*Fs* > 7.42, *ps* < .012], with post-hoc comparisons showing the Stimulus effect to be due to CS- RR being lower than CS+ and S± [*ps* < .024]. Figure 6.4.1.6 presents RR at each factor level.

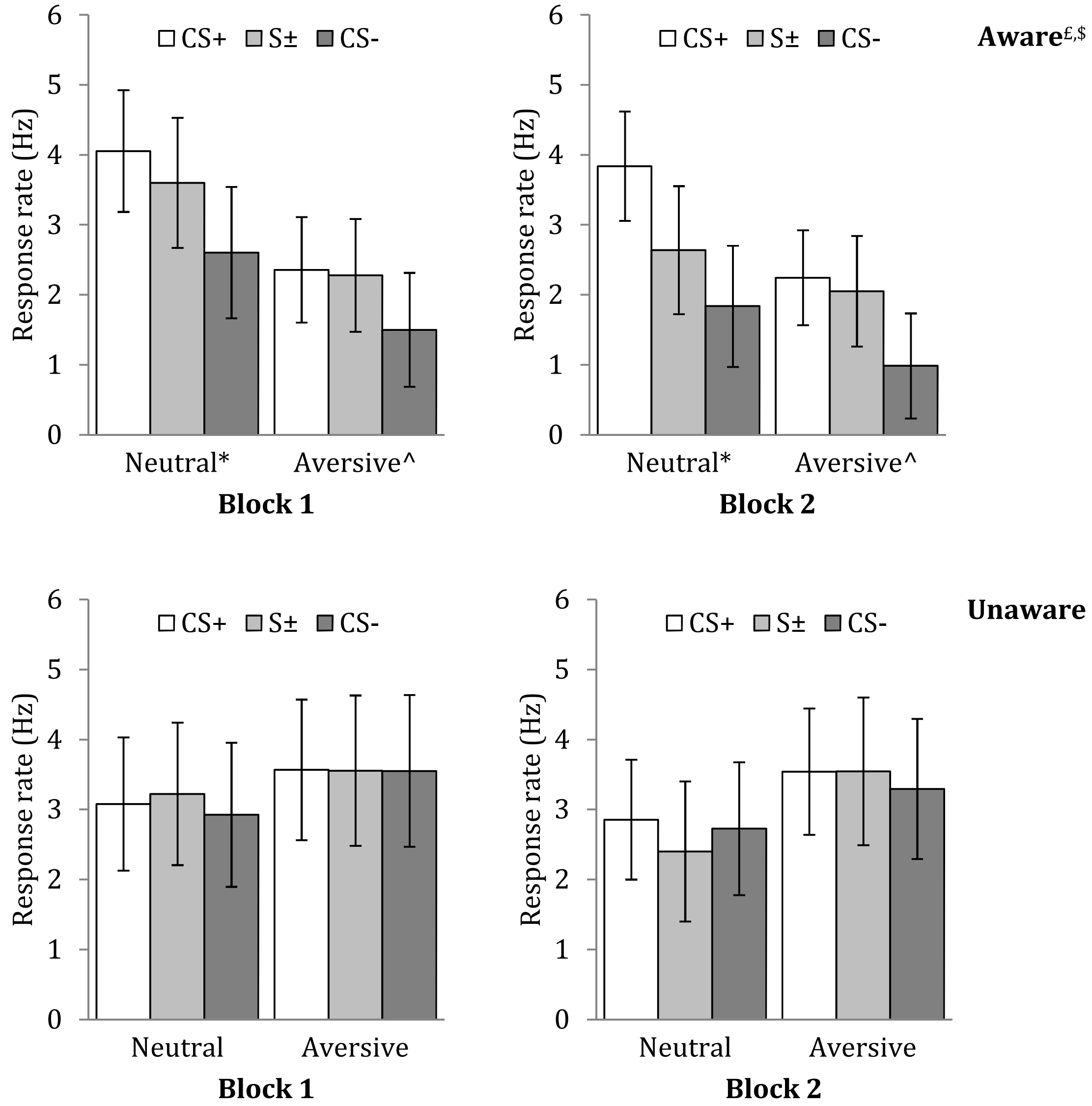

Figure 6.4.1.6. Mean response rate for each stimulus during transfer, shown separately for counter-conditioning (CC) group, awareness [top/bottom] and block [left/right].
Error bars represent 95%CI. * CS+ > S± (block collapsed) [p = .038, one-tailed], ^ CS+ = S± (block collapsed) [p = .212, one-tailed], [£] neutral CC > aversive CC [p = .004], [$] block 1 > block 2 [p = .011]. CS_+, Pavlovian CS predictive of 50p; $S_{\pm}$, grey squares from instrumental training; CS-, Pavlovian CS predictive of winning nothing.

Although the ANOVA in aware participants found no evidence for a differential effect of CC on PIT, i.e. there was no CC*Stimulus interaction, planned contrasts indicated that aversive CC had suppressed CS+ PIT. 1 further participant in the neutral group was removed from this planned analysis due to them reporting anomalous transfer behaviour[1]. Similar to the contrasts performed for pleasantness ratings (see Section 6.4.1.2), RM t-tests were targeted at aware participants of each CC group, comparing CS+ to S± RR, Block collapsed.

[1] This participant reported, during a debriefing session, that their strategy during the transfer phase had been to "press less when the [CS+] appeared, because it meant you'd already won". All other participants reported pressing *more* during CS+ trials, because it was more *likely* that they would win. Removing this participant from the main analyses did not change the pattern of results.

These confirmed a significant increase in CS+ RR within the neutral group [$t(10) = 2.27$, $p = .047$], yet a non-significant increase within the aversive group [$t(15) = .820$, $p = .425$].

6.4.1.5 Transfer expectancy

A mixed ANOVA on expectancy of winning during transfer was conducted with Stimulus (CS+, S±, CS±, CS-), Awareness, and CC as factors. It revealed main effects of Stimulus and CC [$Fs > 5.72$, $ps < .022$], qualified by a Stimulus*Awareness interaction [$F(3,129) = 11.4$, $p < .001$]. The interaction was followed with separate ANOVAs for aware and unaware groups, with Stimulus and CC as factors. In aware participants this found a main effect of Stimulus only [$F(3, 78) = 44.6$, $p < .001$], explained with post-hoc comparisons as due to CS+ > S± = CS± > CS- [$ps < .011$]. Effects were non-significant in unaware participants. Table 6.4.1.1 contains mean expectancy ratings during transfer.

Table 6.4.1.1. Mean (95%CI) expectancy of winning during transfer as a function of awareness, counter-conditioning, and stimulus.

		Stimulus			
	CC	CS_+	$S_\pm$	$CS_\pm$	CS-
Aware*	Neutral	83.4(10.1)	42.9(13.9)	33.5(10.4)	17.1(10.2)
	Aversive	79.6(8.74)	33.1(12.1)	48.1(9.00)	27.8(8.85)
Unaware	Neutral	46.3(11.1)	38.8(15.3)	42.5(11.4)	31.2(11.2)
	Aversive	56.5(11.7)	52.5(16.1)	43.1(12.0)	45.3(11.8)

Note: * CS+ > S± = CS± > CS- [ps < .011]. CS_+, Pavlovian CS predictive of 50p; $S_\pm$, grey squares from instrumental training; $CS_\pm$, Pavlovian CS non-predictive; CS-, Pavlovian CS predictive of winning nothing.

6.4.2 Role of personality in PIT

6.4.2.1 Awareness classification

To investigate whether awareness categorisation could be predicted by personality, separate logistic regression analyses were run for the NEO and TCI with their respective domains as predictors and Awareness as the outcome. For the NEO, the model was non-significant [$\chi^2(5) = 7.37$, $p = .195$]. However, due to the relationship between N and speed of awareness, found in the previous studies, a second analysis was conducted targeted at the six facets of N. This second model was a significant predictor of Awareness [$\chi^2(6) = 16.6$, $p = .011$], correctly classifying 72% of participants, with Vulnerability the only variable contributing significantly to the model [*Exp(B)* = 1.16, $p = .014$]. For the TCI, the initial model incorporating its four domains was non-significant [$\chi^2(4) = 3.70$, $p = .45$]. However, a second model including only the four facets of HA was significant [$\chi^2(4) = 13.4$,

p = .010], correctly classifying 70% of participants, with Shyness and Anticipatory-Anxiety the only significant predictors [*Exps(B)* > 1.10, *ps* < .033].

Finally, to assess their relative contributions, the three significant facets from the NEO and TCI were combined within one model. The overall model was significant [$\chi^2(3) = 13.3$, p = .004], correctly classifying 70% of participants, but Vulnerability was the only significant predictor [*Exp(B)* = 1.09, p = .035]. Table 6.4.2.1 contains parameter estimates for each of the three facets entered into the final regression equation.

Table 6.4.2.1. Parameter estimates (95%CI) of negative-affect facets predictive of Awareness classification included in logistic regression model.

Predictor	*B*	Exp(*B*)	*p*
Vulnerability*	0.09(0.08)	1.09(0.08)	.035
Anticipatory-Anxiety	0.01(0.08)	1.01(0.08)	.771
Shyness	0.04(0.08)	1.04(0.09)	.333
Constant*	-6.60(4.83)		.007

Note: R^2 = .21 (Hosmer Jr & Lemeshow, 2004), Model $\chi^2(3) = 13.3$, p = .004; * p < .05; awareness coded higher.

6.4.2.2 Expectancy discrimination

In addition to their ability to dichotomise participants, personality domains were also entered into multiple regression analyses with CS expectancy discrimination as the outcome to assess their moderating influence on awareness (in aware participants only). For the NEO, the equation containing all five factors was non-significant [$F(5,22) = 1.34$, p = .29]. However, a subsequent model focussing on facets of N was a significant predictor of CS discrimination [R^2 = .49, $F(6,21) = 3.33$, p = .018]. Of the six facets included, only Hostility accounted for unique variance [β = .64, p = .004]. Similarly for the TCI, the model containing its four domains was non-significant [$F(4,23) = 0.97$, p = .44]. But again, a second model including only the four facets of HA was significant [R^2 = .41, $F(4,23) = 3.99$, p = .013], with Fear of Uncertainty and Fatigue contributing significantly to the model [β = .56, p = .040; β = -.50, p = .020, respectively].

Finally, the three uniquely contributing facets from the NEO and TCI were combined in one analysis, which provided a significant model [$F(3,24) = 8.98$, p < .001], with all three predictors explaining unique variance in CS discrimination (Table 6.4.2.2 contains individual coefficients).

Table 6.4.2.2. Regression coefficients (95%CI) of personality facets predicting CS expectancy discrimination.

Predictor	*B*	*β*	*p*
Hostility*	0.07(0.05)	.46	.006
Fear of Uncertainty*	0.09(0.06)	.52	.009
Fatigue*	-0.07(0.06)	-.46	.014
Constant	1.39(3.02)		.353

Note: R^2 = .53, p < .001; * ps < .05.

6.4.2.3 Evaluative conditioning

6.4.2.3.1 Appetitive conditioning

Similar to the expectancy discrimination analysis, regression models were created with the factors of the NEO or TCI as predictors of pleasantness discrimination (CS^+ - CS^-) after Pavlovian conditioning. Data from both awareness groups were combined due to the non-significant effect of awareness on emotional ratings after Pavlovian training (see section 6.4.1.2 above). Using the NEO, a model containing its five factors was significant [R^2 = .23, $F(5,41)$ = 2.48, p = .047], with E and C being the only two significant predictors [*βs* > .40, *ps* < .014]. Table 6.4.2.3 displays equation coefficients for the five factors. To investigate the specific contributions of these two factors, separate models for each were run with their respective six facets; both models were non-significant [*Fs* < 1.26, *ps* > .29]. For the TCI, neither a model containing its four domains, nor the four facets of NS, was significant [*Fs* < 1.25, *ps* > .31].

Table 6.4.2.3. Regression coefficients (95%CI) of NEO factors predictive of CS pleasantness rating discrimination after Pavlovian training.

Predictor	*B*	*β*	*p*
Neuroticism	0.05(0.07)	.19	.182
Extraversion*	0.10(0.08)	.40	.012
Openness	0.03(0.08)	.10	.548
Agreeableness	0.02(0.10)	.04	.781
Conscientiousness*	0.12(0.10)	.41	.014
Constant	-11.9(11.9)		.051

Note: R^2 = .23, p = .047; * p < .05. CS discrimination = CS_+ - CS-.

6.4.2.3.2 Counter-conditioning

Due to the relationship between post-CC pleasantness ratings and transfer RR (refer to section **Error! Reference source not found.Error! Reference source not found.**), the potential moderating role of personality on these two measures was assessed in a similar manner to Pavlovian phase CS discrimination (see section 6.4.2.4 below for transfer discrimination). Post-CC CS pleasantness discrimination index was the outcome variable, with either the NEO or TCI main factors as predictors. This analysis was again targeted at aware participants assigned to neutral CC conditions. For the NEO the model was non-significant [F = 1.98, p = .22]. However, for the TCI, a model containing its four domains was significant [R^2 = .76, F(4,7) = 5.64, p = .024], with NS the only significant independent predictor [β = .92, p = .006]. To explore this relationship further the four facets of NS were entered as predictors, revealing a significant model [R^2 = .79, F(4,7) = 6.71, p = .015] with Impulsiveness as the only significant contributor to the equation [β = .48, p = .046] (see Table 6.4.2.4 for regression coefficients of all four facets).

Table 6.4.2.4. Regression coefficients of Novelty-Seeking facets predictive of CS pleasantness discrimination post-counter-conditioning, for aware participants assigned to neutral counter-conditioning.

Predictor	B	β	p
Exploratory-Excitability	0.08(0.11)	.31	.158
Impulsiveness*	0.17(0.17)	.48	.046
Extravagance	0.02(0.12)	.07	.764
Disorderliness	0.13(0.18)	.40	.141
Constant	-16.9(9.05)		.003

Note: R^2 = .79, p = .015; * p < .05. CS discrimination = CS^+ - CS^-.

To identify individuals most susceptible to the counter-conditioning procedure, multiple repression analyses were run with CC-effect (CS_+ change) as the outcome variable and the factors of the NEO or TCI as predictors. This analysis was targeted at aware participants in the aversive CC condition as they were the only group to show any effect of the CC manipulation. For the NEO, the model was non-significant [F < 1]. Exploratory analyses targeting the facets of either N (due to the aversive nature of CC) or E (due to its relationship with EC above) were similarly non-significant [Fs < 1.30, ps > .35]. In contrast, inputting the four domains of the TCI resulted in a significant overall model [R^2 = .56, F(4,11) = 3.48, p = .045], with NS the only significant individual predictor [β = .86, p = .004]. A subsequent model with the four facets of NS revealed that Extravagance contributed most strongly to this relationship [β = .62, p = .018] (see Table 6.4.2.5 for equation coefficients of the four facets[2]).

[2] This pattern of relationship was similar when inputting Pavlovian CS^+ rating into the model, thus removing the confound of regression to the mean.

Table 6.4.2.5. Regression coefficients (95%CI) of Novelty-Seeking facets predictive of counter-conditioning effect, for aware participants assigned to aversive counter-conditioning.

Predictor	*B*	*β*	*p*
Exploratory-Excitability	-0.02(0.10)	-.09	.679
Impulsiveness	0.06(0.10)	.29	.214
Extravagance*	0.13(0.10)	.62	.018
Disorderliness	0.01(0.11)	.03	.875
Constant	-7.55(7.23)		.042

Note: R^2 = .56, p = .045; * p < .05. Counter-conditioning effect = CS^+ pleasantness rating post-Pavlovian - post-counter-conditioning.

6.4.2.4 Transfer discrimination

Exploration of the moderating role of personality on transfer behaviour was again focussed on aware participants in the neutral CC group, due to there being no reliable transfer effect in other groups. Moreover, RR was taken as the sole outcome measure, as opposed to RI, due to its significant correlation with emotional discrimination (refer to section **Error! Reference source not found.Error! Reference source not found.**), and the lack of relationship involving RI in the previous studies. Separate regressions were run with the TCI and NEO super-factors as predictors, and RR transfer discrimination (CS_+ - CS_-) as the outcome variable. Neither questionnaire produced a significant model [*Fs* < 1].

However, due to the emphasis of the present study to appetitive responding, and Novelty-Seeking facets' relationship to appetitive emotion found above, their relationship with CS_+ facilitation, as opposed to CS discrimination, of RR was explored. Thus the cue-potentiation effect (CS_+ - $S_\pm$) was used as the outcome variable predicted by the four NS facets. After removal of one participant who reported anomalous transfer behaviour (the same participant removed in the behavioural analysis of section 6.4.1.4.2 above), this model approached significance [R^2 = .66, $F(4,6)$ = 3.42, p = .087], with Impulsiveness the sole significant contributor [β = .87, p = .016].

6.5 Discussion

The current study was designed to test whether reward expectancy is sufficient for reward-paired cues to augment instrumental responding, or whether an emotional response to the cue is also necessary. It employed a counter-conditioning procedure to reduce the emotional value of a reward-paired CS, while leaving its predictive value unchanged, and measured whether such a manipulation would influence the ability of the CS to augment a separately trained instrumental response. Tentative evidence was obtained in support of the necessary status of CS-elicited emotion in cue-potentiated behaviour, in that the counter-conditioning procedure reduced liking of a reward cue, reduced responding in the presence of the cue, but did not affect the perceived predictive quality of the cue. These effects of counter-conditioning were statistically weak, however, and so require support from replication.

The study also set out to explain variation in the magnitude of cue-potentiated behaviour through its association with novelty-seeking traits. Tentative support was found for Impulsiveness to positively predict the rise in response rate above baseline upon presentation of the reward-paired cue. Moreover, Impulsiveness, Extravagance, and Extraversion were associated with related measures of the subjective emotional response to the cue, providing parallel evidence for the moderation of instrumental responding by affective processes.

Additionally, targeting the relationship between negative-affect traits and propositional learning of the CS-US associations revealed that multiple facets were able to predict levels of awareness. This held for both the dichotomous classification of participants as either unaware or aware, explained by Vulnerability, as well as the degree to which each predictive CS was differentiated, associated with Hostility, Uncertainty, and [negatively] Fatigue.

While some theories have championed the sufficiency of such propositional discrimination in cue-potentiated reward seeking (Bolles, 1972; de Wit & Dickinson, 2009), and others have emphasised the sufficiency of subjective responses to cues (Bindra, 1974; Robinson & Berridge, 1993), the finding here of an interaction between O expectation and CS emotion provides experimental evidence of the bridge between the two (Toates, 1986). The fact that participants with differential expectancies, yet non-differential emotions, showed minimal differential behaviour (aware aversive group), and participants with non-differential expectancies, yet differential emotions, also showed minimal differential behaviour (unaware groups), provides a double dissociation between the measures of CS-elicited expectancy and emotion. The fact that neither of these groups displayed cue-potentiated behaviour attests to the necessary status of both O expectancy and S emotion in the influence of reward-paired cues on reward-seeking.

The confirmation that the manipulation of cued emotion affected only the proximal behaviour of RR, and did not influence the comparatively distal behaviour of RI, provides support for the findings that CSs have their greatest effect on responses closest to reward delivery (Balleine, 1992; Balleine et al., 1995; Corbit & Balleine, 2003). Furthermore, the manifest relationship here between trait Impulsiveness and cue-facilitation of RR corroborates the greater influence of impulsivity on nicotine consumption compared to nicotine seeking, again, a proximal versus distal behaviour (Hogarth, 2011). More specifically, Balleine and colleagues find that proximal behaviours are sensitive to experiencing an S but not an O, whereas the reverse holds for distal behaviours. Additionally, Hogarth finds that trait impulsivity reduces the influence of O value on proximal responding. Relatedly, the current experiment finds, indirectly, that the trait *increases* the influence of *S* value on proximal responding. Although impulsivity is a nebulous concept (Caswell, Morgan, & Duka, 2013b; Evenden, 1999), both the construct used here and that used by Hogarth concentrates on the aspect of the trait concerned with disregard for future consequences, which may be reduced to insensitivity to O value. While the differing foci of these experiments precludes definitive comparison, they allude to an explanation of cue-potentiated reward-seeking in terms of its increased sensitivity to S emotional value, reduced sensitivity to O expected value, and mediation of the relative balance between the two by impulsivity.

However, before the results of the present experiment are assimilated with this extant literature, subtleties in the data should be noted. Firstly, cue-attributed pleasantness differences between neutral and aversive CC groups were detected only through planned contrasts; the interaction between CC group and Stimulus was non-significant. Thus the effect of CC, although statistically significant with the support of sensitive tests, was comparatively weak. This may have been due to the comparatively low number of CC trials, coupled with a reduction in the number of participants aware of the aversive contingency operating in CC. Although the current design used a greater number of CC pairings than have been used previously (Baeyens et al., 1989; Kerkhof et al., 2011; Van Gucht et al., 2013; Van Gucht et al., 2010), the proportion of CC trials relative to acquisition trials was considerably lower. It may have been, therefore, that the acquisition of CS emotional valence was comparatively well consolidated (Alberini, 2005), and that any change in valence would have required a greater number of CC pairings. It may be prudent, therefore, for future studies to make use of CC that has already occurred in the natural environment. An example of this may be found in the addition of health warnings to cigarette packets. Smokers will have experienced numerous acquisition pairings of the packet itself with nicotine reward, but will more recently have had CC pairings of the packet with unpleasant images. To the extent that smokers now find the packet less pleasant, or even unpleasant, they may present a germane population in which to apply the effects of CC.

Nevertheless, robust abolition of CS-potentiated RR was shown here in a non-dependent sample, thus while the subjective effects of CC could have been more pronounced, the objective effects were well evidenced. However, this conclusion is made more tentative by the inconsistent CS-potentiated RR shown by the neutral CC group, in that one participant was excluded for expressing a transfer strategy that was at odds with all others. This need for removal may have been compounded by the low number of participants in this group reducing the power of the analysis, as four had to be excluded for non-reinforcement in training. But while there may be circumstances under which CS emotion can be overridden by 'higher-order' strategies, the general behaviour of aware participants in the neutral group was to display positive transfer.

The proposal that impulsivity moderates the relationship between cue-augmented emotion and behaviour also requires expansion. CS pleasantness discrimination was associated with Impulsiveness, and Impulsiveness predicted CS_+ RR-effect, but the direct link between CS pleasantness discrimination and CS_+ RR-effect was non-significant, thus precluding a direct test of the mediating effect of Impulsiveness on this relationship. However, there was a direct association between CS pleasantness discrimination and CS RR-*discrimination*, indicating a linear association between emotion and one measure of responding, with Impulsiveness being related to another measure of responding. Coupled with the necessary status of emotion in responding found here, and the published reports of impulsivity's relationship to drug-taking (Caswell, Morgan, & Duka, 2013a; Evenden, 1999; Hogarth, 2011), the current data provide the basis for parallel research into the effects of impulsivity on reward-seeking in terms of its influence on cued emotion. However, the direct effect of CS-elicited emotion in drug-seeking populations, such as the smokers used by Hogarth, remains unclear, thus research should characterise the general behavioural processes before involving individual differences.

More robust is the association between Neuroticism and awareness. The first two studies in this series were supportive of its facilitatory influence, whereas the third found no evidence. This fourth study finds that there is indeed a facilitatory effect of N, and explains the lack of effect from the previous experiment as due to its effect being located at the facet level, rather than the factor level, which the last study did not delve into. The positive result from the first two studies may have been due to their factor level scores being more heavily influenced by relevant facets than the third study. Initially this may contradict previous assertions that negative affect traits are negatively related to reward learning (Avila et al., 1999; Corr et al., 1995), but as the current task contained both rewarded and non-rewarded trials it may have been that participants concentrated on the CS-, and so perceived the task as an aversive learning paradigm. The finding that Vulnerability was the only predictor of awareness classification has face validity, in that this facet assesses an individual's ability to concentrate under pressure, but the relationship between Hostility and CS discrimination is less intuitive, and will require further study.

In summary, the current experiment finds tentative evidence that reducing the appetitive emotional reaction to a reward-predictive cue causes a reduction in response rate when the cue is encountered in an instrumental situation, but only in participants who expect to receive the reward. It therefore appears that both expectations of reward and appetitive emotional responses are necessary for cues to potentiate reward-seeking behaviour. Such processes may be applicable to nicotine seeking, where reward-predictive cues such as cigarette packets have become aversive due to their superposition with health warnings. Thus whether the current results generalise to such a naturalistic situation should be investigated.

7 Naturalistic PIT

An edited version of this chapter is in preparation for the journal Nicotine & Tobacco Research

7.1 Abstract

Background – the preceding experiments culminated in showing that both expectancy and emotion are necessary to influence reward-seeking behaviour, but whether these results translate to the pursuit of addictive drugs requires testing.

Aims – The current study was designed to parse the relative effects of cue-induced emotion, motivation, and expectation, on cigarette-seeking behaviour, to assess whether the emotional connotations of cigarette cues could influence behaviour.

Methods – 16 smokers gave subjective emotional ratings of images of people smoking, cigarette health warnings, or control images. They then learned an instrumental bar-pressing response to receive cigarettes, before the effect of the various images on instrumental responding was tested in extinction. Participants were asked to rate their cigarette craving before responding during test. After the extinction test, participants rated their expectancy of winning cigarettes in the presence of each image.

Results – the smoker group rated health-warning images as less pleasant, more anxiety-provoking, less crave-inducing, but equally likely to predict cigarettes, compared to a non-cigarette-related image. Their response rate after viewing the smoking, warning, or control images better resembled expectancy ratings than emotional or motivational ratings. Furthermore, expectancy ratings correlated positively with response rate for health-warning trials.

Conclusions – cue-induced cigarette-seeking is controlled solely by an expectation of reward, emotional and motivational responses do not play a role. Thus addiction may be characterised by the usurping of drug-seeking by expectancy of reward, at the expense of the emotional or motivational properties of drug-predictive stimuli.

7.2 Introduction

The previous experiment suggested that a positive emotional response to a cue was necessary for the cue to potentiate reward seeking. Similar effects have been reported elsewhere (Hollands et al., 2011; Van Gucht et al., 2010), thus corroborating the importance of emotional processes in reward seeking. However, these confirmatory reports used either money or food as rewards, whereas theories of addiction question the importance of affective reactions in cue-elicited behaviour directed towards drugs of abuse (Everitt & Robbins, 2005; Robinson & Berridge, 1993). It therefore remains to be demonstrated whether the necessary status of cue-induced emotion translates to the addictive drug scene.

While these theories converge on the necessary status of the drug-paired cue in eliciting drug-seeking (Berridge, 2000), they propose that the transition from drug use to drug abuse is characterised by a progressive decoupling of hedonic reactions from resultant behaviour. Where they diverge from each other is in the involvement of *any* subjective response to a cue. On the one hand, Robinson & Berridge (1993) argue that addiction is characterised by the dissociation of motivational processes from emotional processes, with drug intake controlled by how much it is wanted, rather than how much it is liked. On the other, Everitt & Robbins (2005) propose that addiction is a pathological form of habit learning, where the cue initiates a response directly, leaving no room for either subjective motivational or emotional processes.

Research on cigarette use opposes habit theory, and supports the dissociation of wanting and liking, in that smoking cues can induce subjective reactions of craving and pleasantness, but only craving correlates with subsequent nicotine seeking. Thus the degree to which cues influence behaviour is explained by individual differences in nicotine value, represented by craving, which would not be predicted by habit theory (Brian L. Carter & Tiffany, 1999; Hogarth et al., 2010). However, while cigarette use may not be influenced by cue *pleasantness*, it may be influenced by cue *aversiveness*. For example, Volchan et al (Volchan et al., 2013) demonstrated that the health warning pictures found on cigarette packets produced a cigarette avoidance response, manifested as a slowing in approach to the pack, with the perceived aversiveness of the picture correlating with response times. Yet the direction of this effect is questioned by Bargh and colleagues (Earp, Dill, Harris, Ackerman, & Bargh, 2013; Harris, Pierce, & Bargh, in press) who report that no-smoking signs, which may be considered aversive by smokers due to them putatively being a CS-, speed reactions to cigarette stimuli, and that exposure to health warnings increases later cigarette use.

Thus while aversive nicotine cues have been demonstrated to have *some* effect, the direction of effect is unclear, as is the mechanism of effect. Although Volchan et al find confirmatory evidence for an emotional process mediating their results, they did not record cue-induced craving, and so are not able to rule out a greater influence of a motivational process. Indeed, the authors report greater aversive ratings in females, with other data showing females to be more susceptible to cue-induced craving (M. Field & Duka, 2004). Similarly, although Bargh and colleagues used ostensibly aversive stimuli, they did not measure their participants' perceptions of the stimuli, thus they may not have been aversive at all. Indeed, the authors argue that the facilitation of smoking behaviour was dependent on an 'ironic process' whereby the instructed suppression of cigarette thoughts in fact increased their accessibility, thus priming nicotine seeking (Newman, Duff, & Baumeister, 1997; Wegner, 1994). Such an explanation parallels expectancy-based theories of cue-potentiated drug seeking (de Wit & Dickinson, 2009; Hogarth et al., 2013), where an S activates the identity of its associated O, which in turn activates an R which is instrumental in gaining the O. Thus the results of all three studies may be better explained by the nicotine-paired cues eliciting [or not] an expectation of nicotine reward, with any emotional process merely a corollary.

To pick apart these competing explanations, the current study was designed to parse the relative effects of cue-induced emotion, motivation, and expectation, on cigarette-seeking behaviour. To combine the need for real-world applicability with experimental control, it used the health warnings currently used on British cigarette packets as stimuli, but trained smokers on a novel cigarette-seeking response. Furthermore, this new instrumental response was trained in the absence of the stimuli, and the critical assay of cue-potentiated behaviour conducted in extinction, thus evoking conditions similar to the PIT procedure used in the current series. These methods ensured that any effect of the stimuli on behaviour occurred via their influence on emotion, motivation, or expectation, while precluding an explanation in terms of habit (de Wit & Dickinson, 2009; Robert A. Rescorla & Solomon, 1967).

7.3 Method

7.3.1 Participants

Participants were 16 University of Sussex students (8 males and females) who reported smoking at least 5 cigarettes per day. However, one female participant was excluded due to her not receiving positive reinforcement during instrumental training. The remaining participants had a mean age of 21.7 (range 19 – 31); cohort smoking information is displayed in Table 7.3.1.1. A series of t-test on each of the smoking variables, comparing the effect of Gender, were non-significant [*ts* < 1]. Other details were as General Methods.

Table 7.3.1.1. Cohort smoking information.

	Mean	SD	Min	Max
Years since smoking uptake	6.03	2.73	2	14
Cigarettes per day	9.00	3.78	5	20
Minutes since last cigarette	79.3	228	10	900
FTND Total	3.13	1.73	0	6

Note: FTND, Fagerstrom Test for Nicotine Dependence; see Materials for further details of questionnaire.

7.3.2 Materials

7.3.2.1 Behavioural tasks

Nine images were used in the experiment. Two depicted a person smoking (one male one female), two depicted a person holding a pen in their mouth (the same people as for the smoking images), two were cigarette health warnings (lung cancer and throat cancer), two were visually similar to the health warnings but were not smoking-related (two cups and a scarf), the final image was a grey rectangle (see Figure 7.3.2.1 for exemplars). Pen images were designed to be smoking control images, cup and scarf images were used as health warning control images. All images contained text to appear visually similar to UK cigarette packets. Number of syllables was matched between smoking or warning images and their respective controls. Smoking and pen pictures were taken from a set used by Hogarth et al (2010), health warnings were taken from UK cigarette packets, health warning control pictures were custom made. All images were presented at a size of 84mm wide x 118mm high at a resolution of 320 x 410 pixels.

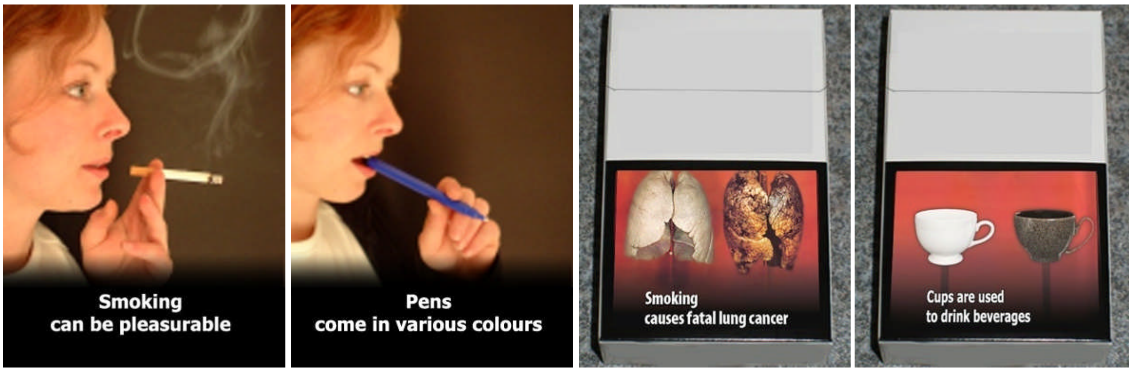

Figure 7.3.2.1. Examples of images used to measure naturalistic transfer.
Note that images were displayed in colour.

All phases recorded responses using a QWERTY keyboard. Number keys and arrow keys were labelled green and yellow, respectively, to highlight their use in the tasks. Throughout the experiment to the left and right of the keyboard was a metal box (height

23 mm, width 190 mm, depth 90mm) with its lid open. Inside the left box were 20 cigarettes of the participant's preferred brand. The right box was initially empty, but was labelled with “Your cigarette box”.

7.3.2.2 Fagerstrom Test for Nicotine Dependence (FTND)

The FTND (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) is a self-rated six item questionnaire that asks raters about the situations in which they smoke. Possible scores range from 0-10, split into tertiles representing low (0-3), medium (4-6), or high (7-10) dependence. See Appendices, section 10.2 for full questionnaire.

7.3.3 Design & Procedure

7.3.3.1 Pavlovian training

There was no Pavlovian phase in this experiment as images had already been associated with cigarettes in the participants' daily lives.

7.3.3.2 Emotional evaluations

The experiment began with evaluative ratings of the nine images. Emotional evaluations asked the same questions of pleasantness and anxiety as detailed in General Methods. However, each picture was separated by a 30s countdown screen to ensure that any extreme emotional response had decayed before presentation of the next image.

7.3.3.3 Instrumental training

Upon completion of the evaluative ratings, participants were asked to call the experimenter, who loaded the following instructions onto the screen:

> In this session, by pressing the spacebar multiple times, you will sometimes win half a cigarette and sometimes lose half a cigarette. Let the experimenter know when you are ready to begin.

After reading the instructions the participant began the first block of instrumental training with the experimenter present. After the first block the experimenter re-iterated the instructions before leaving the experimental cubicle. Details were identical to that of General Methods, save for the following alterations. Rather than winning money participants won half a cigarette. The VR2 schedule was changed to a win/loss with 50% contingency, to ensure that the grey rectangle was not associated with a net win of cigarettes. The VI10 schedule with 18.5s response window remained the same. The total number of trials remained the same, with four blocks of ten trials.

7.3.3.4 Naturalistic transfer

Once instrumental training had been completed participants saw the following instruction screen:

> Now you will continue to earn cigarettes as before, but you will only be told how many at the end of the session. Sometimes the pictures you saw earlier will be presented. After seeing each picture you will be asked how much of an urge you have for a cigarette. You should answer this question as quickly and accurately as possible. You will then be able to earn cigarettes by pressing the spacebar as before. After this two digits will appear on the screen, one after the other. You will be asked whether the second digit was higher than, lower than, or the same as, the first. Press enter to continue.

Pressing 'enter' launched six trials that were designed to present a smooth transition into the naturalistic transfer phase. These trials contained only grey images, and responses were not recorded to allow for errors, but were otherwise identical to the ensuing full transfer phase.

The main transfer trials continued in a similar manner to that detailed in General Methods. However, images were displayed for 5s to allow extra time to read the accompanying text. A cigarette craving question, taken from Hogarth et al (2010), was inserted between image display and instrumental response opportunity, in the form: "How strong is your urge for a cigarette? Press a number key between 1 and 9 to indicate the strength of your urge. 1 = No urge 9 = Strong urge." This questioned remained on screen for 4s to ensure that the gap between image and response was identical across participants. The 18.5s response window remained the same, after which a numerical distracter task was added to the end of each trial to allow any subjective effects of the images to decay before the next trial. A central fixation dot appeared for 1s, followed by a random single digit integer, a 0.5s blank screen, and then another random single digit integer. Participants were then asked: "Was the second digit higher than, lower than, or the same as, the first? Press the 'up' arrow if it was higher, Press the 'down' arrow if it was lower, Press the 'right' arrow if it was the same." The transfer phase was divided into three blocks of twenty trials. Images from each category, i.e. smoking, pen, warning, control, grey, were presented four times per block.

7.3.3.5 Post-transfer outcome-expectancy

Post-transfer expectancy ratings were as General Methods, presenting all nine images from the current collection.

7.3.3.6 FTND

The session ended with participants completing the FTND.

7.3.4 Statistical analyses

Preliminary analyses of the evaluative ratings of each picture confirmed that each was consistent [*ps* > .06] within its respective set – appetitive (smoking), control (both smoking control and health warning control), aversive (health warning) - therefore all subsequent analyses contained the three picture sets plus the grey stimulus.

A power calculation, based on the RR transfer discrimination index (CS+ - CS-) displayed by the neutral group of the previous study, indicated that 11 participants would be sufficient to find a stimulus effect in the current experiment. This *n* was derived using G*Power statistical software (Faul, Erdfelder, Lang, & Buchner, 2007), with parameters of $d = 0.97$, $\alpha = .05$, $\beta = .8$.

However, due to the ~10% rate of exclusion demonstrated in previous studies, caused by participants not learning the instrumental response, and the potential loss of power resultant from including four levels of stimulus here, the number of participants was increased to 16. Additionally, planned contrasts of appetitive/aversive versus grey stimuli were employed throughout subsequent analyses, to concentrate results on theoretically meaningful comparisons. Such contrasts were selected to represent cue-potentiated effects, with the grey stimulus level representing 'baseline' due to its non-predictive association with reward.

To further define the relationships between the subjective and objective variables recorded, correlations were run between smoking experience variables (i.e. those in Table 7.3.1.1) and the planned contrasts above (i.e. cue-potentiation effects, calculated as appetitive/aversive - grey). Additionally, correlations were run within these planned contrasts, between subjective cue-potentiation effects, i.e. pleasantness, anxiety, craving, expectancy, and behavioural cue-potentiation effects, i.e. RI, RR.

Although gender was not the primary concern of the current experiment, due to the significant gender differences found in previous studies of cue-induced subjective responses, ANOVAs included gender as an independent variable.

7.4 Results

7.4.1 Group-level analyses

7.4.1.1 Evaluative ratings

The pattern of pleasantness ratings for the pictorial cues accorded with their category assignment. A mixed ANOVA with Stimulus (appetitive, blank, control, aversive) and Time (pre-, post-experiment) as within-subjects factors, and Gender as the between-subjects factor, found only a main effect of Stimulus [$F(3,42) = 41.7$, $p < .001$]. Post-hoc comparisons revealed this effect as due to the aversive category being significantly lower than all others [$ps < .001$]. The planned contrast found appetitive ratings to be significantly higher than grey [$F(1,13) = 5.39$, $p = .037$].

Anxiety ratings also followed their respective categories. The mixed ANOVA revealed a main effect of Stimulus, and a Stimulus*Time interaction [$Fs > 4.49$, $ps < .025$]. The interaction was followed by separate RM ANOVAs for each time-point, with Stimulus as the only factor. The main effect of Stimulus was significant at both time-points [$Fs > 12.4$, $ps < .001$], with the aversive set evoking more anxiety than all others [$ps < .036$]. The planned contrast of appetitive versus grey (time collapsed) was non-significant [$p = .14$]. Figure 7.4.1.1 displays mean emotional ratings for each stimulus category at each time.

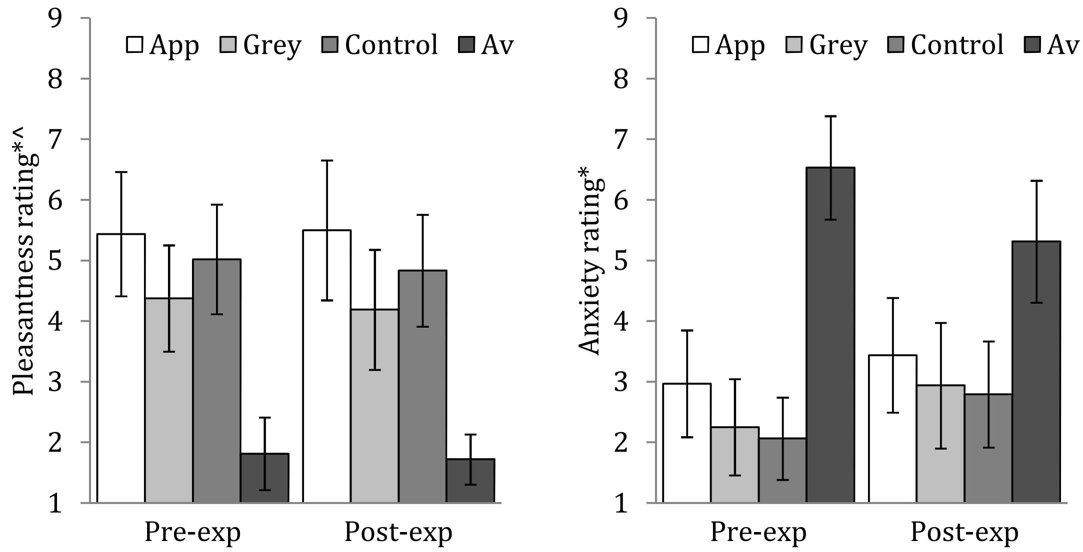

Figure 7.4.1.1. Mean evaluative ratings of pictorial cues pre- and post-experiment.
App, appetitive image category; Av, aversive image category; Grey, grey square from instrumental training; exp, experiment; * Av ≠ App/Grey/Control [ps < .036], ^ App > Grey [p = .037]; error bars represent 95%CI.

7.4.1.2 Instrumental training

All participants learned to press at a rate sufficient to receive reinforcement, both positive and punishment. Mixed ANOVAs of both RI and RR were conducted with Block (1-4) and Gender as factors. Effects were non-significant for RI [$Fs < 1.33$, $ps > .28$], while RR showed a main effect of Block [$F(3,39) = 2.84$, $p = .050$], due to block 1 being significantly lower than block 2 [$p = .018$]. A mixed ANOVA of reinforcement frequency with Reinforcement (positive, punishment) and Gender as factors showed no effects [$Fs < 1$]. Table 7.4.1.1 contains means of RI, RR, and reinforcement frequency.

Table 7.4.1.1. Means (95%CI) of behavioural variables from instrumental training.

	Block			
	1	2	3	4
RI(%)	88.8(5.26)	91.3(6.85)	90.4(7.55)	90.2(6.75)
RR(Hz)	1.96(0.50)*	2.58(0.51)	2.31(0.66)	2.26(0.67)
Pos. reinforcement	10.8(2.46)			
Punishment	10.9(3.16)			

Note: reinforcements are given as the mean total from the full training phase; * block 1 < block 2 [p = .018]; pos. reinforcement, positive reinforcement, RI, response initiation; RR, response rate.

7.4.1.3 Transfer

7.4.1.3.1 Cue-induced craving

Analysis of cue-induced craving during transfer revealed a main effect of cue, but one that was strongest in females (see Figure 7.4.1.2 for mean craving ratings divided by stimulus and gender, and

Table 7.4.1.2 for ratings per block). A mixed ANOVA with Stimulus, Block (1-3) and Gender as factors found a main effect of Stimulus, qualified by a significant Stimulus*Gender interaction [$Fs(2.13, 27.7) > 4.04$, $ps < .027$], and a main effect of Block [$F(2,26) = 18.1$, $p < .001$], explained through a significant linear contrast as due to a uniform increase [$F(1,13) = 26.7$, $p < .001$]. The Stimulus*Gender interaction was followed by separate RM ANOVAs for each gender, with Stimulus as the only factor. In males, the effect was non-significant [$F = 2.23$, $p = .12$]. However, in females there was a significant main effect [$F(3,18) = 11.8$, $p < .001$], with post-hoc comparisons showing the aversive set to be significantly lower than both the appetitive and control set [$ps < .035$]. Furthermore, the planned contrasts of appetitive/aversive versus grey (block and gender collapsed) were significant in both cases [$Fs(1,13) > 6.00$, $ps < .029$].

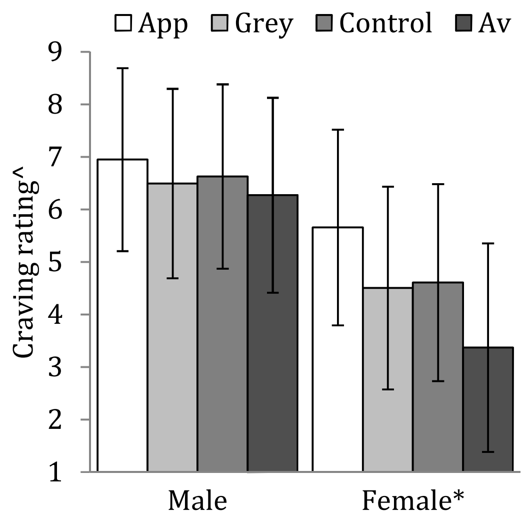

Figure 7.4.1.2. Mean cue-induced craving rating for males and females during transfer.
App, appetitive image category; Av, aversive image category; Grey, grey square from instrumental training; * Av < App/Control [ps < .035], ^ App/Av ≠ Grey [ps < .029]; error bars represent 95%CI.

Table 7.4.1.2. Mean (95%CI) cue-induced craving rating at each block of transfer.

	Block*		
	1	2	3
Craving rating	5.02(1.22)	5.64(1.33)	6.02(1.32)

Note: * significant linear increase across blocks [p < .001].

7.4.1.3.2 Response initiation

A mixed ANOVA with Stimulus, Block, and Gender as factors found no significant results [*Fs* < 1.63, *ps* > .15]. The planned contrasts were also non-significant [*Fs*(1,13) < 1.79, *ps* > .20]. Figure 7.4.1.3[left] displays mean RI for each stimulus category.

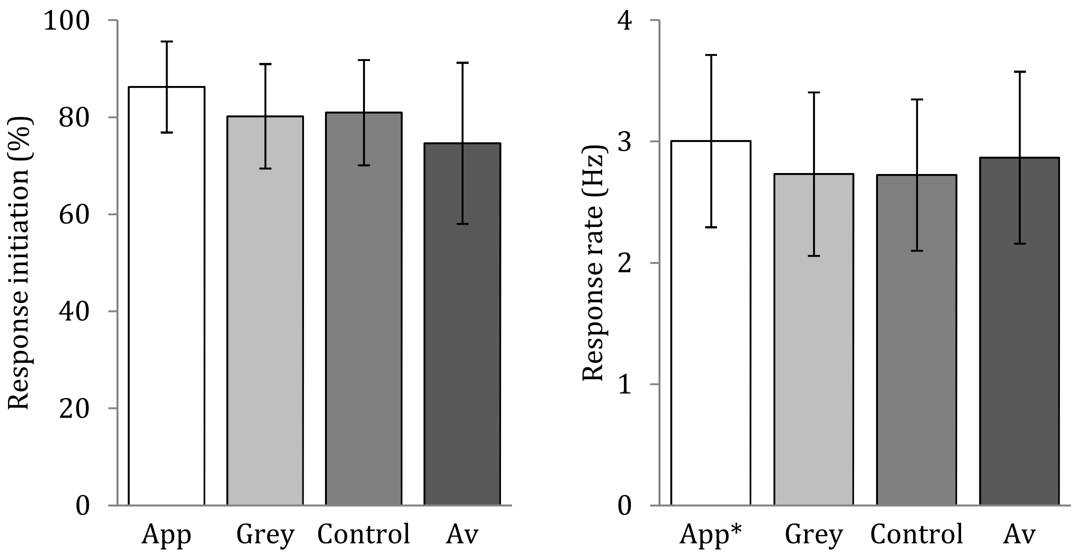

Figure 7.4.1.3. Mean response initiation [left] and response rate [right] during transfer as a function of stimulus.
App, appetitive image category; Av, aversive image category; Grey, grey square from instrumental training; * App > Grey [p = .008]; error bars represent 95%CI.

7.4.1.3.3 Response rate

A similar mixed ANOVA to that of RI was conducted with RR, with similarly non-significant results [*Fs* < 1.19, *ps* > .31]. However, the planned contrasts indicated a significant increase for appetitive versus grey trials [$F(1,14) = 9.73$, $p = .008$] (aversive versus grey was non-significant [$F(1,14) = 1.46$, $p = .25$]). See Figure 7.4.1.3[right] for RR means separated by stimulus.

7.4.1.3.4 Transfer expectancy

A mixed ANOVA of expectancy ratings with Stimulus and Gender as factors revealed a main effect of Stimulus only [$F(3,39) = 6.89$, $p = .001$], with post-hoc comparisons indicating that this effect was due to aversive ratings being significantly lower than both appetitive and control ratings [*ps* < .050]. In addition, planned contrasts found a significant increase in appetitive ratings over grey [$F(1,13) = 7.14$, $p = .019$], yet a non-significant difference between aversive and grey [$F(1,13) = 1.06$, $p = .32$]. Figure 7.4.1.4 contains mean expectancy ratings for each stimulus.

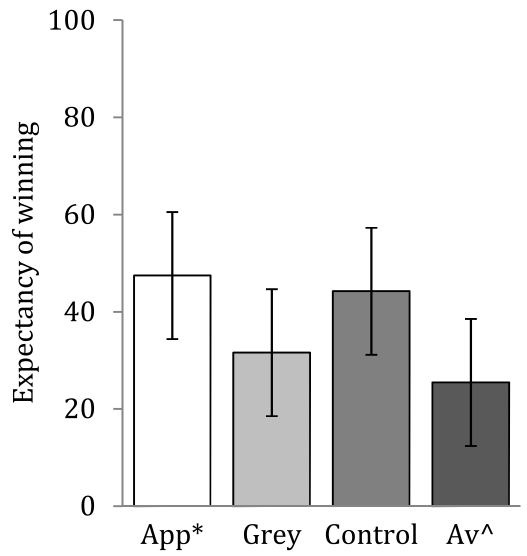

Figure 7.4.1.4. Mean expectancy rating of each stimulus set following transfer.
App, appetitive image category; Av, aversive image category; Grey, grey square from instrumental training; * App > Grey [p = .019],^ Av < App/Control [ps < .050]; error bars represent 95%CI.

7.4.2 Individual-level analyses

7.4.2.1 Role of smoking experience in PIT

The only significant correlation between smoking experience scores (the variables included in Table 7.3.1.1) and cue-potentiation variables (see section 7.3.4 above for details) was the negative relationship between FTND and the anxiety-effect of the aversive cue [r = -.69, p = .005] (see Figure 7.4.2.1 for scatterplot). Exploration of this result by running separate correlations between FTND and anxiety ratings of the aversive or grey cues found only a significant negative relationship for the aversive cue [r = -.65, p = .009].

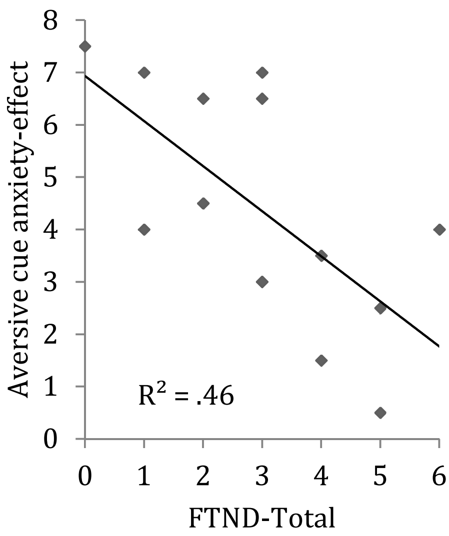

Figure 7.4.2.1. Correlation between Fagerstrom Test for Nicotine Dependence Total score and aversive cue-potentiated anxiety effect.
Linear trend-line represents r = -.69, p = .005.

7.4.2.2 Role of subjective experience in PIT

The only significant correlation between the subjective and objective cue-potentiation effects was for the aversive cue between its expectancy of winning and RR [r = .52, p = .048] (see Figure 7.4.2.2[left] for scatterplot). Exploration of this result with separate correlations between expectancy and RR for the aversive or grey cues found non-significant relationships [*rs* < .29, *ps* > .30].

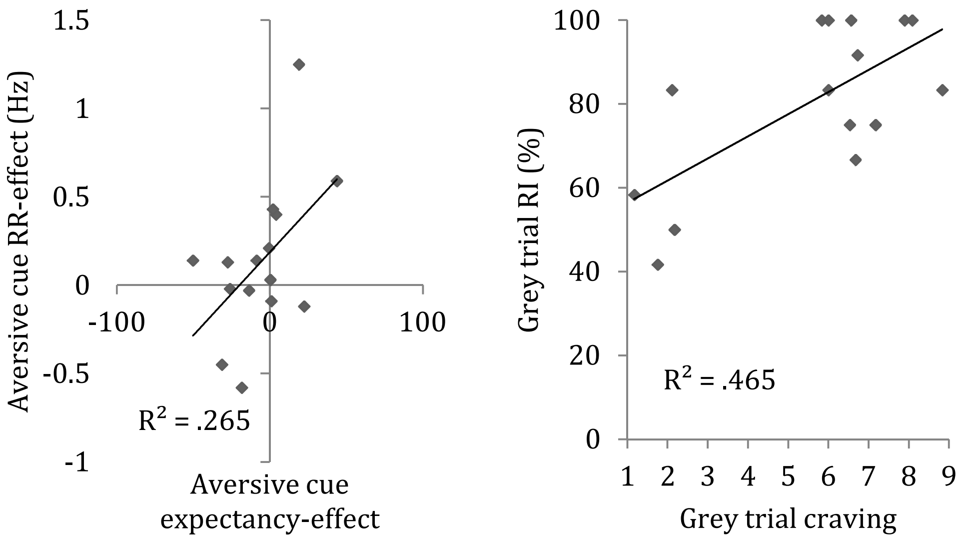

Figure 7.4.2.2. Correlations between aversive cue-potentiated expectancy-effect & response rate-effect [left], and between grey trial craving & response initiation [right].
Linear trend-lines represent r = .52, p = .048 [left] and r = .68, p = .005 [right].

Further exploratory analyses of the relationship between subjective and objective measures, investigating appetitive, aversive, and grey cues separately, found only a significant correlation between craving rating and RI elicited on grey stimulus trials [r = .68, p = .005] (see Figure 7.4.2.2[right] for scatterplot).

7.4.2.3 Role of personality in PIT

7.4.2.3.1 Evaluative ratings

The five NEO factors were initially non-significant predictors of evaluative-effects (valenced cue minus grey) [$Fs(5,9) < 1.3$, $ps > .33$]. However, after the removal of one outlier (standardised residual > 2) a significant model predicting the pleasantness-effect of the aversive cue was found [$R^2 = .83$, $F(5,8) = 7.79$, $p = .006$], with all factors except N contributing significantly [$\beta s > .70$, $ps < .004$] (see Table 7.4.2.1 for individual coefficients). To explore this result separate regressions were run with these four significant factors as predictors of pleasantness rating of either the aversive or grey stimuli. The model for the aversive cue was non-significant [$F < 1$], as was that of the grey cue [$F(4,9) = 2.8$, $p = .10$].

Table 7.4.2.1. Regression coefficients of NEO factors predicting aversive cue pleasantness-effect.

Predictor	*B*	*β*	*p*
Neuroticism	-0.01(0.05)	-0.04	.822
Extraversion*	0.08(0.08)	0.77	.004
Openness*	0.11(0.05)	0.87	.001
Agreeableness*	-0.09(0.04)	-0.84	.002
Conscientiousness*	0.06(0.03)	0.70	.003
Constant*	-9.90(4.70)		.001

Note: R^2 = .83, p = .006; pleasantness-effect = aversive – grey cue rating; * p < .004.

The four TCI domains were significant predictors of only the appetitive cue pleasantness-effect [R^2 = .73, $F(4,10)$ = 6.73, p = .007], with NS the only contributor [β = -.79, p = .001]. This relationship was investigated with separate models regressing either appetitive or grey cue pleasantness rating on NS; the appetitive cue model was significant [β = -.58, R^2 = .33, $F(1,13)$ = 6.52, p = .024], whereas the grey model was not [$F < 1$].

When using evaluative discrimination scores, the only significant model was that regressing anxiety discrimination on NEO factors [R^2 = .74, $F(5,9)$ = 5.11, p = .017], with N and O as significant predictors [β = .50, β = -.82, respectively, *ps* < .033]. This model was explored by separating the analyses of appetitive and aversive cue anxiety, with N and O as predictors. Both models were significant [Rs^2 > .64, $Fs(2,12)$ > 4.23, *ps* < .041], although N was the sole significant predictor of aversive cue anxiety [β = .64, p = .016], whereas O was the sole significant predictor of appetitive cue anxiety [β = .58, p = .020] (see Figure 7.4.1.1 for scatterplots illustrating these two relationships)[3].

[3] A correlation was run between N and FTND, because of their common association with aversive-cue anxiety, but was non-significant [p = .70].

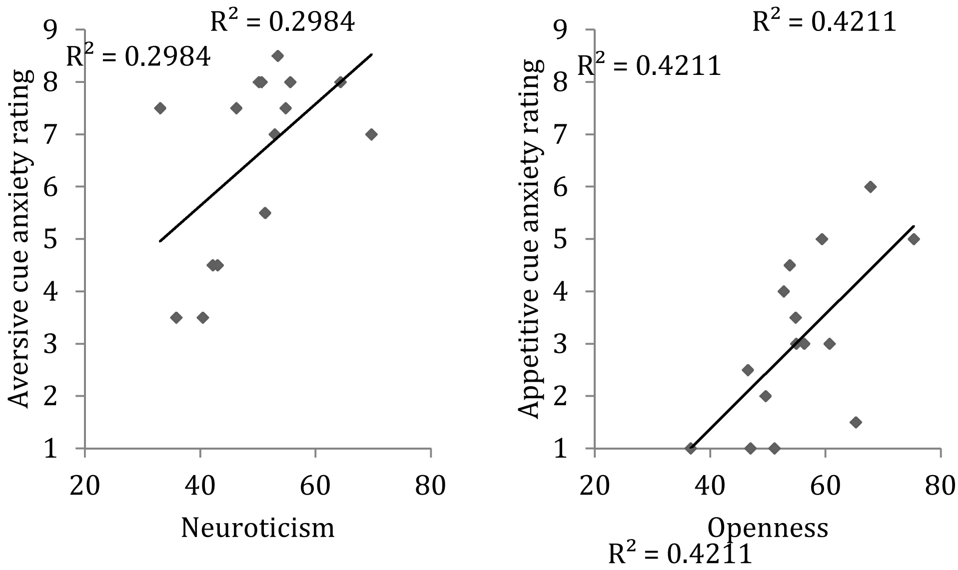

Figure 7.4.2.3. Correlations between NEO personality factors and anxiety ratings of the aversive [left] or appetitive stimulus sets [right].
Linear trend-lines represent r = .55, p = .035 [left] and r = .65, p = .009 [right].

7.4.2.3.2 Cue-potentiated craving

Models regressing the five NEO factors on craving were also non-significant for both appetitive and aversive cues [*Fs* < 1.4, *ps* > .32]. However, after removing one outlier (std res > 2) the model significantly predicted the appetitive cue craving-effect [R^2 = .80, *F*(5,8) = 6.57, *p* = .010], with C the only significant contributor [*β* = .57, *p* = .011]. Follow-up analyses with craving ratings of either the appetitive or grey cues regressed on C were non-significant [*Fs*(1,12) < 1.1, *ps* > .32].

Both TCI models were initially non-significant as well. However, the removal of one outlier (std res > 2) revealed a significant model for aversive cue-potentiated craving [R^2 = .70, *F*(4,9) = 5.38, *p* = .017] explained by RD and P [*βs* < -.52, *ps* < .035] (see Table 7.4.2.2 for full model coefficients). Subsequent models containing these two domains as predictors of either aversive or grey cue trial craving were non-significant [*Fs* < 1].

Table 7.4.2.2. Regression coefficients of TCI domains predictive of aversive cue craving-effect.

Predictor	*B*	*β*	*p*
Novelty-Seeking	-0.03(0.04)	-.38	.079
Harm-Avoidance	-0.03(0.06)	-.22	.298
Reward-Dependence*	-0.05(0.04)	-.64	.007
Persistence*	-0.05(0.05)	-.52	.035
Constant*	7.64(5.71)		.014

Note: $R^2 = .70$, $p = .017$; craving-effect = aversive – grey cue rating; * $p < .014$.

Models predictive of craving discrimination were all non-significant [*Fs* < 2.0, *ps* > .18].

7.4.2.3.3 Cue-potentiated behaviour

Again, NEO models were not initially able to predict either RI or RR cue-effects [$Fs(5,9) < 2.6$, *ps* > .10]. However, after the removal of one outlier (std res > 2) the model predicting appetitive cue-potentiation of RR was significant [$R^2 = .85$, $F(5,8) = 9.21$, $p = .004$], comprising N, O, and C [*βs* > .55, *ps* < .011]. These three factors were taken into subsequent models predicting either appetitive or grey cue-related RR; neither was significant [*Fs* < 1].

Table 7.4.2.3. Regression coefficients of NEO factors predictive of appetitive cue response-rate-effect.

Predictor	*B*	*β*	*p*
Neuroticism*	-0.03(0.01)	-.92	.001
Extraversion	-0.00(0.01)	-.14	.432
Openness*	0.02(0.01)	.55	.011
Agreeableness	0.01(0.01)	.21	.260
Conscientiousness*	0.01(0.01)	.57	.006
Constant	0.17(1.17)		.748

Note: $R^2 = .85$, $p = .004$; response-rate-effect = appetitive – grey trial response rate; * $p < .011$.

TCI models were non-significant for modulation effects [*Fs* < 1.3, *ps* > .34]. When analysing RR discrimination, both NEO and TCI equations were also initially non-significant [*Fs* < 2.3, *ps* > .13]. However, the removal of one outlier (std res > 2) from the TCI model lead to a significant effect [$R^2 = .67$, $F(4,9) = 4.62$, $p = .026$], with HA the sole significant predictor [$\beta = -.74$, $p = .006$]. Follow-up analyses of this result with separate regressions including HA as the predictor of either appetitive or aversive trial RR were non-significant [*Fs* < 1].

7.4.2.3.4 Expectancy ratings

NEO and TCI models were non-significant [*Fs* < 1].

7.5 Discussion

The aim of the current investigation was to characterise the mechanism by which aversive smoking-related cues influence smoking behaviour, by measuring smokers' subjective reactions of aversiveness, pleasantness, craving, and cigarette expectancy, as well as their objective reactions of cigarette-seeking, after viewing a range of naturalistic smoking stimuli. At the group level, subjective measures were broadly in line with the assigned category of each image. Images of people smoking were attributed higher pleasantness, craving, and expectancy ratings, whereas health-warning images were attributed higher anxiety, lower pleasantness and craving, though their expectancy ratings did not differ, compared to baseline. In contrast, behavioural measures showed only an increase in response rate under appetitive conditions; response initiation was unaffected by stimulus presentation.

Further information was provided by the individual differences in smoking uptake and subjective reactions. Fagerstrom dependence scores correlated negatively with anxiety ratings of the aversive images, though only expectancy ratings predicted aversive cue response rate potentiation. Furthermore, there was a significant correlation between craving and response initiation for grey trials only. Analyses of personality traits found that higher Novelty-Seeking was associated with lower appetitive cue pleasantness ratings, whereas Neuroticism predicted higher aversive cue anxiety. Appetitive cue induced craving was associated positively with Conscientiousness, whereas aversive craving was correlated negatively with Persistence. Finally, Conscientiousness positively predicted appetitive cue potentiation of response rate, whereas the negative affect traits of Neuroticism and Harm Avoidance negatively predicted response rate differences. The pattern of data concerning personality provided further complexity, but due to the increased potential for erroneous results stemming from the low number of participants (Maxwell, 2000) discussion shall be limited to those posited as most relevant by previous research.

The overall pattern of data indicates that cue-induced cigarette seeking is best explained by the cue's ability to elicit an expectation of reward, but not its ability to elicit emotional reactions. If taking the appetitive cue in isolation, it is difficult to separate its effects of pleasantness, craving, and expectancy on RR, as all show an increase, yet none are correlated with RR. However, concentrating on the aversive cue illuminates the dissociation of emotion and craving from cigarette seeking, and instead confirms the coupling of expectancy with cigarette seeking. Despite evoking significantly less pleasantness, more anxiety, and less craving, the aversive images did not significantly influence behaviour. Instead, the non-significant effect on expectancy matched the non-significant effect on behaviour, and any variance in expectancy significantly explained the variance in RR.

Such a synthesis corroborates the explanation, advocated by multiple researchers, of addiction as being pathologically mediated by drug expectation (de Wit & Dickinson, 2009; Hogarth et al., 2007; Hogarth & Duka, 2006). This stance argues that a drug-paired S activates the identity of its associated O, which necessarily activates its associated R, thus inducing drug-seeking. The value attributed to the O is represented separately, and so is not argued to be necessary for an S→O→R process, supported here by the lack of influence of cue-induced craving on RR. The present results add to this literature by finding that the emotional value attributed to the S, as opposed to the O, is not necessary to encourage responding either.

Thus as well as confirming expectancy-based hypotheses, the present data question the motivation-based hypothesis of incentive salience (Robinson & Berridge, 1993), as well as the S→R-based hypothesis of habit theory (Everitt & Robbins, 2005). Incentive salience might predict that, if any subjective measure were to explain drug seeking, it would be craving, whereas habit theory would predict no influence at all due to the preclusion of direct S→R association.

However, the present results may still be aligned with existing theories of addiction. For example, Robinson and Berridge (1995) specify that the central mediating mechanism between cue and drug-seeking is *unconscious* wanting. Moreover, they argue that this unconscious wanting becomes hyper-sensitised as addiction develops, and is decoupled from conscious representations of value such as craving. Therefore, the current data may in fact provide partial support for this decoupling process, in that cue-potentiated cigarette-seeking was greater than its concomitant cue-potentiated craving.

The present result that *expectancy* appeared sufficient to elicit cigarette seeking may paradoxically also support unconscious drivers of addiction. Tiffany's (1990) model of automatized drug-seeking proposes that the S→R association is mediated by 'action schemata' – memory units coding reward-seeking motor sequences. These schemata run subconsciously, and are independent of separate processes contributing to conscious drug urges. Nevertheless, they may still be sensitive to outcome expectancies. Cues signalling the availability of cigarettes elicit faster cigarette-seeking than cues signalling non-availability (B. L. Carter & Tiffany, 2001; Juliano & Brandon, 1998). Thus cue-elicited expectancy of cigarettes may form an occasion-setter than primes the running of action schemata, and so the tighter coupling of expectancy, compared to craving, with responding here may further support the assertion that drug seeking is controlled by automatic processes.

The present results also support the findings of Bargh and colleagues (Earp et al., 2013; Harris et al., in press), who showed that no-smoking signs and health warnings increased subsequent smoking-related behaviour. These authors explain their results in a manner resembling expectancy theory, in that they propose that the smoking stimuli encouraged cigarette seeking by virtue of their ability to activate smoking thoughts, independent of the emotional valence of the thought-provoking stimulus. Their finding of response facilitation of health warnings, compared to the non-significant effect here, may have been due to the different control conditions used. Whereas Bargh and colleagues used control stimuli that bore no relation to smoking, thus setting a low baseline, the current experiment used a grey stimulus that may have been an occasion-setter for cigarette reward (Bouton & Swartzentruber, 1986; Holland, 1989), thus increasing 'background' responding. A similar explanation may be used to compare the seemingly inhibitory effect of health warnings shown by Volchan et al (Volchan et al., 2013). This paper used no control condition at all, instead comparing brand logos with health warnings, thus it is uncertain whether reaction times were facilitated in one condition or inhibited in the other.

Such discordant results highlight the importance of appropriate control conditions. Whereas Bargh and colleagues' data may apply to occasions where cigarette use is not ordinarily encouraged, i.e. within a psychology experiment ostensibly not about smoking, the present findings may apply to situations where smoking-related behaviours are facilitated (Bouton & Swartzentruber, 1986; Crombag et al., 2001). The unexpected pattern of data obtained from the putative 'control' stimuli used here, resembling as it did the appetitive condition more than the grey condition, may be similarly explained, in that all contained elements of cigarette use, in the form of an object placed in a mouth, or a box resembling a cigarette packet. Indeed, multiple studies report that smokers have an attentional bias to smoking relevant elements of a visual scene, with such bias manifested as approach of emotionally salient cues, and the degree of bias predicted by dependence status (Bradley, Mogg, Wright, & Field, 2003; M. Field et al., 2004; Hogarth & Duka, 2006). Thus the control stimuli may not have been appropriate for the purposes of the current investigation.

Nevertheless, the grey condition appears to have filled the role of a baseline condition somewhat better, in that it was rated as an intermediary between appetitive and aversive stimuli in all subjective measures except anxiety, where floor effects dominated. Correlational analysis also found that grey trial craving positively predicted subsequent RI, suggesting that the value of the cigarette O impinged on the beginning of an instrumental chain, where RI was the distal response, and RR the proximal. Such an interpretation lends further support to the assertions of Balleine and colleagues (1992; Balleine et al., 1995; Corbit & Balleine, 2003), and Hogarth (2011), who suggest that distal responses are more sensitive to O manipulation, whereas proximal responses are more sensitive to S manipulation. It also supports a similar dissociation of RI from RR in the previous experiment. Where results diverge is in the mechanism through which an S interacts with a proximal response; the previous study found that emotional value is necessary, whereas the current data indicate that O expectancy is sufficient. Such differential findings lend support to the characterisation of addiction in terms of a progressive loss of control of emotional factors in determining behaviour, and a concomitant gain of control by expectancy processes (de Wit & Dickinson, 2009; Hogarth et al., 2007; Hogarth & Duka, 2006).

While such a description may suggest that aversive images may become increasingly less effective as dependence takes hold, the reverse is that they may be more effective earlier in the addiction cycle. The finding here of a negative correlation between FTND and aversive cue anxiety attests to the possibility that those more heavily dependent were less affected by health warnings, but conversely that those less dependent were more affected. Although the general patterns of behavioural results was null for aversive cues within the context of the study, Harris et al (in press) argue that the long-term effects of health messages may be more apparent. Thus aversive images may have a greater effect outside the laboratory if targeted at those in the early stages of smoking uptake. Further targeting may take into account individual differences in personality, with the correlations between N and either aversive cue anxiety, or appetitive cue RR increases, supporting previous reports of a greater effect of aversive Ss on neurotic individuals (Avila et al., 1999; Corr et al., 1995; McLaughlin & Eysenck, 1967).

In conclusion, the current experiment finds that the aversiveness of health warnings found on cigarette packets does not exert a generalisable influence on cigarette-seeking. Instead, their effect may depend on their predictive relationship with cigarettes, such that those who associate the images with nicotine will seek cigarettes based on an expectation of their availability. However, those in the early stages of nicotine dependence, as well as those with tendencies towards negative-affect, may be more susceptible to suppression of responding by aversive images, and so should be targeted by health campaigns.

8 General discussion

8.1 Synopsis of results

8.1.1 Re-iteration of aims

Research leading up to the current programme had made competing claims for the relative roles of emotion and expectation in the control of human reward seeking. On the one hand, data supporting emotional responses to reward cues in the absence of expectancy awareness suggested that *conditioned* responses could occur without expectancy (Hofmann et al., 2010). One the other, studies had confirmed that *instrumental* responses were only influenced by reward-paired cues if the cue elicited an expectation of reward (Hogarth et al., 2007; Hogarth & Duka, 2006). But these data supporting the necessary status of expectancy may have based their findings on methods that inadvertently suppressed emotional control of responding. Thus the current body of work was designed to facilitate the involvement of emotional processes, in order to investigate four aspects of reward-seeking that required greater clarity:

1. The ability of the *hedonic value* of reward-paired cues to influence reward-seeking
2. The involvement of reward *expectation* in the effects of reward-paired cues on reward-seeking
3. The moderating role of *personality* in the influence of cue-elicited emotion or outcome expectation on reward-seeking.
4. The potential changes to reward-seeking processes that occur as a result of *addiction*.

8.1.2 Behavioural results

The most consistent finding throughout the current series was the necessary status of reward expectation in controlling cue-elicited reward seeking. Experiments 1-4 found that differential instrumental responding in the presence of different conditioned-stimuli was only demonstrated by participants reporting expectancy awareness. Results from Experiment 3, i.e. the display of transfer in a group originally classified as unaware, at first appeared to question the necessary status of expectancy (refer to section 5.4.1.4). But the fact that this group held differential expectancies of winning money in the presence of different cues, as assessed immediately after the transfer phase (see section 5.4.1.5), instead supports an expectancy account of behaviour.

Less consistent, but culminating in Experiment 4, was the role of cue-induced hedonic value in moderating cue-elicited reward-seeking. Experiment 1 showed no evidence for the involvement of CS hedonic value during transfer, with responding uninfluenced by the presence of CSs with higher or lower hedonic value relative to each other. The single-response design of experiments 2 and 3 was used to encourage transfer in unaware participants, where responding based on expectancy could be discounted, and so any behavioural effects in aware participants confounded emotion with expectation. But having confirmed that expectancy awareness was necessary for transfer performance, Experiment 4 manipulated the hedonic value of a CS so that the effects of emotion and expectation could be dissociated in aware participants. This hedonic value reduction via a counter-conditioning phase brought about a stochastic response rate reduction in the transfer phase. However, the success of the counter-conditioning manipulation was statistically weak, and so any conclusions drawn about the necessary status of CS hedonic value are suggestive rather than definitive. Thus, while reward expectation appears necessary for reward seeking, it may not be sufficient in all situations, with CS hedonic value having potential necessary status, at least under the circumstances created by Experiment 4.

But Experiment 5 limits the circumstances under which CS hedonic value may play a role in reward-seeking. The results from this smoker population indicated that expectancy was sufficient to control cigarette-seeking. Expectancy of gaining cigarettes correlated with response rate during the transfer phase, and a cue that was rated as less pleasant, and more aversive, than a non-smoking cue did not suppress responding. Therefore the influence of CS hedonic value appears not to extend to addiction-related behaviours, highlighting emotional processes as a candidate for identifying those functions which are pathological in addiction.

8.1.3 Personality results

The parallel investigation of personality moderation of the associative learning tasks used in the current programme underlines the relevance of Extraversion and Neuroticism for reward-seeking. Extraversion was related to the evaluative discrimination of Pavlovian cues in all experiments except Experiment 2, and so presents itself as a potential moderator of behaviour controlled by CS hedonic value. Neuroticism predicted propositional discrimination of the Pavlovian cues in all experiments except Experiment 3, and so may impinge on a system controlling behaviour via reward expectation. Any influence of these traits on behaviour appears indirect, from the current results, as these factors did not predict measures of transfer behaviour. Nonetheless, by providing a detailed analysis of personality traits at the facet level, Experiment 4 uncovered tentative evidence that Impulsiveness was a predictor of reward-cue potentiation of transfer response rate.

Although this result involving Impulsiveness came from an exploratory analysis, thus requiring replication under more statistically rigorous conditions, the validity and applicability of the main findings from the series are supported by comparison with the wider reward-seeking literature.

8.2 Integration with extant literature

8.2.1 Implications for normal reward seeking

The necessary status of reward expectation in mediating cue-induced reward-seeking concurs with a growing body of literature (Bolles, 1972; Brandon et al., 2004; Hogarth et al., 2007; Hogarth & Duka, 2006; Lovibond & Shanks, 2002). Using both specific and single-response PIT designs, it was shown that expectancy awareness mediates the effects of cues on behaviour. This result is in agreement with a number of human PIT studies that have explicitly assessed awareness (Bray et al., 2008; Hogarth et al., 2007; Talmi et al., 2008), and suggests that results from those where awareness was not explicitly assessed were also dependent on such awareness (Hogarth & Chase, 2011; Nadler et al., 2011; Prévost et al., 2012).

But whether expectancy awareness is *sufficient* for PIT is questioned by the current series. In support of the sufficiency of awareness, Experiment 1 showed that an aware group of participants responded equally to 10p and 50p CSs, despite attributing higher hedonic value to the 50p CS. This implies that CS hedonic value had no influence on behaviour, leaving only reward expectation to explain the response pattern. Relatedly, studies that have contrasted *reward* value, rather than *CS* value, have shown similar responding for rewards that are differentially valued, but equally expected (Colwill & Rescorla, 1988; Corbit et al., 2007; Hogarth, 2012; Hogarth & Chase, 2011).

But in opposition, Experiment 4 may have demonstrated that PIT could be abolished by manipulation of CS hedonic value, rather than manipulation of reward hedonic value, implying that both expectancy and value representations are necessary for PIT. This CS-value-sensitive PIT result adds to the previous reports of outcome-value-sensitive PIT (Corbit et al., 2007; Dickinson & Dawson, 1987) by widening the targets amenable to revaluation from US to CS. The apparent discrepancy, either between Experiment 1 and 4 reported here, or the devaluation insensitive versus sensitive studies reported elsewhere, is attributed to the different methodological versions of PIT used (Corbit & Balleine, 2005; de Wit & Dickinson, 2009; Holland, 2004). The inclusion of multiple rewards and responses, where a CS can cue a specific response, has been shown to be insensitive to outcome revaluation (Colwill & Rescorla, 1988; Corbit et al., 2007; Hogarth, 2012; Hogarth & Chase, 2011). In contrast, the inclusion of a single response (Dickinson & Dawson, 1987), or a CS that cannot cue a specific response (Corbit et al., 2007), appears to engender outcome value sensitivity.

More specifically, it may be that single response paradigms engender sensitivity to *current* outcome value, whereas multiple response paradigms rely on *learned* outcome value. For instance, if the performing animal is allowed access to a devalued reward in the presence of a Pavlovian cue, then instrumental responding in the presence of the cue regains sensitivity to current outcome value (Dickinson & Balleine, 1994). Thus, even in situations where expectancy appears sufficient for transfer, such as in Experiment 1 here, this expectancy may still be bound to some representation of value. Over repeated training, the animal may shift its reliance from resource-costly goal-directed processes towards resource-light automatic processes (Tiffany, 1990). Thus rather than re-iteratively computing the value of a particular outcome, if the cost of responding and benefit of the outcome remain relatively constant, then it may be more efficient to rely on learned associations between S→O and R→O. Contexts affording multiple responses may be especially demanding of cognitive resources, and so shift responding towards learned value representations at an earlier stage in training.

It may be, therefore, that the apparent sufficiency of expectancy awareness in the display of PIT is dependent on the test conditions. Those conditions that encourage decisional processes, e.g. in the selection of possible responses, engender an S→O→R architecture where the sensory properties of an outcome are sufficient to prime a specific response (de Wit & Dickinson, 2009; Hommel et al., 2001). The results of Experiment 1 add to this literature by indicating that such discriminative priming can occur in the presence of relatively few discriminatory signals, in that two monetary outcomes sharing a large number of sensory properties were able to prime specific responses.

But to suggest that expectancy is sufficient for PIT requires 'expectancy' to be qualified. Although it may initially be interpreted as a 'cold' cognitive representation, it may in fact comprise multiple dissociable aspects. As stated above, expectancy may occur in parallel with learned value representations. Therefore, what is necessary may be a combination of outcome sensory representations and [learned] outcome value representations. Reports of the insensitivity of specific PIT to devaluation do not necessarily mean insensitivity to *value*, but rather *current* value. Indeed, Colwill & Rescorla (1990) reports that devaluing a food stimulus to the point that it becomes aversive does impact transfer. Therefore, at least some aspect of hedonic value may be represented, if only the valence of reward. This may accord with the results of Experiment 1, where seeking of two positively valenced rewards was equally controlled by their respective CSs.

It may be, therefore, that the choice of response is governed by the sensory expectation of an outcome, but that response execution requires facilitation by some form of outcome value representation. Expectancy's role in instrumental performance may therefore be multifaceted, coding both for the sensory target of action, and also the utility of action. The sensory properties may prime a specific set of motor programmes, akin to the S⍰O⍰ stages of an S⍰O⍰R process (Hommel et al., 2001). But in order for the sequence to be completed with an 'R', the value component of expectancy may be required to provide sufficient impetus to any primed response units for activation to occur. This suggestion is similar that the Associative-Cyberkinetic (A-C) model put forward by de Wit & Dickinson (2009), although it adds that value components may also recruit memory systems, rather than relying solely on current value representations. Thus, 'expectancy' may be a global term that can be dissociated into the sensory and value components of an outcome, which would itself comprise aspects of response cost, and outcome benefit (Hogarth et al., 2014; Redish, 2007).

In contrast, conditions where response decisions are reduced may allow S[R→O] processes to be recruited that require expectation and *CS* hedonic activation. Under S[R→O] circumstances the initial decision to respond may be governed by the identity of the outcome (Dickinson & Balleine, 1994), i.e. sensory expectancy, but the ensuing response requires augmentation by the hedonic CS in order to be completed. Thus responding is again primed by sensory expectations, similar to the A-C model, but now adds that motor units are activated by value stemming directly from the S, rather than the O (Cabanac, 1979). This interpretation is supported by results from Experiment 4, which demonstrated that response initiation was unaffected by the reduction of CS hedonic value, but that the ensuing response rate was diminished.

But such an explanation of single-response studies as amenable to an S[R→O] mechanism would predict that expectancy awareness is not necessary to show a transfer effect. Although knowledge of the R→O contingency would be required to initiate an instrumental response (Dickinson & Balleine, 1994), knowledge of the S→O contingency is not required to elicit a conditioned hedonic response (Hofmann et al., 2010). Therefore expectancy awareness should not affect the ability of the stimulus to augment responding. Yet unaware participants in the current series consistently failed to demonstrate transfer. They developed a conditioned hedonic response to reward-predictive stimuli, and acquired knowledge of the causal association between response and reward. Yet their responses in the presence of the hedonic CS were no different to those in its absence, i.e. their S[R→O] was no different to their R→O.

It may have been that the contrived nature of the experimental task inhibited hedonic reactions during transfer in unaware participants. An anecdotal observation was that a number of unaware participants reported that the transfer phase was frustrating, confusing, or boring, whereas aware participants did not report these feelings nearly as much. The task may therefore have suppressed any positive emotions in unaware participants, more so than aware participants, and so rendered the previously hedonic effects of the reward-paired CS null. Such a suggestion should be tested by making transfer tests more stimulating.

The facilitation of positive emotion may be further enhanced by recruiting participants scoring highly on Extraversion. In the studies which showed an effect of personality on evaluative discrimination, Extraversion was the most consistent predictor. This result accords with previous findings of Extraversion, and related traits of positive affect, as a predictor of appetitive responses to positively-valenced stimuli (Brunelle et al., 2004; Canli et al., 2001). This may present highly extraverted individuals as suitable candidates for the display of S[R→O] mediated behaviour, in that their increased hedonic response to a reward-predictive CS may encourage more consistent potentiation of responding. Such a suggestion will require further research, however, as Extraversion did not predict transfer behaviour in the current series.

Instead, the related trait of Novelty-Seeking, specifically its Impulsiveness facet, was shown in Experiment 4 to predict cue-potentiated responding during transfer. Although the predictive ability of Impulsiveness in Experiment 4 was statistically tenuous, the validity of the relationship is supported by its theoretical underpinning as a proxy for a reward-approach system (Cloninger et al., 1994), and the demonstration that trait impulsivity interacts with instrumental responding for reward in a prior report (Hogarth, 2011). Furthermore, the Excitement-Seeking facet of Extraversion has been associated with increased engagement in reward-seeking activities, e.g. cigarette use, alcohol use and gambling (Bagby et al., 2007; Ruiz et al., 2003; Terracciano & Costa, 2004), thus highlighting this constellation of positive-affect traits as potential moderators of behaviour controlled by hedonic cues.

Although the present set of results strengthen the existence of a relationship between Extraversion and emotion, they do not necessarily strengthen any explanation behind the relationship. At a mundane level, the finding that Extraversion predicts positive emotion may simply support the existing definition of Extraversion as representing positive emotion (Costa & McCrae, 1992). Although the present experimental design adds a degree of specificity to the Extraversion definition, in that emotions were directed towards conditioned stimuli, this cue-specific effect is already predicted by Cloninger and colleagues (1994). Where the present set of data may add to the literature on Extraversion, and its effect on reward learning, is in the fact that awareness had little impact on the predictive validity of Extraversion in evaluative conditioning. This may suggest that Extraversion has a direct effect on emotion, rather than an indirect one via propositional processes. Previously, it could have been said that the trait imbued a greater ability to represent positive outcome expectancies. But a lack of expectancy awareness did not ameliorate the effect of Extraversion. Thus, the trait may have its effects on reward-seeking through augmenting the value of CSs themselves, rather than the outcomes that they predict. Extraversion, and it's related Novelty-Seeking traits, may therefore be relevant to the sign-tracking versus goal-tracking literature, to the extent that such a dichotomy represents a propensity to attribute value to a CS versus an outcome (Flagel et al., 2009; Saunders, O'Donnell, Aurbach, & Robinson, 2014; Saunders & Robinson, 2013).

In contrast, behaviour controlled by outcome expectation may be moderated by Neuroticism and its related negative-affect traits. Neuroticism predicted the rate at which participants developed propositional knowledge of the different CS contingencies, and so may facilitate expectancy-based modes of reward-seeking. This enhancement of expectancy awareness was consistent across the majority of experiments in the present series, and is supported by the extant literature (Corr et al., 1995). A direct effect of Neuroticism on transfer behaviour was not found, though this may have been because the relationship between expectancy awareness and PIT takes a binary form, i.e.

present/absent, thus precluding correlational analysis. But a linear effect exists between Neuroticism and reward-seeking in the extant literature, in the form of Neuroticism's relationship to addiction (Bagby et al., 2007; Piedmont, 2001; Piedmont & Ciarrocchi, 1999; Terracciano & Costa, 2004). Therefore Neuroticism's prediction of expectancy awareness here may provide a mediating mechanism for the Neuroticism→addiction association.

Although a tentative suggestion, the involvement of Neuroticism in expectancy awareness, and so outcome prediction, suggests that its role in learning may be via prediction error (Robert A Rescorla & Wagner, 1972; Schultz, Dayan, & Montague, 1997). Due to the propensity of Neuroticism to facilitate negative emotions (Costa & McCrae, 1992), yet correct predictions in a reward learning task, it may have been that higher Neuroticism elicited more negative expectancies in the early stages of Pavlovian conditioning. These negative expectancies would create a larger prediction error on receipt of reward, and so facilitate learning. Indeed, higher negative expectancies of drug outcomes are associated with higher drug use (Kirchner & Sayette, 2007; Lopez-Vergara et al., 2012; Martens & Gilbert, 2008). Although the most apparent explanation for this relationship is that higher drug use offers more opportunity to experience their negative effects, it remains possible that negative expectancies precede drug use escalation. Future research may therefore benefit from longitudinal analyses that follow adolescents with negative expectancies towards drugs, and compare their rates of drug uptake with peers exhibiting less negative attitudes prior to drug use.

But the current personality data is questionable on the grounds of its weak reliability throughout the different experiments. Although the majority of experiments were in accord with one another, Experiment 2 reported a null result for Extraversion on emotion, and Experiment 3 reported a null result for Neuroticism on awareness. Additionally, the TCI was a weaker predictor than the NEO across the range of experimental measures. It may be, therefore, that the context-dependent nature of personality (Munafò & Flint, 2011; Rushton, Brainerd, & Pressley, 1983; Uziel, 2015), and the poor psychometric properties of the questionnaires (Draycott & Kline, 1995; Gana & Trouillet, 2003; Miettunen, Lauronen, Kantojärvi, Veijola, & Joukamaa, 2008; Saggino, 2000), hampered consistent results. To ameliorate such difficulties of reliability, it may be prudent in future to meta-analyse small studies. Relatedly, a 'fixed-effects' analysis was conducted on the present data, where each individual experiment was combined into one large dataset, which supported the general pattern of the individual experiments. Extraversion remained the only higher-order predictor of CS hedonic value, although Harm-Avoidance was added to Neuroticism in predicting expectancy awareness.

8.2.2 Implications for addiction

Experiment 5 indicated that cigarette-seeking in smokers was controlled by the expectation of cigarettes, but was not affected by the hedonic properties of a cigarette-paired CS. This hedonic insensitivity presents a contrast to Experiment 4, where a non-smoker sample was putatively sensitive to CS hedonic value, and so may represent a behavioural process that forms part of the pathology of addiction.

The control of nicotine-seeking by expectancy is corroborated elsewhere, with the finding that cued tobacco seeking and consumption is insensitive to the devaluation of nicotine (Hogarth, 2012; Hogarth et al., 2010). The current data furthers the extant literature by adding that cued tobacco seeking is also insensitive to the hedonic value of the cue. Bargh & colleagues (Earp et al., 2013; Harris et al., in press) come to a similar expectancy-dominant conclusion with their results that no-smoking signs and health-warning advertisements increase smoking behaviours, despite being considered aversive by smokers.

Due to this insensitivity to emotional processes of reward-seeking, smokers may be biased away from S[R→O] control of behaviour, and instead towards S→O→R. They would therefore be more sensitive to the contingencies that exist between smoking stimuli and nicotine than the emotional valence of the stimuli (Dickinson & Charnock, 1985; Trick et al., 2011). The fact that Experiment 5 used the health warnings currently in use on UK cigarette packets attests to the applicability of this result. If smokers see these images simply as CSs for nicotine, then placing these images in the wider environment may have a counter-productive effect and actually increase rates of smoking.

However, the negative correlation between Fagerstrom dependence scores and anxiety ratings of the health warnings may suggest that these aversive images have an impact at the onset of addiction, in that participants with lower dependence rated the warnings as more aversive. Indeed, Bargh & colleagues (Earp et al., 2013; Harris et al., in press) suggest that although the acute effect of smoking cues may be to encourage smoking, the long-term effect of health warnings may be to discourage cigarette uptake. It would be informative to compare a group of recent smokers to more experienced smokers on tests of cue-induced cigarette-seeking to determine the validity of Bargh & colleagues' prediction.

Just as Experiment 5 suggested that cue-induced cigarette-seeking was insensitive to CS value, the experiment also suggested that cigarette-seeking was insensitive to US value, in that cue-induced craving did not relate to instrumental responding. Craving has been shown to track outcome value (M. Field et al., 2004; Hogarth et al., 2010), thus the lack of relationship between craving and seeking in Experiment 5 provides further support to previous studies finding insensitivity to outcome devaluation in cued smoking (Hogarth, 2012; Hogarth & Chase, 2011).

It also questions the involvement of cue-induced motivational processes in cigarette addiction, thus potentially opposing Incentive Sensitisation theory (Robinson & Berridge, 1993). However, rather than presenting a complete rebuttal of Incentive Sensitisation, the present data hint at an expansion of the theory. A central tenet of much addiction research is that nucleus accumbens (NAc) dopamine (DA) is largely responsible for allowing cues to gain salience. Combined with extant neuroscientific literature, the importance of outcome expectancy may extend DA's remit in addiction to pre-frontal regions responsible for outcome representations (Naneix, Marchand, Di Scala, Pape, & Coutureau, 2012; Takahashi et al., 2011; Winter, Dieckmann, & Schwabe, 2009). Whereas DA in the accumbens may be critical for imbuing the CS itself with value (Wyvell & Berridge, 2000, 2001), DA in the orbito-frontal cortex (OFC) may be necessary for imbuing the outcome with value (Valentin, Dickinson, & O'Doherty, 2007)}(Winter et al., 2009). Outcome devaluation studies ascribe a central role of the OFC, in combination with amygdala nuclei (Corbit & Balleine, 2005), to integrating the sensory and value components of an outcome. Thus the OFC may provide a candidate location for coding outcome expectancies.

But rather than the NAc and OFC networks representing competing systems, one driving behaviour by immediate appreciation of CS salience, the other driving behaviour after deliberation of an action's consequences, recent evidence suggests that the two may act synergistically. For example, manipulating the uncertainty of reward magnitude predicted by a CS, which might be argued to rely on OFC (Takahashi et al., 2011; Tobler, O'Doherty, Dolan, & Schultz, 2007), has a corollary effect on CS value (Anselme, Robinson, & Berridge, 2013): as uncertainty increases, sign-tracking also increases. It may be that as the ability to represent outcome value is impeded, as would be the case with uncertain rewards, behaviour comes under control from CSs themselves, rather than a representation of their outcome. Conversely, if expectancy is facilitated, as was the case with participants scoring highly on Neuroticism, then outcome representations may guide responding. The available evidence relevant to addiction suggests that this latter, outcome expectancy, process is compromised in some way. Addicts appear pre-occupied with drug CSs, and their behaviour is seemingly insensitive to outcome representations (Hogarth et al., 2010; Miles et al., 2003). Indeed, Robinson & Berridge (1993) argue that NAc DA is sensitised over repeated drug exposure (Wyvell & Berridge, 2001), suggesting a progressive increase in control by CS value. But whether such sensitisation occurs in OFC DA release has received less attention. The source neurons of NAc DA, stemming from the VTA, form a network including the OFC (Vázquez-Borsetti, Cortés, & Artigas, 2009). Thus OFC activity may be involved in NAc sensitisation, and may be sensitised itself in a feed-forward mechanism. This OFC DA sensitisation may manifest itself as an excessive incentive value being attributed to an outcome, i.e. an excessive positive outcome expectancy, and so explain the apparent loss of value sensitivity in drug users when presented with drug cues (Hogarth, 2012; Hogarth, Attwood, Bate, & Munafó, 2012). Thus reward expectancy itself may not be a problem, but rather the excessive reward expectancy that may result from chronic drug exposure. Targeting these aberrant expectancies may therefore prove useful in relapse prevention (Witkiewitz & Marlatt, 2004).

But in contrast, the present experiment did reveal a correlation between *grey* trial craving and subsequent cigarette-seeking. The grey stimulus was non-predictive of cigarette reward (Robert A. Rescorla, 1967), having been equally associated with winning and losing cigarettes, and so represented a baseline condition in the transfer phase. Previous reports corroborate the relationship between craving and cigarette-seeking under free-choice conditions (Hogarth, 2011; Hogarth et al., 2010). Therefore, the correlation between craving and response initiation on grey trials suggests that nicotine-seeking in the absence of CSs is goal-directed. This may represent another avenue for prevention using health warnings, which have been shown to devalue nicotine (Hogarth & Chase, 2011), with aversive messages acting on potential smokers both to devalue nicotine and devalue the hedonic properties of nicotine cues.

But whether the role of craving shown in Experiment 5 differs from its potential role in experiments 1-4, i.e. whether craving effects are unique to addicts or apply to non-addict populations, cannot be directly addressed in the current series.

8.3 Methodological issues

While the inclusion of subjective ratings of craving in the earlier studies may have been informative, it would not be predicted to glean much additional information (Berridge, 2000; M. Field et al., 2004; Toates, 1986), and may even hamper the validity of other subjective measures (Van Gucht, Vansteenwegen, Van den Bergh, & Beckers, 2008). In non-addict populations, ratings of CS-induced craving and pleasantness are highly coupled (Van Gucht et al., 2013; Van Gucht et al., 2010), such that changes in one are reflected by changes in the other. Thus it is unlikely that the addition of craving ratings would have provided different information to pleasantness ratings. Moreover, Van Gucht & colleagues (Van Gucht et al., 2008) report that the concurrent measurement of both craving and pleasantness can interfere with the reliability of each measure, thus suggesting that one or other should be used. As experiments 1-4 were concerned with CS value, more than reward value, it was more appropriate to measure pleasantness than craving.

An additional assumption throughout the series was that the grey stimulus encountered during instrumental training represented 'baseline' trials, and so was used in a similar manner to inter-stimulus-interval (ISI) periods more often seen in non-human research (e.g. Colwill & Rescorla, 1988; Corbit et al., 2007; Lovibond, 1981). Within the current series this grey stimulus generated intermediate levels of reward expectancy, similar to the non-predictive CS from Pavlovian training, and in between the winning and non-winning CSs from Pavlovian training. Thus its use as a control for CS-potentiated expectancy appears justified. However, pleasantness ratings were not taken for the grey stimulus, thus its suitability for CS-potentiated hedonic value may be questioned. Nonetheless, using a similar set of images, Trick & colleagues (Trick et al., 2011) show that transfer-phase responding in the presence of the non-predictive Pavlovian CS was similar to responding in the presence of the grey stimulus. Thus although the inclusion of non-predictive Pavlovian CS trials would provide an additional control condition, results from this Pavlovian control condition would not be expected to differ from the grey stimulus control condition.

Additional comparison to non-human paradigms provides another methodological detail that may have influenced the present results, in the form of the temporal contiguity between CS and either US, in Pavlovian training, or response, in transfer. The current series used a trace procedure, where the CS terminated prior to the delivery of reward, or opportunity to press. This is in contrast to the delay procedure used more often in other studies (e.g. Colwill & Rescorla, 1990; Corbit & Balleine, 2005; Crombag et al., 2008), where CS and US or response are presented concurrently. This may have the effect of encouraging a propositional representation of reward on presentation of the CS, at the expense of an emotive representation (Konorski, 1967), therefore reducing the capacity of CS hedonic value to influence behaviour. Indeed, Lovibond (1981) reports that a trace conditioning procedure with a fixed ISI was less influential in producing PIT than a trace procedure with a variable ISI. Lovibond explains this effect as being due to the *termination* of CS being a reliable predictor of reward in the fixed condition, but less so in the variable condition. Also relevant is a study by Crombag & colleagues (Crombag et al., 2008) that showed a greater PIT effect when the temporal overlap of CS and US was made increasingly variable.

While such alterations to Pavlovian training may not have a great effect, because consistent emotional responses to reward-predictive stimuli was demonstrated, using a delay procedure in the transfer phase may create suitable conditions for unaware participants to display transfer. Aware groups may be able to sustain the hedonic trace elicited by the CS into the transfer response window, due to them being able to activate emotional processes via US representations as well as CS presentations. But unaware groups have only the CS presentations to elicit a hedonic response, after which the hedonic trace may fade, and so be less able to augment responding. Further study is therefore required to test the role of CS hedonic value on instrumental responding under delay conditions.

8.4 Future directions

While the current studies find that *remotely* trained hedonic CSs do not influence unaware participants' behaviour others indicate that *proximally* trained stimuli do impart such influence (Pessiglione et al., 2008; Pessiglione et al., 2007). Pessiglione & colleagues (Pessiglione et al., 2008; Pessiglione et al., 2007) used subliminal stimulus presentation to prevent expectancy of the available outcome, and used discriminative instrumental paradigms where the stimulus signalled the utility of a response in gaining the outcome. Thus their design allowed a direct S→R association to form, whereas the current experiments' PIT design precluded such direct association. Similar to the present results an emotional conditioned response to the reward-paired stimulus was shown, but in contrast to the present data greater instrumental responding was also shown. Thus hedonic responses in unaware individuals may influence behaviour if the stimulus has gained direct access to the response.

These subliminal techniques should be converted into a PIT paradigm to measure whether experimental manipulation of expectancy, rather than the quasi-experimental separation used presently, will also show the lack of PIT seen in unaware participant throughout the current series. Moreover, if the Pavlovian phase is conducted liminally, thus allowing expectancy to form, whereas the transfer phase is conducted sub-liminally, thus 'knocking-down' expectancy, it will be possible to test the stage at which expectancy is necessary for transfer. Robinson & Berridge (1993) argue that unconscious motivational processes drive cue-potentiated drug-seeking, thus the absence of PIT under subliminal conditions would test this unconscious assertion.

If a PIT effect is seen under subliminal conditions, then this may imply that vulnerability to relapse in addicts may be amplified by being unaware of the stimulus triggering drug-seeking. Whereas those possessing knowledge of their drug-seeking triggers may be able to use cue-exposure treatment to extinguish their effects (Conklin & Tiffany, 2002), those unable to identify the cause of their behaviour may be unable to implement such strategies. This would put them at greater risk of relapse. This may present a paradoxical situation, however, with an appreciation of relevant cues potentially encouraging expectancy driven drug-procurement. Further study will be required to understand the most effective treatment strategy.

It may in fact be that unconscious versus conscious mechanisms of drug seeking are equally liable to elicit relapse. For example, work on sign-trackers versus goal trackers, putative models for addicts controlled by CS value versus US expectancy, respectively, suggests that drug seeking may be equally intractable in both populations (Flagel et al., 2009; Saunders et al., 2014). While sign trackers may be more sensitive to the priming effects of discrete cues, goal trackers may be more sensitive to contextual cues (Saunders et al., 2014). To the extent that sign-trackers direct motivational value to the stimulus, whereas goal trackers direct motivational value to the outcome, the unaware/aware dichotomy of the current thesis may have relevance to sign- versus goal-trackers, and in turn their relevance to addiction. Unaware participants attributed emotional value to the CS_+, which would in turn predict an attentional bias to the CS_+ (Austin & Duka, 2010), and so may represent sign-tracking. Aware participants, on the other hand, displayed 'approach' behaviour to the outcome, in the form of increased instrumental responding, which may constitute goal-tracking. The experimental set-up of the current series precludes more specific analogies at present, but future work may wish to investigate the potential for unaware/aware participants to provide human populations analogous to sign- versus goal-tracking rats. It may be that unaware individuals are more susceptible to the relapse priming effect of discrete cues which they have imbued with incentive salience. Aware individuals, on the other hand, may be more liable to relapse in the face of contextual cues which provoke an expectation of drug availability.

In order to test the relevance of unaware participants to sign-tracking, it will be necessary to better understand the mechanisms leading to unaware evaluative conditioning. One explanation may be that evaluative knowledge precedes declarative knowledge. Thus unaware participants may simply be ‘slow learners’. This accords with one theory of consciousness which asserts that meta-cognitive processes determine conscious awareness (Cleeremans, 2014). This meta-cognitive theory proposes that animals develop unconscious Pavlovian and instrumental associations, and are able to use these associations in limited situations, but do not become conscious of these associations until meta-cognitive processes are recruited to manipulate the low-level associations. Applied to unaware participants, it may be that they develop the implicit association between CS_+ and reward, and so respond autonomically, but do not habitually recruit meta-cognition of the implicit evaluative knowledge, and so cannot respond declaratively.

However, the description of unaware participants as ‘slow learners’ is questioned by data showing a facilitatory effect of autonomic arousal on declarative learning (Garfinkel, Seth, Barrett, Suzuki, & Critchley, in press; Katkin, Wiens, & Öhman, 2001; Raes & Raedt, 2011). Katkin and colleagues (2001) demonstrated that participants who show increased sensitivity to CS-elicited autonomic arousal were better able to predict the occurrence of shock. Moreover, Raes & Raedt (2011) showed that experimentally increasing sensitivity to interoceptive states increased learning rate. Thus, it may follow that unaware participants should be able to use their autonomic reactions during Pavlovian conditioning to facilitate their expectations of reward. However, the ability to accurately sense one’s arousal, the predisposition to attend to one’s arousal, and the metacognitive awareness of the causes of one’s arousal, have been shown to be dissociable (Garfinkel et al, in press). Unaware participants may possess accuracy, in that they ‘correctly’ attributed greater hedonic reactions to the CS_+, but again lack metacognition concerning the causes of their hedonic judgement. But the parallels between ‘interoceptive awareness’ and expectancy awareness have not received attention. Therefore, further research is required to understand whether expectancy unaware participants are more prone to sign-tracking, whether this potential sign-tracking puts them at greater risk of relapse from discrete drug-paired cues, and whether facilitating interoceptive awareness might facilitate expectancy awareness, which may in turn facilitate goal tracking and control by contextual cues.

Aside from addiction, it may also be interesting to test the effects of expectancy awareness in other clinical populations. Due to the overlapping symptoms of drug withdrawal and depression (Harrison, Liem, & Markou, 2001), disorders characterised by a lack of motivation may benefit from exactly the processes that cause a problem in addicts. Whereas addiction may be controlled by excessive positive outcome expectancies (Hendershot et al., 2011), depression may be ameliorated by such expectancies. People experiencing depression demonstrate blunted anticipation of reward (Brinkmann & Franzen, 2013), and so may lack the motivation to perform many behavioural routines. Yet the presentation of a reward-paired cue appears to elicit a response regardless of explicit value representations under PIT conditions (Hogarth & Chase, 2011; Holland, 2004). If the same processes that encourage responding in drug seekers could be harnessed in depression, then therapies with a behavioural component may be improved. PIT has been shown to be insensitive to serotonin manipulation in non-humans (Sanders, Hussain, Hen, & Zhuang, 2007), suggesting that SSRI's may not prove effective in cue-potentiated responding. But with the discussion of cue-potentiated behaviour centred around the role of DA, it may be prudent to understand how other pharmacological agents such as DA may help depression.

8.5 Conclusions

The current series of experiments aimed to explicate the seemingly contradictory data concerning the roles played in reward seeking by conditioned-stimulus-elicited emotion and outcome expectation. Reward-seeking processes were characterised in non-dependent samples, before comparing their contribution in smokers. Further data suggest a role of personality in reward-seeking behaviours, thus personality was assessed in parallel as a moderator of reward-seeking. It was shown that outcome expectation, and potentially cue-elicited emotion, were necessary for cue-potentiated monetary-reward seeking, yet in smokers cigarette outcome expectation was sufficient for cue-potentiated cigarette-reward seeking; the emotional value of the conditioned-stimuli did not play a role. Moderating influences of Extraversion and Neuroticism were found for cue-elicited emotion and outcome expectation, respectively. It is therefore proposed that the emotional properties of reward-predictive stimuli may be important for reward seeking in the absence of addiction, whereas when addiction to reward is present control of reward seeking can occur via reward expectation only. Furthermore, control of behaviour by emotion may be facilitated by Extraversion, due to its propensity towards emotional processes, whereas control by expectation may be facilitated by Neuroticism, due to its inclination towards predictive learning. Future research should test the ability of reward-predictive cues to influence reward-seeking subliminally, to test whether a cue can act on behaviour outside of conscious awareness.

9 References

Adams, C. D., & Dickinson, A. (1981). Instrumental responding following reinforcer devaluation. *The Quarterly Journal of Experimental Psychology Section B, 33*(2), 109-121.

Agboola, S., McNeill, A., Coleman, T., & Bee, J. L. (2010). A systematic review of the effectiveness of smoking relapse prevention interventions for abstinent smokers. *Addiction, 105*(8), 1362-1380.

Alberini, C. M. (2005). Mechanisms of memory stabilization: are consolidation and reconsolidation similar or distinct processes? *Trends in Neurosciences, 28*(1), 51-56.

Altman, J., Everitt, B. J., Robbins, T. W., Glautier, S., Markou, A., Nutt, D., . . . Phillips, G. D. (1996). The biological, social and clinical bases of drug addiction: commentary and debate. *Psychopharmacology, 125*(4), 285-345.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders IV text revised* (4 ed.). Arlington, VA: American Psychiatric Association.

Anselme, P., Robinson, M. J. F., & Berridge, K. C. (2013). Reward uncertainty enhances incentive salience attribution as sign-tracking. *Behavioural Brain Research, 238*(1), 53-61.

Ansorge, U. (2002). Spatial intention-response compatibility. *Acta Psychologica, 109*(3), 285-299.

Austin, A. J., & Duka, T. (2010). Mechanisms of attention for appetitive and aversive outcomes in Pavlovian conditioning. *Behavioural Brain Research, 213*(1), 19-26.

Avila, C., Parcet, M. A., Ortet, G., & Ibáñez-Ribes, M. I. (1999). Anxiety and counter-conditioning: the role of the behavioral inhibition system in the ability to associate aversive stimuli with future rewards. *Personality and Individual Differences, 27*(6), 1167-1179.

Baeyens, F., Eelen, P., & van den Bergh, O. (1990). Contingency Awareness in Evaluative Conditioning - a Case for Unaware Affective-Evaluative Learning. *Cognition & Emotion, 4*(1), 3-18.

Baeyens, F., Eelen, P., van den Bergh, O., & Crombez, G. (1989). Acquired affective-evaluative value: Conservative but not unchangeable. *Behaviour Research and Therapy, 27*(3), 279-287.

Bagby, R. M., Vachon, D. D., Bulmash, E. L., Toneatto, T., Quilty, L. C., & Costa, P. T. (2007). Pathological gambling and the five-factor model of personality. *Personality and Individual Differences, 43*(4), 873-880.

Ball, S. A., Tennen, H., Poling, J. C., Kranzler, H. R., & Rounsaville, B. J. (1997). Personality, temperament, and character dimensions and the DSM-IV personality disorders in substance abusers. *Journal of Abnormal Psychology, 106*(4), 545-553.

Balleine, B. W. (1992). Instrumental performance following a shift in primary motivation depends on incentive learning. *Journal of Experimental Psychology: Animal Behavior Processes, 18*(3), 236-250.

Balleine, B. W., Garner, C., Gonzalez, F., & Dickinson, A. (1995). Motivational control of heterogeneous instrumental chains. *Journal of Experimental Psychology: Animal Behavior Processes, 21*(3), 203-217.

Bedard, M., & Weingarten, H. P. (1989). Postabsorptive glucose decreases excitatory effects of taste on ingestion. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology, 256*(5), R1142-R1147.

Berkun, M. M., Kessen, M. L., & Miller, N. E. (1952). Hunger-reducing effects of food by stomach fistula versus food by mouth measured by a consummatory response. *Journal of Comparative and Physiological Psychology, 45*(6), 550-554.

Berridge, K. C. (2000). Reward learning: Reinforcement, incentives, and expectations. In D. L. Medin (Ed.), *The Psychology of Learning and Motivation* (Vol. 40, pp. 223-278): Academic Press.

Berridge, K. C., Flynn, F. W., Schulkin, J., & Grill, H. J. (1984). Sodium depletion enhances salt palatability in rats. *Behavioral Neuroscience, 98*(4), 652-660.

Berridge, K. C., & Robinson, T. E. (1995). The Mind of an Addicted Brain: Neural Sensitization of Wanting versus Liking. *Current Directions in Psychological Science, 4*(3), 71-76.

Bindra, D. (1974). A motivational view of learning, performance, and behavior modification. *Psychological Review, 81*(3), 199-213.

Bolles, R. C. (1972). Reinforcement, expectancy, and learning. *Psychological Review, 79*(5), 394-409.

Bouton, M. E., & Swartzentruber, D. (1986). Analysis of the associative and occasion-setting properties of contexts participating in a Pavlovian discrimination. *Journal of Experimental Psychology: Animal Behavior Processes, 12*(4), 333-350.

Bradley, B. P., Mogg, K., Wright, T., & Field, M. (2003). Attentional bias in drug dependence: Vigilance for cigarette-related cues in smokers. *Psychology of Addictive Behaviors, 17*(1), 66-72.

Brandon, T. H., Herzog, T. A., Irvin, J. E., & Gwaltney, C. J. (2004). Cognitive and social learning models of drug dependence: implications for the assessment of tobacco dependence in adolescents. *Addiction, 99*, 51-77.

Bray, S., Rangel, A., Shimojo, S., Balleine, B., & O'Doherty, J. P. (2008). The Neural Mechanisms Underlying the Influence of Pavlovian Cues on Human Decision Making. *The Journal of Neuroscience, 28*(22), 5861-5866. doi: 10.1523/jneurosci.0897-08.2008

Brinkmann, K., & Franzen, J. (2013). Not everyone's heart contracts to reward: Insensitivity to varying levels of reward in dysphoria. *Biological Psychology, 94*(2), 263-271.

Brunelle, C., Assaad, J.-M., Barrett, S., Avila, C., Conrod, P., Tremblay, R., & Pihl, R. (2004). Heightened heart rate response to alcohol intoxication is associated with a reward-seeking personality profile. *Alcoholism: clinical and experimental research, 28*(3), 394-401.

Cabanac, M. (1979). Sensory Pleasure. *The Quarterly Review of Biology, 54*(1), 1-29.

Cabanac, M., & Lafrance, L. (1990). Postingestive alliesthesia: The rat tells the same story. *Physiology & Behavior, 47*(3), 539-543.

Canli, T., Zhao, Z., Desmond, J. E., Kang, E., Gross, J., & Gabrieli, J. D. E. (2001). An fMRI study of personality influences on brain reactivity to emotional stimuli. *Behavioral Neuroscience, 115*(1), 33-42.

Cannon, D., Clark, L. A., Leeka, J., & Keefe, C. (1993). A reanalysis of the Tridimensional Personality Questionnaire (TPQ) and its relation to Cloninger's Type 2 alcoholism. *Psychological assessment, 5*(1), 62-66.

Carter, B. L., & Tiffany, S. T. (1999). Meta-analysis of cue-reactivity in addiction research. *Addiction, 94*(3), 327-340.

Carter, B. L., & Tiffany, S. T. (2001). The cue-availability paradigm: The effects of cigarette availability on cue reactivity in smokers. *Experimental and Clinical Psychopharmacology, 9*(2), 183-190.

Caswell, A. J., Morgan, M. J., & Duka, T. (2013a). Acute alcohol effects on subtypes of impulsivity and the role of alcohol-outcome expectancies. *Psychopharmacology, 229*(1), 21-30.

Caswell, A. J., Morgan, M. J., & Duka, T. (2013b). Inhibitory Control Contributes to "Motor"-but not "Cognitive"-Impulsivity. *Experimental Psychology, 60*(5), 324-334.

Cleeremans, A. (2014). Connecting conscious and unconscious processing. *Cognitive Science, 38*(6), 1286-1315.

Cloninger, C. R. (1987). Neurogenetic adaptive mechanisms in alcoholism. *Science, 236*, 410-416.

Cloninger, C. R., Przybeck, T. R., Svrakic, D. M., & Wetzel, R. D. (1994). *The Temperament and Character Inventory (TCI): A Guide to its Development and Use*. St Louis, MO: Center for Psychobiology of Personality.

Colwill, R. M., & Rescorla, R. A. (1985). Postconditioning devaluation of a reinforcer affects instrumental responding. *Journal of Experimental Psychology: Animal Behavior Processes, 11*(1), 120-132.

Colwill, R. M., & Rescorla, R. A. (1988). Associations between the discriminative stimulus and the reinforcer in instrumental learning. *Journal of Experimental Psychology: Animal Behavior Processes, 14*(2), 155-164.

Colwill, R. M., & Rescorla, R. A. (1990). Effect of Reinforcer Devaluation on Discriminative Control of Instrumental Behavior. *Journal of Experimental Psychology: Animal Behavior Processes, 16*(1), 40-47.

Conklin, C. A., & Tiffany, S. (2002). Applying extinction research and theory to cue-exposure addiction treatments. *Addiction, 97*(2), 155.

Conrod, P., Castellanos, N., & Mackie, C. (2008). Personality-targeted interventions delay the growth of adolescent drinking and binge drinking. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 49*(2), 181.

Conway, K. P., Kane, R. J., Ball, S. A., Poling, J. C., & Rounsaville, B. J. (2003). Personality, substance of choice, and polysubstance involvement among substance dependent patients. *Drug and Alcohol Dependence, 71*(1), 65-75.

Corbit, L. H., & Balleine, B. W. (2003). Instrumental and Pavlovian incentive processes have dissociable effects on components of a heterogeneous instrumental chain. *Journal of Experimental Psychology: Animal Behavior Processes, 29*(2), 99.

Corbit, L. H., & Balleine, B. W. (2005). Double Dissociation of Basolateral and Central Amygdala Lesions on the General and Outcome-Specific Forms of Pavlovian-Instrumental Transfer. *The Journal of Neuroscience, 25*(4), 962-970. doi: 10.1523/jneurosci.4507-04.2005

Corbit, L. H., Janak, P. H., & Balleine, B. W. (2007). General and outcome-specific forms of Pavlovian-instrumental transfer: the effect of shifts in motivational state and inactivation of the ventral tegmental area. *European Journal of Neuroscience, 26*(11), 3141-3149.

Corr, P. J., Pickering, A., & Gray, J. (1995). Personality and reinforcement in associative and instrumental learning. *Personality and Individual Differences, 19*(1), 47.

Costa, P., & McCrae, R. (1992). *NEO PI-R Professional Manual*. Odessa, FL: Psychological Assessment Resources.

Crombag, H. S., Badiani, A., Chan, J., Dell'Orco, J., Dineen, S. P., & Robinson, T. E. (2001). The ability of environmental context to facilitate psychomotor sensitization to amphetamine can be dissociated from its effect on acute drug responsiveness and on conditioned responding. *Neuropsychopharmacology, 24*(6), 680-690.

Crombag, H. S., Galarce, E. M., & Holland, P. C. (2008). Pavlovian influences on goal-directed behavior in mice: The role of cue-reinforcer relations. *Learning & Memory, 15*(5), 299-303. doi: 10.1101/lm.762508

de Wit, S., & Dickinson, A. (2009). Associative theories of goal-directed behaviour: a case for animal–human translational models. *Psychological Research, 73*(4), 463-476.

Dickinson, A., & Balleine, B. (1994). Motivational control of goal-directed action. *Animal Learning & Behavior, 22*(1), 1-18.

Dickinson, A., & Balleine, B. (1995). Motivational Control of Instrumental Action. *Current Directions in Psychological Science, 4*(5), 162-167.

Dickinson, A., Balleine, B., Watt, A., Gonzalez, F., & Boakes, R. A. (1995). Motivational control after extended instrumental training. *Animal Learning & Behavior, 23*(2), 197-206.

Dickinson, A., & Charnock, D. J. (1985). Contingency effects with maintained instrumental reinforcement. *The Quarterly Journal of Experimental Psychology Section B, 37*(4), 397-416.

Dickinson, A., & Dawson, G. R. (1987). Pavlovian processes in the motivational control of instrumental performance. *The Quarterly Journal of Experimental Psychology Section B: Comparative and Physiological Psychology, 39*(3), 201-213.

Dickinson, A., & Pearce, J. M. (1977). Inhibitory interactions between appetitive and aversive stimuli. *Psychological Bulletin, 84*(4), 690-711.

Dickinson, A., Wood, N., & Smith, J. W. (2002). Alcohol seeking by rats: Action or habit? *The Quarterly Journal of Experimental Psychology Section B, 55*(4), 331-348.

Draycott, S. G., & Kline, P. (1995). The Big Three or the Big Five--the EPQ-R vs the NEO-PI: a research note, replication and elaboration. *Personality and Individual Differences, 18*(6), 801-804.

Drevets, W. C., Gautier, C., Price, J. C., Kupfer, D. J., Kinahan, P. E., Grace, A. A., . . . Mathis, C. A. (2001). Amphetamine-induced dopamine release in human ventral striatum correlates with euphoria. *Biological psychiatry, 49*(2), 81-96.

Earp, B. D., Dill, B., Harris, J. L., Ackerman, J. M., & Bargh, J. A. (2013). No sign of quitting: incidental exposure to “no smoking” signs ironically boosts cigarette-approach tendencies in smokers. *Journal of Applied Social Psychology, 43*(10), 2158-2162.

Elsner, B., & Hommel, B. (2001). Effect anticipation and action control. *Journal of Experimental Psychology: Human Perception and Performance, 27*(1), 229-240.

Estes, W. K. (1943). Discriminative conditioning. I. A discriminative property of conditioned anticipation. *Journal of Experimental Psychology, 32*(2), 150-155.

Evenden, J. (1999). Impulsivity: a discussion of clinical and experimental findings. *J Psychopharmacol, 13*(2), 180-192. doi: 10.1177/026988119901300211

Everitt, B. J., & Robbins, T. W. (2005). Neural systems of reinforcement for drug addiction: from actions to habits to compulsion. *Nat Neurosci, 8*(11), 1481-1489.

Eysenck, H., & Eysenck, S. (1991). *Manual of the Eysenck Personality Scales*. London: Hodder & Stoughton.

Fancher, R. E. (1996). *Pioneers of psychology*: WW Norton & Co.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191.

Fedoroff, I. D. C., Polivy, J., & Herman, C. P. (1997). The Effect of Pre-exposure to Food Cues on the Eating Behavior of Restrained and Unrestrained Eaters. *Appetite, 28*(1), 33-47.

Festinger, L. (1962). *A theory of cognitive dissonance* (Vol. 2): Stanford university press.
Field, A. P., & Davey, G. C. L. (1999). Reevaluating Evaluative Conditioning: A Nonassociative Explanation of Conditioning Effects in the Visual Evaluative Conditioning Paradigm. *Journal of Experimental Psychology: Animal Behavior Processes, 25*(2), 211-224.
Field, M., & Duka, T. (2004). Cue reactivity in smokers: the effects of perceived cigarette availability and gender. *Pharmacology Biochemistry and Behavior, 78*(3), 647-652.
Field, M., Mogg, K., & Bradley, B. P. (2004). Eye movements to smoking-related cues: effects of nicotine deprivation. *Psychopharmacology, 173*(1-2), 116-123.
Flagel, S. B., Akil, H., & Robinson, T. E. (2009). Individual differences in the attribution of incentive salience to reward-related cues: Implications for addiction. *Neuropharmacology, 56*(Supplement 1), 139-148.
Gana, K., & Trouillet, R. (2003). Structure invariance of the Temperament and Character Inventory (TCI). *Personality and Individual Differences, 35*(7), 1483-1495.
Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (in press). Knowing your own heart: Distinguishing interoceptive accuracy from interoceptive awareness *Biological Psychology*.
Geier, A., Pauli, P., & Mucha, R. F. (2000). Appetitive nature of drug cues confirmed with physiological measures in a model using pictures of smoking. *Psychopharmacology, 150*(3), 283-291.
Giancola, P. R., Zeichner, A., Newbolt, W. H., & Stennett, R. B. (1994). Construct validity of the dimensions of Cloninger's tridimensional personality questionnaire. *Personality and Individual Differences, 17*(5), 627-636.
Glautier, S. (2004). Measures and models of nicotine dependence: positive reinforcement. *Addiction, 99*, 30-50.
Goldman, M. S. (1999). Risk for Substance Abuse: Memory as a Common Etiological Pathway. *Psychological Science, 10*(3), 196-198. doi: 10.1111/1467-9280.00133
Grillon, C. (2002). Associative learning deficits increase symptoms of anxiety in humans. *Biological psychiatry, 51*(11), 851-858.
Harris, J. L., Pierce, M., & Bargh, J. A. (in press). Priming effect of antismoking PSAs on smoking behaviour: a pilot study. *Tobacco Control*. doi: 10.1136/tobaccocontrol-2012-050670
Harrison, A. A., Liem, Y. T. B., & Markou, A. (2001). Fluoxetine combined with a serotonin-1A receptor antagonist reversed reward deficits observed during nicotine and amphetamine withdrawal in rats. *Neuropsychopharmacology, 25*(1), 55-71.
Heatherton, T. F., Kozlowski, L. T., Frecker, R. C., & Fagerstrom, K.-O. (1991). The Fagerström Test for Nicotine Dependence: a revision of the Fagerstrom Tolerance Questionnaire. *British Journal of Addiction, 86*(9), 1119-1127.
Hendershot, C., Witkiewitz, K., George, W., & Marlatt, G. A. (2011). Relapse prevention for addictive behaviors. *Substance Abuse Treatment, Prevention, and Policy, 6*(1), 17.
Hinson, J. M., & Staddon, J. E. R. (1983). Matching, maximizing, and hill-climbing. *Journal of the Experimental Analysis of Behavior, 40*(3), 321-331.
Hofmann, W., De Houwer, J., Perugini, M., Baeyens, F., & Crombez, G. (2010). Evaluative Conditioning in Humans: A Meta-Analysis. *Psychological Bulletin, 136*(3), 390-421.
Hogarth, L. (2011). The role of impulsivity in the aetiology of drug dependence: reward sensitivity versus automaticity. *Psychopharmacology, 215*(3), 567-580.
Hogarth, L. (2012). Goal-directed and transfer-cue-elicited drug-seeking are dissociated by pharmacotherapy: Evidence for independent additive controllers. *Journal of Experimental Psychology: Animal Behavior Processes, 38*(3), 266-278.
Hogarth, L., Attwood, A. S., Bate, H. A., & Munafó, M. R. (2012). Acute alcohol impairs human goal-directed action. *Biological Psychology, 90*(2), 154-160.
Hogarth, L., Balleine, B. W., Corbit, L. H., & Killcross, S. (2013). Associative learning mechanisms underpinning the transition from recreational drug use to addiction. *Annals of the New York Academy of Sciences, 1282*, 12-24.
Hogarth, L., & Chase, H. W. (2011). Parallel goal-directed and habitual control of human drug-seeking: Implications for dependence vulnerability. *Journal of Experimental Psychology: Animal Behavior Processes, 37*(3), 261-276.
Hogarth, L., Dickinson, A., & Duka, T. (2010). The associative basis of cue-elicited drug taking in humans. *Psychopharmacology, 208*(3), 337-351.

Hogarth, L., Dickinson, A., Wright, A., Kouvaraki, M., & Duka, T. (2007). The role of drug expectancy in the control of human drug seeking. *Journal of Experimental Psychology: Animal Behavior Processes, 33*(4), 484.

Hogarth, L., & Duka, T. (2006). Human nicotine conditioning requires explicit contingency knowledge: is addictive behaviour cognitively mediated? *Psychopharmacology, 184*(3), 553-566.

Hogarth, L., Retzler, C., Munafò, M. R., Tran, D. M. D., Troisi Ii, J. R., Rose, A. K., . . . Field, M. (2014). Extinction of cue-evoked drug-seeking relies on degrading hierarchical instrumental expectancies. *Behaviour Research and Therapy, 59*(0), 61-70. doi: http://dx.doi.org/10.1016/j.brat.2014.06.001

Holland, P. C. (1989). Occasion Setting with Simultaneous Compounds in Rats. *Journal of Experimental Psychology-Animal Behavior Processes, 15*(3), 183-193.

Holland, P. C. (1990). Event representation in Pavlovian conditioning: Image and action. *Cognition, 37*(1-2), 105-131.

Holland, P. C. (2004). Relations Between Pavlovian-Instrumental Transfer and Reinforcer Devaluation. *Journal of Experimental Psychology: Animal Behavior Processes, 30*(2), 104-117.

Hollands, G. J., Prestwich, A., & Marteau, T. M. (2011). Using Aversive Images to Enhance Healthy Food Choices and Implicit Attitudes: An Experimental Test of Evaluative Conditioning. *Health Psychology, 30*(2), 195-203.

Hommel, B., Masseler, J., Aschersleben, G., & Prinz, W. (2001). The Theory of Event Coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences, 24*(05), 849-878. doi: doi:10.1017/S0140525X01000103

Hosmer Jr, D. W., & Lemeshow, S. (2004). *Applied logistic regression*: John Wiley & Sons.

Hull, C. L. (1943). *Principles of behavior: an introduction to behavior theory*. Oxford, England: Appleton-Century.

Jenkins, H. M., & Moore, B. R. (1973). The form of the auto-shaped response with food or water reinforcers. *J Exp Anal Behav, 20*(2), 163-181.

Juliano, L. M., & Brandon, T. H. (1998). Reactivity to instructed smoking availability and environmental cues: Evidence with urge and reaction time. *Experimental and Clinical Psychopharmacology, 6*(1), 45-53.

Katkin, E. S., Wiens, S., & Öhman, A. (2001). Nonconscious fear conditioning, visceral perception, and the development of gut feelings. *Psychological Science, 12*(5), 366-370.

Kerkhof, I., Vansteenwegen, D., Baeyens, F., & Hermans, D. (2011). Counterconditioning: An effective technique for changing conditioned preferences. *Experimental Psychology (formerly Zeitschrift für Experimentelle Psychologie), 58*(1), 31-38.

Kirchner, T. R., & Sayette, M. A. (2007). Effects of smoking abstinence and alcohol consumption on smoking-related outcome expectancies in heavy smokers and tobacco chippers. *Nicotine and Tobacco Research, 9*(3), 365-376.

Knapp, W. P., Soares, B. G. O., Farrel, M., & Lima, M. S. (2007). Psychosocial interventions for cocaine and psychostimulant amphetamines related disorders. *Cochrane Database of Systematic Reviews*(3).

Konorski, J. (1967). *Integrative activity of the brain*. Chicago: University of Chicago Press.

Koob, G. F., & Moal, M. L. (1997). Drug Abuse: Hedonic Homeostatic Dysregulation. *Science, 278*(5335), 52-58. doi: 10.1126/science.278.5335.52

Lamb, R. J., Preston, K. L., Schindler, C. W., Meisch, R. A., Davis, F., Katz, J. L., . . . Goldberg, S. R. (1991). The reinforcing and subjective effects of morphine in post-addicts: a dose-response study. *Journal of Pharmacology and Experimental Therapeutics, 259*(3), 1165-1173.

Lang, P., Bradley, M., & Cuthbert, B. (2008). *International affective picture system (IAPS): affective ratings of pictures and instruction manual.* Gainsville, FL: University of Florida.

Le Bon, O., Basiaux, P., Streel, E., Tecco, J., Hanak, C., Hansenne, M., . . . Dupont, S. (2004). Personality profile and drug of choice; a multivariate analysis using Cloninger's TCI on heroin addicts, alcoholics, and a random population group. *Drug and Alcohol Dependence, 73*(2), 175-182.

Lopez-Vergara, H. I., Colder, C. R., Hawk Jr, L. W., Wieczorek, W. F., Eiden, R. D., Lengua, L. J., & Read, J. P. (2012). Reinforcement sensitivity theory and alcohol outcome expectancies in early adolescence. *American Journal of Drug and Alcohol Abuse, 38*(2), 130-134.

Lovibond, P. F. (1981). Appetitive pavlovian-instrumental interactions: Effects of inter-stimulus interval and baseline reinforcement conditions. *The Quarterly Journal of Experimental Psychology Section B, 33*(4), 257-269.

Lovibond, P. F. (1983). Facilitation of instrumental behavior by a Pavlovian appetitive conditioned stimulus. *Journal of Experimental Psychology: Animal Behavior Processes, 9*(3), 225-247.

Lovibond, P. F., & Shanks, D. R. (2002). The role of awareness in Pavlovian conditioning: Empirical evidence and theoretical implications. *Journal of Experimental Psychology: Animal Behavior Processes, 28*(1), 3.

Lubow, R. E. (1973). Latent inhibition. *Psychological Bulletin, 79*(6), 398-407.

Lubow, R. E., & Moore, A. U. (1959). Latent Inhibition - the Effect of Nonreinforced Pre-Exposure to the Conditional Stimulus. *Journal of Comparative and Physiological Psychology, 52*(4), 415-419.

Martens, K. M., & Gilbert, D. G. (2008). Marijuana and tobacco exposure predict affect-regulation expectancies in dual users. *Addictive Behaviors, 33*(11), 1484-1490.

Maxwell, S. E. (2000). Sample size and multiple regression analysis. *Psychological methods, 5*(4), 434.

McCrae, R. R., & Costa, P. T. (1989). Rotation to maximize the construct validity of factors in the NEO Personality Inventory. *Multivariate Behavioral Research, 24*(1), 107-124.

McLaren, I. P. L., & Mackintosh, N. J. (2002). Associative learning and elemental representation: II. Generalization and discrimination. *Animal Learning & Behavior, 30*(3), 177-200.

McLaughlin, R. J., & Eysenck, H. J. (1967). Extraversion, neuroticism and paired-associates learning. *Journal of Experimental Research in Personality, 2*(2), 128-132.

Mehrabian, A., & Russell, J. A. (1978). A questionnaire measure of habitual alcohol use. *Psychological Reports, 43*(3), 803-806.

Miettunen, J., Lauronen, E., Kantojärvi, L., Veijola, J., & Joukamaa, M. (2008). Inter-correlations between Cloninger's temperament dimensions -- A meta-analysis. *Psychiatry Research, 160*(1), 106-114.

Miles, F. J., Everitt, B. J., & Dickinson, A. (2003). Oral cocaine seeking by rats: Action or habit? *Behavioral Neuroscience, 117*(5), 927-938.

Miller, N. E., & Kessen, M. L. (1952). Reward effects of food via stomach fistula compared with those of food via mouth. *Journal of Comparative and Physiological Psychology, 45*(6), 555-564.

Milton, F., & Wills, A. J. (2004). The influence of stimulus properties on category construction. *Journal of Experimental Psychology-Learning Memory and Cognition, 30*(2), 407-415.

Most, S. B., Chun, M. M., Widders, D. M., & Zald, D. H. (2005). Attentional rubbernecking: Cognitive control and personality in emotion-induced blindness. *Psychonomic Bulletin & Review, 12*(4), 654-661.

Munafò, M. R., & Flint, J. (2011). Dissecting the genetic architecture of human personality. *Trends in Cognitive Sciences, 15*(9), 395-400.

Murphy, S. T., Monahan, J. L., & Zajonc, R. B. (1995). Additivity of Nonconscious Affect: Combined Effects of Priming and Exposure. *Journal of personality and social psychology, 69*(4), 589-602.

Nadler, N., Delgado, M. R., & Delamater, A. R. (2011). Pavlovian to Instrumental Transfer of Control in a Human Learning Task. *Emotion, 11*(5), 1112-1123.

Naneix, F., Marchand, A. R., Di Scala, G., Pape, J., & Coutureau, E. (2012). Parallel maturation of goal-directed behavior and dopaminergic systems during adolescence. *Journal of Neuroscience, 32*(46), 16223-16232.

Newman, L. S., Duff, K. J., & Baumeister, R. F. (1997). A New Look at Defensive Projection: Thought Suppression, Accessibility, and Biased Person Perception. *Journal of personality and social psychology, 72*(5), 980-1001.

Nordquist, R. E., Voorn, P., de Mooij-van Malsen, J. G., Joosten, R. N. J. M. A., Pennartz, C. M. A., & Vanderschuren, L. J. M. J. (2007). Augmented reinforcer value and accelerated habit formation after repeated amphetamine treatment. *European Neuropsychopharmacology, 17*(8), 532-540.

Olds, J., & Milner, P. (1954). Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain. *Journal of Comparative and Physiological Psychology, 47*(6), 419-427.

Pessiglione, M., Petrovic, P., Daunizeau, J., Palminteri, S., Dolan, R. J., & Frith, C. D. (2008). Subliminal Instrumental Conditioning Demonstrated in the Human Brain. *Neuron, 59*(4), 561-567.

Pessiglione, M., Schmidt, L., Draganski, B., Kalisch, R., Lau, H., Dolan, R. J., & Frith, C. D. (2007). How the Brain Translates Money into Force: A Neuroimaging Study of Subliminal Motivation. *Science, 316*(5826), 904-906. doi: 10.1126/science.1140459

Piedmont, R. L. (2001). Cracking the Plaster Cast: Big Five Personality Change during Intensive Outpatient Counseling. *Journal of Research in Personality, 35*(4), 500-520.

Piedmont, R. L., & Ciarrocchi, J. W. (1999). The Utility of the Revised NEO Personality Inventory in an Outpatient, Drug Rehabilitation Context. *Psychology of Addictive Behaviors, 13*(3), 213-226.

Pomerleau, C. S., Pomerleau, O. F., Flessland, K. A., & Basson, S. M. (1992). Relationship of tridimensional personality questionnaire scores and smoking variables in female and male smokers. *Journal of Substance Abuse, 4*(2), 143-154.

Prévost, C., Liljeholm, M., Tyszka, J. M., & O'Doherty, J. P. (2012). Neural Correlates of Specific and General Pavlovian-to-Instrumental Transfer within Human Amygdalar Subregions: A High-Resolution fMRI Study. *The Journal of Neuroscience, 32*(24), 8383-8390. doi: 10.1523/jneurosci.6237-11.2012

Raes, A. K., & Raedt, R. D. (2011). Interoceptive awareness and unaware fear conditioning: Are subliminal conditioning effects influenced by the manipulation of visceral self-perception? *Consciousness and Cognition, 20*(4), 1393-1402.

Redish, A. D. (2007). Reconciling reinforcement learning models with behavioral extinction and renewal: implications for addiction, relapse, and problem gambling. *Psychological Review, 114*(3), 784.

Rescorla, R. A. (1967). Pavlovian conditioning and its proper control procedures. *Psychological Review, 74*(1), 71-80.

Rescorla, R. A., & Solomon, R. L. (1967). Two-process learning theory: Relationships between Pavlovian conditioning and instrumental learning. *Psychological Review, 74*(3), 151.

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. *Classical conditioning II: Current research and theory, 2*, 64-99.

Robinson, T. E., & Berridge, K. C. (1993). The neural basis of drug craving: An incentive-sensitization theory of addiction. *Brain Research Reviews, 18*(3), 247-291.

Rosner, S., Hackl-Herrwerth, A., Leucht, S., Vecchi, S., Srisurapanont, M., & Soyka, M. (2010). Opioid antagonists for alcohol dependence. *Cochrane Database of Systematic Reviews*(12).

Ruiz, M. A., Pincus, A. L., & Dickinson, K. A. (2003). NEO PI-R predictors of alcohol use and alcohol-related problems. *Journal of Personality Assessment, 81*(3), 226.

Rushton, J. P., Brainerd, C. J., & Pressley, M. (1983). Behavioral development and construct validity: The principle of aggregation. *Psychological Bulletin, 94*(1), 18-38.

Russell, M. A. H., Peto, J., & Patel, U. A. (1974). The Classification of Smoking by Factorial Structure of Motives. *Journal of the Royal Statistical Society. Series A (General), 137*(3), 313-346.

Saggino, A. (2000). The Big Three or the Big Five? A replication study. *Personality and Individual Differences, 28*(5), 879-886.

Sanders, A. C., Hussain, A. J., Hen, R., & Zhuang, X. (2007). Chronic blockade or constitutive deletion of the serotonin transporter reduces operant responding for food reward. *Neuropsychopharmacology, 32*(11), 2321-2329.

Saunders, B. T., O'Donnell, E. G., Aurbach, E. L., & Robinson, T. E. (2014). A Cocaine Context Renews Drug Seeking Preferentially in a Subset of Individuals. *Neuropsychopharmacology*.

Saunders, B. T., & Robinson, T. E. (2013). Individual variation in resisting temptation: Implications for addiction. *Neuroscience & Biobehavioral Reviews, 37*(9, Part A), 1955-1975. doi: http://dx.doi.org/10.1016/j.neubiorev.2013.02.008

Schultz, W., Dayan, P., & Montague, P. R. (1997). A Neural Substrate of Prediction and Reward. *Science, 275*(5306), 1593-1599. doi: 10.1126/science.275.5306.1593

Schweizer, E., Rickels, K., De Martinis, N., Case, G., & Garcia-Espana, F. (1998). The effect of personality on withdrawal severity and taper outcome in benzodiazepine dependent patients. *Psychological Medicine, 28*(03), 713.

Spielberger, C. (1983). *Manual for the State-Trait Anxiety Inventory (STAI)*. Palo Alto, CA: Mind Garden.

Stallings, M., Hewitt, J., Cloninger, C. R., Heath, A., & Eaves, L. (1996). Genetic and environmental structure of the TPQ: three or four temperament dimensions. *Journal of personality and social psychology, 70*(1), 127-140.

Stevenson, R. J., Boakes, R. A., & Wilson, J. P. (2000). Counter-conditioning Following Human Odor-Taste and Color-Taste Learning. *Learning and Motivation, 31*(2), 114-127.

Stewart, J., de Wit, H., & Eikelboom, R. (1984). Role of unconditioned and conditioned drug effects in the self-administration of opiates and stimulants. *Psychological Review, 91*(2), 251-268.

Svrakic, D. M., Whitehead, C., Przybeck, T. R., & Cloninger, C. R. (1993). Differential diagnosis of personality disorders by the seven-factor model of temperament and character. *Archives of General Psychiatry, 50*(12), 991.

Tackett, J., Quilty, L., Sellbom, M., Rector, N., & Bagby, R. (2008). Additional evidence for a quantitative hierarchical model of mood and anxiety disorders for DSM-V: The context of personality structure. *Journal of Abnormal Psychology, 117*(4), 812-825.

Takahashi, Y. K., Roesch, M. R., Wilson, R. C., Toreson, K., O'Donnell, P., Niv, Y., & Schoenbaum, G. (2011). Expectancy-related changes in firing of dopamine neurons depend on orbitofrontal cortex. *Nat Neurosci, 14*(12), 1590-1597. doi: http://www.nature.com/neuro/journal/v14/n12/abs/nn.2957.html#supplementary-information

Talmi, D., Seymour, B., Dayan, P., & Dolan, R. J. (2008). Human Pavlovian Instrumental Transfer. *The Journal of Neuroscience, 28*(2), 360-368. doi: 10.1523/jneurosci.4028-07.2008

Terracciano, A., & Costa, P. T. (2004). Smoking and the Five Factor Model of personality. *Addiction, 99*(4), 472-481.

Thorndike, E. L. (1898). Animal Intelligence: An Experimental Study of the Associative Processes in Animals. *Psychological Monographs: General and Applied, 2*(4), 1-109.

Thorndike, E. L. (1911). *Animal intelligence: Experimental studies.* New York: Macmillan.

Tiffany, S. T. (1990). A cognitive model of drug urges and drug-use behavior: Role of automatic and nonautomatic processes. *Psychological Review, 97*(2), 147-168.

Toates, F. (1986). *Motivational systems* (Vol. 4). Cambridge: CUP Archive.

Tobler, P. N., O'Doherty, J. P., Dolan, R. J., & Schultz, W. (2007). Reward Value Coding Distinct From Risk Attitude-Related Uncertainty Coding in Human Reward Systems. *J Neurophysiol, 97*(2), 1621-1632. doi: 10.1152/jn.00745.2006

Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review, 55*(4), 189-208.

Torrubia, R., Ávila, C., Moltó, J., & Caseras, X. (2001). The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) as a measure of Gray's anxiety and impulsivity dimensions. *Personality and Individual Differences, 31*(6), 837-862.

Trick, L., Hogarth, L., & Duka, T. (2011). Prediction and uncertainty in human Pavlovian to instrumental transfer. *Journal of Experimental Psychology: Learning, Memory and Cognition, 37*(3), 757.

Trull, T. J., Waudby, C., & Sher, K. (2004). Alcohol, Tobacco, and Drug Use Disorders and Personality Disorder Symptoms. *Experimental and Clinical Psychopharmacology, 12*(1), 65.

Tunstall, B. J., Verendeev, A., & Kearns, D. N. (2012). A comparison of therapies for the treatment of drug cues: Counterconditioning vs. extinction in male rats. *Experimental and Clinical Psychopharmacology, 20*(6), 447-453.

Uziel, L. (2015). Life seems different with you around: Differential shifts in cognitive appraisal in the mere presence of others for neuroticism and impression management. *Personality and Individual Differences, 73*, 39-43.

Valentin, V. V., Dickinson, A., & O'Doherty, J. P. (2007). Determining the Neural Substrates of Goal-Directed Learning in the Human Brain. *J. Neurosci., 27*(15), 4019-4026. doi: 10.1523/jneurosci.0564-07.2007

Van Gucht, D., Baeyens, F., Hermans, D., & Beckers, T. (2013). The inertia of conditioned craving. Does context modulate the effect of counterconditioning? *Appetite, 65*(0), 51-57.

Van Gucht, D., Baeyens, F., Vansteenwegen, D., Hermans, D., & Beckers, T. (2010). Counterconditioning reduces cue-induced craving and actual cue-elicited consumption. *Emotion, 10*(5), 688-695.

Van Gucht, D., Vansteenwegen, D., Van den Bergh, O., & Beckers, T. (2008). Conditioned craving cues elicit an automatic approach tendency. *Behaviour Research and Therapy, 46*(10), 1160-1169.

Vázquez-Borsetti, P., Cortés, R., & Artigas, F. (2009). Pyramidal neurons in rat prefrontal cortex projecting to ventral tegmental area and dorsal raphe nucleus express 5-HT2A receptors. *Cerebral Cortex, 19*(7), 1678-1686.

Volchan, E., David, I. A., Tavares, G., Nascimento, B. M., Oliveira, J. M., Gleiser, S., . . . Oliveira, L. (2013). Implicit Motivational Impact of Pictorial Health Warning on Cigarette Packs. *PLoS ONE, 8*(8), e72117.

Wardell, J. D., Read, J. P., Colder, C. R., & Merrill, J. E. (2012). Positive alcohol expectancies mediate the influence of the behavioral activation system on alcohol use: A prospective path analysis. *Addictive Behaviors, 37*(4), 435-443.

Watson, J. B. (1913). Psychology as the behaviorist views it. *Psychological Review, 20*(2), 158-177.
Wegner, D. M. (1994). Ironic processes of mental control. *Psychological Review, 101*(1), 34.
Wikler, A. (1973). Dynamics of drug dependence: Implications of a conditioning theory for research and treatment. *Archives of General Psychiatry, 28*(5), 611-616.
Wills, T. A., Vaccaro, D., & McNamara, G. (1994). Novelty seeking, risk taking, and related constructs as predictors of adolescent substance use: An application of Cloninger's theory. *Journal of Substance Abuse, 6*(1), 1-20.
Winter, S., Dieckmann, M., & Schwabe, K. (2009). Dopamine in the prefrontal cortex regulates rats behavioral flexibility to changing reward value. *Behavioural Brain Research, 198*(1), 206-213. doi: http://dx.doi.org/10.1016/j.bbr.2008.10.040
Witkiewitz, K., & Marlatt, G. A. (2004). Relapse prevention for alcohol and drug problems: That was zen, this is tao. *American Psychologist, 59*(4), 224-235.
Wolford, G., Newman, S. E., Miller, M. B., & Wig, G. S. (2004). Searching for Patterns in Random Sequences. *Canadian Journal of Experimental Psychology, 58*(4), 221-228.
World Health Organisation. (2004). Global status report on alcohol 2004: World Health Organisation.
World Health Organisation. (2009). Guidelines for the psychosocially assisted pharmacological treatment of opioid dependence: World Health Organisation.
Wyvell, C. L., & Berridge, K. C. (2000). Intra-Accumbens Amphetamine Increases the Conditioned Incentive Salience of Sucrose Reward: Enhancement of Reward "Wanting" without Enhanced "Liking" or Response Reinforcement. *The Journal of Neuroscience, 20*(21), 8122-8130.
Wyvell, C. L., & Berridge, K. C. (2001). Incentive Sensitization by Previous Amphetamine Exposure: Increased Cue-Triggered "Wanting" for Sucrose Reward. *The Journal of Neuroscience, 21*(19), 7831-7840.
Yin, H. H., & Knowlton, B. J. (2006). The role of the basal ganglia in habit formation. *Nature Reviews Neuroscience, 7*(6), 464-476.

10 Appendices

10.1 Pilot studies

10.1.1 Instrumental schedules

Due to the potential ceiling effects on transfer phase responding in Experiment 2, a pilot study was conducted to ascertain the most effective instrumental schedule to lower baseline levels of responding. Inspection of the methods used in non-human studies suggested that the VR2 and VI2.75 schedules used in Experiment 2 were considerably lower than elsewhere in the literature (Corbit & Balleine, 2005; Crombag et al., 2008; Lovibond, 1981, 1983; Wyvell & Berridge, 2000, 2001), thus the pilot study increased both to contrast their effects on behaviour within a human population. It also introduced an aversive outcome to instrumental responding, as such a protocol has face validity in models of addictive behaviour, yet has not been extensively used in a PIT paradigm.

10.1.1.1 Method

This pilot study concentrated on an instrumental training phase. However, to ensure circumstances representative of a PIT paradigm, it began with a Pavlovian conditioning phase similar to that detailed in General Methods. Participants were 40 undergraduate students (9 male, mean age 20.7) attending an international summer school at Sussex University. Pavlovian conditioning was as General Methods, though with only 4 blocks rather than 8 to expedite data collection.

Participants were then randomly allocated to one of five instrumental training conditions – VR2 VI2.75 (control), VR2 VI10 (VI increase), VR2 VI10 with variable response window (VI window), VR2 VI2.75 with partial aversive outcome (VR aversive), and VR4 VI2.75 (VR increase). All schedules followed the general protocol specified in General Methods, save for their respective response requirements. In addition, all groups except those in the VR increase condition had only two blocks of training, both to expedite data collection and to balance the number of rewards gained between groups. Those in the VI window condition had a variable response window that was on average 10s, range 1.5-18.5, rather than the fixed windows of the other conditions. This was used to represent the variable onset of reward delivery used in other studies. The VR aversive condition replaced "You win nothing" trials with "You lose 50p", thus there was a 50% chance of either win or loss.

The entire session lasted between 30mins (for control) and 40mins (for VI increase). This pilot study also introduced the question-mark into the "Press the button?" prompt, as well the blank screen upon responses initiation, as detailed in General Methods but absent from experiments 1&2, to emphasise to participants that responding was not mandatory.

Data were analysed separately for RI and RR using one-way ANOVAs with five levels. The sole IV was Schedule; Block was not entered due to the different numbers between groups. Thus the DV was mean RI or RR from the entire session.

10.1.1.2 Results and conclusion

Analyses indicated that the VR aversive condition was most effective in reducing RI, whereas VI increase was most suited to lowering RR. Figure 10.1.1.1 displays mean RI [top] and RR [bottom].

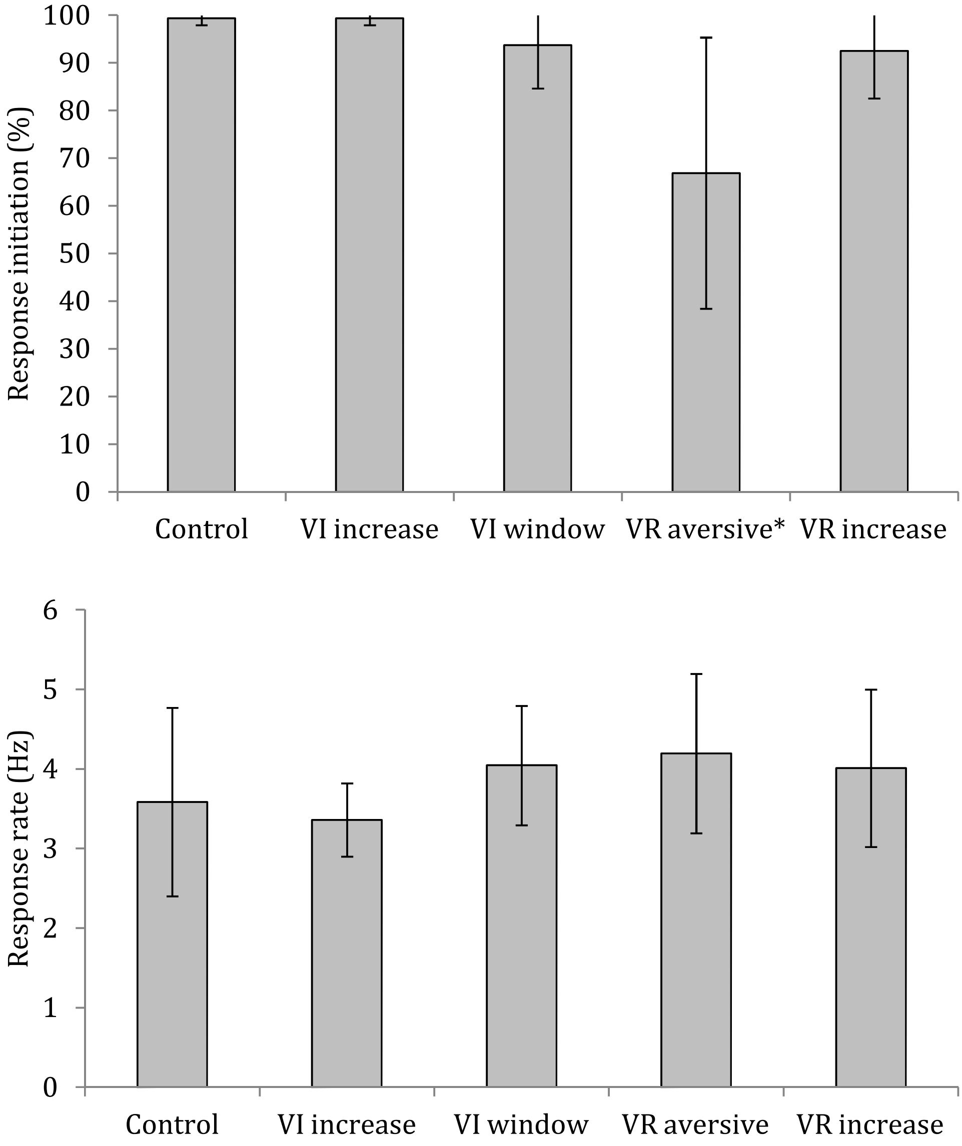

Figure 10.1.1.1. Mean response initiation [top] and response rate [bottom] as a function of instrumental training schedule used in pilot study.
**** VR aversive < all others, ps < .022.***

The effect of Schedule was significant for RI [$F(4,35) = 5.65$, $p = .001$], with post-hoc comparisons specifying this difference as between VR aversive and all other levels [*ps* < .022]. Effects were non-significant for RR [$F < 1$].

The aversive manipulation was demonstrably successful in lowering the number of trials where a response had been made, confirming its suitability for further investigations. While differences in RR were non-significant, the lowest absolute value, and smallest variance, came from the VI increase, suggesting that this condition would prove most successful in lowering baseline responding in future studies.

10.1.2 Counter-conditioning

Because the translation of counter-conditioning (CC) methodology (Baeyens et al., 1989; Tunstall et al., 2012; Van Gucht et al., 2010), from that used in the literature to the Pavlovian protocol used in the current series, required making a number of changes, the effectiveness of the new method in reducing pleasantness ratings of a reward-predictive cue was tested in a pilot sample.

10.1.2.1 Method

A full list of the International Affective Picture System (IAPS) images used in the CC phase is contained in Table 10.1.2.1.

Table 10.1.2.1. List of IAPS images used during counter-conditioning.

Category	Name	IAPS number
Aversive	CryingBoy	2800
	CryingBoy	2900
	MafiaHit	3010
	BurnVictim	3053
	Mutilation	3062
	PizzaRoaches	7380
	Cemetery	9220
	Child	9040
	Dirty	9300
	SlicedHand	9405
	DeadMan	9433
	CarAccident	9911
Neutral	NeutFace	2200
	ElderlyMan	2520
	Chess	2580
	Chess	2840
	Tourist	2850
	Shadow	2880
	Door/flowers	5731
	RollingPin	7000
	Basket	7010
	SquareBlock	7185

ClothesRack	7217
Chair	7235
NeutFace	2210
MaleJudge	2221
OldMan	2570
Woman	2620
TwinMen	2890
Stool	7025
DustPan	7040
Fork	7080
Umbrella	7150
Lamp	7175
Office	7550
Kleenex	7950
ElderlyMan	2480
Bulimic	2702
BoyOnCar	2870
Plant&soil	5740
Spoon	7004
Bowl	7006
Mug	7035
HairDryer	7050
Book	7090
Truck	7130
Golfer	8311
Boy	9070

A power calculation based on the data of Van Gught et al (2010) indicated that 12 participants would be sufficient to detect an effect. Because of the concentration of the ensuing Experiment 4 on differential outcome expectancy, the pilot study was run until 12 *aware* participants (9 female; mean age = 20.92, range 18 – 30) had been recruited. This involved testing 21 participants in total; data from the 9 unaware participants was not analysed due to low power.

Other methodological details were as described in Experiment 4, though participants did not complete any personality questionnaires or instrumental phases. Only the aversive version was used, as the non-significant effects of neutral counter-conditioning have been established in previous reports.

10.1.2.2 Results and conclusion

Participants developed differential evaluative-conditioning after the Pavlovian phase, but any differences were successfully abolished by the CC manipulation. Figure 10.1.2.1 displays mean pleasantness ratings of each CS at each time-point.

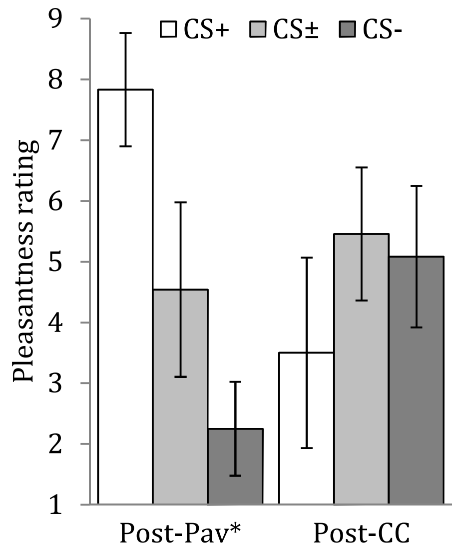

Figure 10.1.2.1. Mean pleasantness rating of reward-predictive stimuli after Pavlovian training or counter-conditioning.
Pav, Pavlovian training; CC, counter-conditioning; * CS+ > CS± > CS- [ps < .025]; error bars represent 95%CI.

An RM ANOVA of pleasantness ratings with Time-point (post-Pavlovian, post-CC) and Stimulus as factors confirmed a significant effect of Stimulus and a significant Stimulus*Time-point interaction [$Fs(2,22) > 6.41$, $ps < .006$]. The interaction was followed by separate RM ANOVAs for each time-point, with Stimulus as the only factor; the effect was significant after Pavlovian training [$F(2,22) = 31.3$, $p < .001$], with CS+ > CS± > CS- [*ps* < .025], but non-significant after CC [$F(1.14,12.6) = 2.82$, $p = .12$].

The CC protocol was demonstrated to be successful in reducing the pleasantness attributed to the CS_+, and transferred some effect to the CS-, to the extent that any stimulus differences were abolished. The current method is therefore confirmed as suitable for a complete study of the effects of CC on PIT.

10.2 Fagerstrom Test for Nicotine Dependence

	Point(s)
1. How many cigarettes do you smoke per day?	
a) 10 or less	0
b) 11 – 20	1
c) 21 – 30	2
d) 31 or more	3
2. How soon after you wake up do you smoke your first cigarette?	
a) 0 – 5 min	3
b) 30 min	2
c) 31 – 60 min	1
d) After 60 min	0
3. Do you find it difficult to refrain from smoking in places where smoking is not allowed (e.g. hospitals, government offices, cinemas, libraries etc)?	
a) Yes	1
b) No	0
4. Do you smoke more during the first hours after waking than during the rest of the day?	
a) Yes	1
b) No	0
5. Which cigarette would you be the most unwilling to give up?	
a) First in the morning	1
b) Any of the others	0
6. Do you smoke even when you are very ill?	
a) Yes	1
b) No	0