The Impact of Stress and Impulsivity on Pavlovian Instrumental Transfer in Humans

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Abstract

Pavlovian instrumental transfer (PIT) is a phenomenon thought to underlie the maintenance of addictive behaviours, in which a conditioned stimulus (CS), previously paired with a specific outcome, can influence the performance of an instrumental response (R). PIT can be specific (the CS selectively elevates the performance of an R paired with the same outcome) and general (CSs elevate the performance of any R paired with an outcome of the same motivational value). To study both specific and general PIT effects, an avoidance-based and an appetitive PIT task were conducted in Chapter II. Both effects were observed successfully in the two types of PIT tasks.

As exposure to stressors has been considered a risk factor for relapsing in addiction, in Chapter III, the novel avoidance-based PIT task in Chapter II was applied to explore the relationship between anxiety and specific or general PIT effects. To measure anxiety/stress, personality scales, and mood induction procedures (online: using heavy metal music and unpleasant pictures; in-person: using a procedure in which participants were told they had to give a speech) were applied. In all experiments, specific or general effects showed a non-significant relationship with anxiety or stress levels. These results did not support the suggestion that stress or anxiety can affect PIT. This may be because the variability of the anxiety level was limited, and the mood induction procedures did not work to their maximum effect in changing the anxiety levels.

In addition, impulsivity is a personality trait that plays an important role in various types of addiction. It has been proposed that individuals with high impulsivity levels keep consuming rewards even if they are satisfied, which results in addiction; this may be because they are

insensitive to the devaluation of rewards. Therefore, in Chapter IV, the novel appetitive task conducted in Chapter II was used to examine the relationship between impulsivity, PIT effects, and devaluation effects on the PIT effects. In all experiments, the results did not show a correlation between PIT effects and impulsivity levels. Results also showed that devaluation abolished general PIT, diminished Pavlovian-directed devaluation of specific PIT, and left instrumental-directed devaluation of specific PIT intact. Although instrumental-directed outcome devaluation did not influence the magnitude of specific PIT, it was negatively correlated to negative urgency. These results did not support the hypothesis that impulsivity correlated to PIT.

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Chapter I: General Introduction

1.1 Pavlovian conditioning

Ivan Pavlov's physiological research on studying the digestive system directed him to discover the conditioned reflex, a phenomenon in animal learning, that has been called classical or Pavlovian conditioning. In his physiological research, Pavlov illustrated to what extent the nervous system coordinated with reflexes of digestion when dogs eat food. These reflexes do not need to be learnt. The food, a biologically potent stimulus, is an unconditioned stimulus (US), that can automatically elicit a biological response (e.g., salivation), known as the unconditional response (UR). In 1897, Ivan Pavlov observed a phenomenon that his dog salivated after hearing a metronome, which he had previously paired with feeding the dog. This raised the assumption that the dog learnt the association between the metronome and food, and the association can be observed from the dog's response (Windholz, 1986). It has been interpreted into the theory that before conditioning, a CS (e.g., metronome, a biologically neutral stimulus) cannot elicit responding. However, after repeated pairing of the CS with the US, the CS can evoke a conditional response (CR), via indirect activation of the US and hence the UR, which is usually similar to the UR evoked by the US (Pavlov, 1928). This theory is called Pavlovian conditioning.

1.2 Instrumental conditioning

In 1901, Thorndike observed cats escaping from a puzzle box. Thorndike reported that a cat could give responses that enabled it to escape more accurately and faster the more times it experienced the puzzle box situation. It can be succinctly described as alterations in behaviour within a particular situation: a response giving rise to satisfaction was likely to be repeated, while a response producing discomfort was likely to be avoided. Inspired by Thorndike's idea, Skinner (1953) created an operant conditioning chamber to test his subjects by providing one or two simple, repeatable responses. Using rats and pigeons in experiments, he observed that the frequency of behaviour could be enhanced via gaining reinforcement and decreased by getting punishment. This has been later interpreted into the theory of instrumental conditioning, also known as operant conditioning: animals can learn the association between behaviour (R) and the following consequence (O； Dickinson & Balleine, 1994). Compared to Pavlovian conditioning, the operant learning process focuses on intentional behaviours only. To strengthen or weaken responding, subjects are rewarded or punished for exhibiting a specific behaviour.

1.3 Pavlovian instrumental transfer (PIT)

Pavlovian instrumental transfer (PIT) is an effect where conditioned stimuli, through Pavlovian training, can influence instrumental action. In a typical PIT task, subjects usually experience instrumental conditioning and Pavlovian conditioning separately first, then exposure to stimuli in extinction while having access to instrumental action. The presentation of CSs elevates levels of operant responding. This phenomenon was initially observed in the 1940s, when cues, followed by the presentation of rewards, enhanced operant responses. Specifically, rats who had previously been trained that responding can produce food were placed in a box where they pressed a lever without food appearing. The response rates increased when a cue previously paired with food was presented (Estes & Skinner, 1941; Walker, 1942; Estes, 1943).

1.4 Appetitive PIT and Avoidance-based PIT

PIT tasks can be categorized into different types. The initial finding was observed by using appetitive PIT tasks. In appetitive PIT, outcomes are rewards, such as food (Estes & Skinner, 1941; Walker, 1942; Estes, 1943) or money (Nadler, Delgado & Delamater, 2011). Participants are trained to respond to get rewards. Stimuli represent appetitive outcomes mentally and increase response rates that produce appetitive outcomes. Unlike appetitive PIT tasks, outcomes in avoidance-based PIT tasks are aversive, such as electric shock (LoLordo, 1967) or air blast (Henderson et al., 1980). Participants are trained to respond to stimuli that are paired with aversive outcomes to avoid the outcomes. Stimuli predicting aversive outcomes can increase response rates that avoid aversive outcomes.

No matter whether appetitive or aversive reinforcements were used in a PIT task, each reinforcer has its sensory characteristics and affective (motivational) characteristics. Konorski's theory declared that the sensory characteristics of a reinforcer produce URs with different natures while the affective characteristics of a reinforcer elicit responses with either appetitive or aversive motivation (Konorski, 1948, 1967). While each outcome's sensory features are different, its affective characteristics can only be sorted into appetitive or aversive forms. All appetitive reinforcers share the same appetitive motivational status, and an enhanced appetitive motivational state can inhibit an aversive motivational state. Similarly, all aversive reinforcers provoke the same aversive motivational state, and an increased aversive motivational state can reduce appetitive motivation. For example, cats who experienced an air blast while eating food refused to eat the food in the test spot immediately (Masserman, 1943); rats who received food in instrumental training decreased their instrumental responses when both food and shocks presented as outcomes (Fowler & Miller, 1963).

1.5 Designs in Observing PIT Effects

Effects in PIT can be specific or general, depending on if the effect was affected by the sensory or affective properties of the outcomes. In specific effects, the CS selectively elevates the performance of an R paired with the outcome of the same sensory and motivational value. In general effects, CSs elevate the performance of any R paired with an outcome of the same motivational value. Different types of PIT task designs have been used in previous studies.

The standard procedure of a specific PIT task is shown in Table 1. Two stimuli are each paired with one of two different rewards (S1-O1, S2-O2) in the Pavlovian step. Then, two operant behaviours are paired with the two outcomes (R1-O1, R2-O2). In the transfer task stage, the performance of instrumental behaviour is examined while the stimuli are presented separately without presenting outcomes. The specific PIT effect means the CS selectively elevates the performance of an R paired with the same outcome (S1: R1 > R2, S2: R2 > R1).

Table 1
A Specific PIT Task

Pavlovian conditioning	Instrumental training	Transfer test
S1-O1	R1-O1	S1: R1, R2
S2-O2	R2-O2	S2: R1, R2

A standard PIT task with both specific and general effects can be designed as in Table 2 (Quail et al., 2017). There were three stages in their experimental design. In the first step, two instrumental responses were separately related to two different outcomes (R1-O1, R2-O2). In the second phase, four different stimuli were paired with four different outcomes. Two of the cues were paired with the same outcomes as in the instrumental stage, while the remaining two were paired with a new outcome and nothing (S1-O1, S2-O2, S3-O3, S4-nothing). In the transfer test, the four stimuli were presented separately, and responses were recorded. The specific effect (S1: R1 > R2, S2: R2 > R1) was observed, as well as the general effect —

participants gave more total responses of R1 and R2 to S3 rather than S4 (S3: R1+R2 > R4: R1+R2). The general effect means that compared to S4, which is paired with nothing, S3 elevates more responses that are paired with a novel outcome of the same motivational value as O1 and O2 (S3: R1, R2). The researchers concluded that this behavioural task is appropriate for humans to identify general and specific PIT effects. Some studies (e.g., Corbit and Balleine, 2005) may not include S4 in their design (see Table 3). In this design, general effects were measured by comparing the number of responses to S3 with no stimuli. It is less accurate than the design with S4 included as an active baseline.

Table 2
A Standard PIT Task with both Specific and General Effects

Instrumental training	Pavlovian conditioning	PIT transfer test
R1-O1	S1-O1	S1: R1, R2
R2-O2	S2-O2	S2: R1, R2
	S3-O3	S3: R1, R2
	S4-nothing	S4: R1, R2

Table 3
General and Specific PIT

Instrumental training	Pavlovian conditioning	Transfer test
R1-O1	S1-O1	S1: R1, R2
R2-O2	S2-O2	S2: R1, R2
	S3-O3	S3: R1, R2

Single lever PIT tasks (Table 4) have been frequently used in previous research (e.g., Pool, et al., 2015). It includes two different cues in the Pavlovian stage. One is paired with an outcome, while the second is paired with nothing (S1-O, S2-nothing). The instrumental stage paired response (R) to the outcome (O). The test phase presents S1 and S2, and participants are allowed to make responses. The PIT effect is that response rates would be higher during S1 than during S2, although the outcomes are not presented. Some researchers considered the PIT effect observed in this design as the general effect (e.g. Pool et al., 2015). However, it may not be the best design to study general effects as participants were not responding to novel outcomes.

Table 4

A Single Lever PIT Task

Pavlovian conditioning	Instrumental training	Transfer test
S1-O	R-O	S1: R
S2-nothing		S2: R

1.6 Differences between Specific Effect and General Effect

Specific and general PIT effects may be mediated by different neural bases. For example, Corbit and Balleine (2005) used rats who were divided into three groups: group one with damage to the basolateral amygdala complex (BLA), group two with damage to the central nucleus of the amygdala (CN), and group three experienced similar treatment without neurotoxin injected (sham lesions). In Experiment 2, all the rats learned the relationship between pressing two levers and two kinds of food (R1-O1, R2-O2), and the associations between three stimuli and three rewards (S1-O1, S2-O2, S3-O3) first. Then, in the transfer test, responses were recorded while the three stimuli were presented one after another. The results showed that both specific and general effects could be observed in the sham-lesioned group.

However, in the BLA group, there were few R1 to S1 and R2 to S2 resulting in the specific effect being abolished. The general effect could still be observed in the BLA group. In contrast, rats in the CN group gave a low response to S3, which result in the general effect being abolished. The specific effect could still be observed in the CN group. Therefore, this study supported the idea that BLA mediates specific PIT effects, while CN mediates general PIT effects.

Moreover, by conducting experiments with the same PIT task design above, Corbit and Balleine (2011) reported that specific and general effects are mediated by the core and shell of nucleus accumbens separately. Rats were arranged into three groups: cell-body lesion of the nucleus accumbens (NAC) core group, cell-body lesion of the NAC shell group, and sham surgery group. The results showed that both specific and general effects could be observed in the sham group. The specific effect in the shell lesion group was abolished as rats gave few responses to the stimuli that were paired with the same outcomes as the responses, while the general effect was observed. The general effect in the core lesion group was abolished as rats gave limited responses to S3, while the specific effect was observed. Researchers concluded that NAC shell mediated specific effects, while NAC core mediated general effects.

In human studies, Prévost et al. (2012) found that the activity of amygdala differs between specific and general effects. A high-resolution fMRI protocol optimized for the amygdala and a standard PIT task with both specific and general effects were used. In the PIT task, participants first learned pressing keys can get outcome pictures of sweet or salty food (R1-O1, R2-O2). Then, participants learnt four different fractal images related to different outcomes (S1-O1, S2-O2, S3-O3, S4-nothing) before the transfer test. Both specific and general effects were observed. The correlations between blood oxygen level-dependent (BOLD) signals from fMRI and the magnitude of specific or general effects were analysed. The results showed that the ventral amygdala in the basolateral complex and ventrolateral putamen is involved in specific effects, while the dorsal amygdala in the centromedial complex is involved in the general effect.

1.7 Mechanisms of PIT

Both S-R and R-O associations have been suggested as accounts that underlie instrumental learning. Thorndike (1901) assumed that a cat learnt to respond (R) to escape a puzzle box (S) in instrumental conditioning and this S-R association can be strengthened by reinforcement (O). Tolman (1948) disagreed with Thorndike and argued that animals can learn reinforcers of their behaviour (R-O). The S-R association only explains a reason that caused responses when stimuli are presented. This implies a consideration of whether instrumental behaviour is habitual (S-R) or goal-directed (R-O).

Devaluation, a procedure that changed the values of the US or the outcome (Cartoni, Balleine, & Baldassarre, 2016), has been used to explore mechanisms in instrumental behaviour. For example, in 2002, Dickinson and colleagues trained rats to press one lever to get ethanol and press another lever to get food. Then, either the ethanol or the food was devalued by pairing to injection of lithium chloride, which can make rats feel ill. Testing in extinction, researchers found that the devaluation procedure made rats respond less to the food lever but not the ethanol lever. This indicated, different from food-seeking, the altered value of outcome could not affect drug-seeking behaviour. Therefore, they conclude that food-seeking is a goal-directed action (R-O) while drug-seeking is a habit (S-R). However, ethanol has a stronger motivational value than food, resulting in the two processes being incomparable. This study did show that changing the values of the outcomes can change the instrumental behaviour towards the outcomes. When pairing two responses with two outcomes with equal motivational values (sucrose solution and food pellet), the number of responses to the devalued outcome was less than the responses to the non-devalued outcome (Colwill & Rescorla, 1985). These results supported the R-O account. In contrast, researchers supported S-R rather than R-O and argued instrumental behaviour is independent of the value of the outcome by showing non-significant results with similar designs applied (Adams, 1980).

Showing effects that cues can influence instrumental responses, PIT was debated to be habitual (S-R) or goal-directed (S-O-R). Goal-directed behaviour is flexible and completed by organism intention. This behaviour requires organisms' knowledge that the CS can predict the US and that performing actions (R) produces the outcome (US/O). In the S-O-R account, the CS activates the US representation in Pavlovian conditioning, and R activates the US/O representation in instrumental conditioning. The R-O association is assumed to be bidirectional (Asratyan, 1974; Elsner & Hommel, 2001): the outcome representation in the mind can provoke responses (O-R). Therefore, when stimuli are presented, they activate the outcome representation, hence evoking responses (S-O-R). Different from goal-directed behaviour, habitual behaviour is an automatic behaviour that is strengthened by reinforcement aiming to limit cognitive resources (Smith & Laiks, 2018). In the S-R account, values of the outcomes are not expected to influence responses to stimuli. The mechanism in PIT has been tested by including a devaluation procedure or forward/backward training trials in Pavlovian conditioning.

Some studies have used devaluation to test accounts in PIT. For example, in research that used rodents, Corbit et al. (2007) reported that the general PIT effect was abolished by shifting rats' state from hungry to satiation, but the specific effect was unchanged (Experiment 1). Specifically, after learning that three different audio stimuli were paired with three kinds of food (S1-O1, S2-O2, S3-O3), and two instrumental actions were paired with two of the three kinds of food (R1-O1, R2-O2), hungry rats showed both specific and general effects in the transfer test. Next, the rats experienced 24 hours of free access to a maintenance diet. Then, the satiety rats did the PIT task again and showed low response rates when S3 presented — no difference with the response rates in preCS stage. The specific PIT was maintained. This indicated that the general effects depend on the motivational value of the outcomes and are sensitive to devaluation, which supported the S-O-R link.

The findings above are echoed by other researchers. Aitken et al. (2016) agreed devaluation can abolish general PIT. The rats first learnt associations between two audio stimuli and two kinds of food — sucrose solution and grain pellets (S1-O1, S2-O2). Then, the rats learnt R1 was paired with a novel grape-flavoured food O3. In the transfer test, presenting S1 and S2 can elevate responses from hungry rats, but not rats sated with the control home chow food. Although the task was a single-lever program, the observed PIT effect was general since O3 had different sensory features from O1 and O2. The results showed that the general effect could be eliminated when the rats' motivational levels decreased. However, specific PIT might be less sensitive to devaluation procedures than general PIT. Holland (2004) reported non-significant results in observing how devaluation affects specific PIT (Experiment 2). The rats experienced devaluation procedures (receiving food with LiCl injection followed) between two times of transfer tests. The size of the specific effects before and after devaluation showed no differences.

In addition, in human studies that explore how devaluation affects PIT, Watson et al. (2004) applied a standard PIT task with both specific and general effects. The participants learnt the four stimuli (neutral fractal pictures) were paired with the four outcomes (pictures of popcorn, chocolate, nuts, and words 'nothing') separately. They also learnt to press two keys were paired with two out of the three reinforcement outcomes. Then, half participants ate 100g of popcorn or chocolate. Finally, in the test, participants were offered access to the two keys with stimuli or non-stimuli pictures presented. The results showed that presenting S1 elevated R1 while presenting S2 elevated R2, and this phenomenon was not influenced by satiation. Also, a higher number of responses was observed during S3 than the words 'nothing' were presented. Although devaluation did not influence the size of the general effect, the researchers found that the reported hunger score was positively correlated to the size of the general effect. These results confirmed that satiety can decrease general effects.

Seabrooke et al. (2019) supported S-O-R by showing devaluation influenced specific PIT effects. Claiming that it would be more sensitive if devalued outcomes and non-devalued outcomes were compared on the same baseline (paired with the same R), Seabrooke et al. designed their specific PIT task in Table 5. The O3 and O4 were devalued before the transfer test, but not O1 and O2. Specific PIT effects were observed when S1 and S2 were presented, but not S3 and S4 were presented. Therefore, this study suggested PIT is goal-directed by showing evidence that devaluation could affect specific PIT.

Table 5
Design in Seabrooke et al (2019)

Instrumental training	Pavlovian training	Instrumental booster	Outcome devaluation	Transfer test
R1-O1, O3	S1-O1	R1-O1, O3	O1+, O3-	S1: R1 vs R2?

R2-O2, O4	S2-O2	R2-O2, O4	O2+, O4-	S2: R1 vs R2?
	S3-O3			S3: R1 vs R2?
	S4-O4			S4: R1 vs R2?

In addition, Hinojosa-Aguayo & González (2020) argued that the devaluation procedure can affect specific PIT, but not general PIT (Experiment 2). After learning R1-O1, R2-O2, S1-O1, S2-O2, S3-O3, and S4-nothing, female undergraduate students experienced the O1 devaluation procedure. Specifically, the original outcome was pictures of snacks, and this outcome was devalued in a way that presented two cockroaches running over the snack in a gif picture. In the transfer test, it was reported that a devaluation effect was observed — less R1 than R2, as well as a devaluation effect on specific PIT — fewer R1 to S1 than R2 to S2, while R1 to S2 and R2 to S1 were both at similarly low levels. Also, there were fewer R1 than R2 when S3 and S4 were presented, but the devaluation effect did not influence general PIT. This may be because the response rates to S3 were low, which result in a weak general effect. It could be difficult to observe any change in the general PIT as floor effect may appear. The researchers argued that PIT is a goal-directed behaviour as the devaluation effect decreased the specific effect.

Adding devaluation in PIT tasks, researchers supported S-O-R by presenting significant results that devaluation affected PIT effects, and supported S-R by showing non-significant results.

Besides devaluation procedures, forward (S-O) and backward (O-S) conditioning procedures have also been used in PIT tasks as a method to test accounts. The S-O-R account depends on the process by that S activate O representation, which can be formed strongly by forward conditioning (S-O) but shaped weakly by backward conditioning (O-S), in further to evoke R. However, in the S-R account, O evoke S in the Pavlovian stage, and then S evoke R which was paired with the O. The S-R account can be facilitated when O present. This indicates the S-R strengthen more on backward conditioning (O-S) rather than forward S-O associations where S is absent when O activate R.

For instance, with forward / backward training trials included, Cohen-Hatton et al. (2013) supported the S-R account by suggesting O mediated a direct S-R association. The researchers first conducted an effective specific PIT task in Experiment 1. Specifically, rats learnt R1-O1, R2-O2, received O1 when S1 was presented throughout (S1+O1), and O2 when S2 was presented throughout (S2+O2). Results in the transfer test showed a specific effect. Then, in Experiments 2 and 3, the Pavlovian stages were changed — with both forward (S1-O1) and backward (O2-S2) training trials included. The results showed that specific effects could be observed in backward training trials, but not forward training trials. This indicated that the O-S, but not the S-O association facilitated the PIT effect, which further supported the S-R account. In Experiment 4, after instrumental training (R1-O1, R2-O2), rats experienced both backward O1-S1, O2-S2 and forward S1-O2, S2-O1 trials. In the test, the rats responded more to R1 than R2 when S1 was presented, and more to R2 than R1 when S2 was presented. This indicated outcomes appeared backwards (O-S), but not forward (S-O), in training influenced responses to stimuli (O-S-R). The researchers suggested that this result provided direct support for their hypothesis regarding the S-R account in PIT.

However, Alarcón et al. (2018) supported the S-O-R account with forward/backward trials. With human participants, the researchers conducted four experiments to explore associative mechanisms in specific PIT. The first two experiments used the same experimental design. The only difference between the two experiments was instrumental responses were trained concurrently in the first experiment and trained separately in the second experiment. In both experiments, participants learnt R1-O1, R2-O2 in the instrumental stage, and A-O1, B-O2, O1-C, O2-D in the Pavlovian stage. The four stimuli were neutral images with no specific meaning, and the two outcomes were food and drink pictures. Results from transfer tests in both experiments showed specific effects when the forward CSs, but not backward CSs, were presented. This showed evidence that forward CSs produced stronger specific PIT effects than backward CSs. In the third experiment, researchers modified the Pavlovian stage — outcomes were presented both before and after the stimuli. In the inconsistent group, the two outcomes presented before and after the stimulus were different (O1 → A → O2, O2 → B → O1, O1 → C → O2, O2 → D → O1) and in the consistent group, the outcomes were the same (O1 → A → O1, O2 → B → O2, O1 → C → O1, O2 → D → O2). In the data treatment procedure, forward CS-Outcome relations were used to refer to 'same' or 'different' responses. For example, in the inconsistent group, R2 was the 'same' response when A was presented as A-O2 was a forward relation while O1-A was a backwards relation. The results showed that specific effects appeared in both inconsistent and consistent groups and were caused by a similar number of 'same' and 'different' responses. This indicated although the outcomes presented before and after the CSs were different, the forward CS-Outcome relation is the one that produced specific PIT effects. Experiment 4 repeated these results. The findings in these four experiments showed evidence that it was S-O, but not O-S, contributed to the formation of specific PIT effects, which further supported the S-O-R theory.

So far, with methods of adding devaluation procedures or applying forward/backward trials, there is more convincing evidence in supporting the S-O-R rather than S-R account in PIT.

1.8 Use PIT Tasks to Explore Addictive Behaviours

Different types of PIT tasks are widely used to study addiction in animals and humans. In 2007, a specific PIT task was used as a task to addictive behaviour (Experiment 2, Hogarth et al, 2007). The stimuli A, B, X, and Y were four abstract patterns (resembling looked like four different wheels). Stimulus A was paired with winning cigarettes and losing money, stimulus B was paired with winning money and losing cigarettes, and stimuli X and Y were contextual stimuli. The outcomes were an icon of a cigarette or a symbol of money (i.e., £). Participants, who were regular smokers, learnt that pressing the ‘D’ or ‘H’ keys was paired to get cigarette or money separately when cigarette-related or money-related stimuli were presented. In the transfer test, cigarette-related stimuli increased responses to the outcome of cigarettes, and money-related stimuli increased responses to the outcome of money. This indicated that participants responded to get a specific outcome. A specific PIT task has been used as an addictive behaviour mechanism among smokers.

Besides specific PIT, single-lever PIT tasks are also applied in similar research. LeBlanc and colleagues (2012) studied drug-seeking and drug-taking actions by applying a single-lever PIT task with a drug self-administration procedure. In the Pavlovian stage, the rats learned one of the two auditory stimuli (CS-) was paired with nothing, and the other (CS+) was paired with the infusion of cocaine. Then, in the instrumental stage, rats can get cocaine by using a seeking-taking chain. In the transfer test, tested in extinction, rats showed an increased number of both seeking and taking actions when the CS+ was presented compared to CS-. These results suggested that the cocaine-related stimulus can evoke drug-seeking and taking behaviour. A single-lever PIT task has been used to explore cocaine-addictive behaviour.

A general PIT task has also been used to study rats' alcohol-seeking actions. In the first experiment conducted by Corbit and Janak (2007), the rats learned one of two auditory stimuli (CS+) was paired to accessing ethanol (EtOH) and the other was paired with nothing (CS-) in the Pavlovian conditioning stage. Then the rats learnt one of the two levers was activated (paired with ethanol) and the other lever was inactivated in the instrumental training stage. In the transfer test, researchers observed that rats responded more to the activated lever than the inactivate one when CS+ was presented. This suggested that the EtOH-paired cue evoked EtOH-seeking responses. Then, in their second experiment, the rats learned one response was paired with EtOH, and the other response was paired with sucrose. Two cues were paired with EtOH and sucrose separately. The results showed that the sucrose cue evoked the response that was paired with sucrose before, however, the ethanol cue increased responses to both levers. Experiment 3 was identical to experiment 2, except that both levers and cues were paired to natural rewards (polycose and sucrose) separately. Researchers found a specific effect when either of the cues was presented in the transfer test. These results suggested that different from food-related cues that can evoke specific lever pressing, EtOH-cue promoted a more general effect in PIT tasks. One interpretation of the results was that the motivation of getting alcohol can be much stronger than getting other natural rewards, and participants were motivated to get rewards with the same affective/motivational value. A general PIT task has been used to explore alcohol-addictive behaviour.

Alcohol-dependent patients may show more reward-seeking behaviours in PIT tasks. For example, Garbusow et al. (2014) recruited alcohol-dependent patients and healthy controls and designed a PIT task with a modified instrumental phase. In the instrumental stage, participants saw some shells presented separately on the screen —— some were 'good' shells, and some were 'bad' shells. When participants pressed a button, the 'good' shells were paired with an

80% chance to win and 20% to lose 20 cents; the 'bad' shells were paired with an 80% chance of losing and 20% to get 20 cents. At the end of this stage, participants learnt that to get more money, they need to press a button to collect 'good' shells or not do anything to avoid 'bad' shells. Then, in the Pavlovian stage, participants learnt that five audio-visual compound stimuli (multicolour fractal images with a pure tone) were paired to +2, +1, 0, -1, and -2 euros separately. In the transfer test stage, researchers added four stimuli (two alcoholic drink pictures and two water glass pictures). These four visual stimuli and the previous five audio-visual compound stimuli were presented as background randomly with a 'good' shell or a 'bad' shell. The number of responses to the button was recorded. The results showed that both alcohol-dependent patients and healthy controls showed PIT effects. The size of PIT effects during money-related CSs and alcohol-related CSs were highly correlated. Alcohol-dependent patients showed stronger PIT effects than controls when aversive CSs were presented. The researchers think that their PIT task suggested a method to observe the decision-making process in addiction.

Different from the opinions above, Takahashi et al. (2019) think that although performance in PIT tasks correlated to drug-seeking behaviour, it could not predict the development of addiction. In their experiment, researchers used cocaine addiction model rats —— a group of rats that experienced long-term cocaine self-administration (CSA) training (i.e., R-cocaine). Both the cocaine addiction model group and the control group experienced a PIT task and CSA training. In the PIT task, rats learnt the light cue was paired to sucrose solution in the Pavlovian stage; the activated lever, but not the inactivated lever, was paired to sucrose in the instrumental stage. Researchers did not observe that cocaine addiction model rats behaved differently from non-addicted-like rats in the transfer test: the cue elevated responses to the activated lever, but not the inactivated lever. Then, in the CSA training, rats could get cocaine infusion by pressing a lever while a light cue was on. However, when the light was off, pressing the lever could get nose poke, but not cocaine infusion. In this case, the R can be associated with both appetitive and aversive outcomes while different CSs predict different types of outcomes, indicating results in CSA measured strength of CS-O learning. Researchers found that rates of cocaine-seeking (pressing levers while the cue light was on) behaviour in CAS was positively related to the size of the sucrose PIT effect. These results indicated that a stronger PIT effect predicted a better association of CS-O learning, but not a development of addiction.

It can be seen that applying PIT tasks have been suggested as a method to study addictive behaviour and various types of PIT tasks have been used. The experiments conducted in this PhD project used PIT as a behavioural mechanism to study addiction.

1.9.1 Stress/Anxiety and Addiction

The feeling of anxiety has been referred to as a stress related emotion (Lazarus, 1976). Spielberger et al. (1983) also mentioned that the concept of stress is used to describe a negative situation that evokes anxiety reactions or stress reactions. In addition, anxiety can be defined as feelings of stress, unease, worry, and tension (Nolen-Hoeksema, 2011). In Depression Anxiety Stress Scales (DASS; Lovibond, & Lovibond, 1995), the anxiety subscale measures autonomic arousal, while the stress subscale assesses chronic non-specific arousal. It can be seen the concepts of anxiety and stress share similarities and can be used interchangeably in some situations. Anxiety can be divided into two types: state and trait. In State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983), the state scales measure participants' feelings at the moment while the trait scales assess participants' feelings in general. When the state of anxiety last long, individuals feel difficult to process it and may develop anxiety disorders. Generalised Anxiety Disorder Assessment (GAD-7; Spitzer et al., 2006), which measures anxiety in the last two weeks, can be used as a screening tool in clinics. Scales of DASS, STAI and GAD-7 have all been used wildly to measure anxiety levels in research and clinics.

Stress/anxiety is closely related to addiction. Exposure to stressors is a risk factor for maintaining, and relapsing into addiction. Animal research showed that rats tend to get more intravenous cocaine via a self-administration setting when experiencing non-contingent electric foot shock (Goeders & Guerin, 1994). In human studies, family stressors (e.g., disrupted family status, poor family relations) significantly predict cannabis use among adolescents (Butters, 2002); more stressful features (e.g., high job strain, low reward) in a work environment are associated with a higher likelihood of smoking among employees (Kouvonen et al., 2005); experiencing traumatic events positively correlated to high-risk drinking (McFarlane, 1998). In addition, anxiety and addiction are co-occurring disorders —— individuals with any type of addictive disorder are also diagnosed with anxiety disorder, and vice versa (Grant et al., 2004; Kessler et al., 2005; Ostovar et al., 2015). By conducting multiple linear regression, researchers found that self-reported state anxiety (i.e., anxiety in specific situations or moments), trait anxiety (i.e., the individual difference in presenting state anxiety), and neuroticism (i.e., trait disposition to experience negative effects) can significantly predict online gaming addiction (Lemmens, Valkenburg & Peter, 2009； Mehroof & Griffiths, 2010). High anxiety levels (Matar Boumosleh, & Jaalouk, 2017; Hawi, & Samaha, 2017) or social anxiety (Enez Darcin et al, 2016) significantly predict smartphone addiction. Furthermore, Younes et al. (2016) found a strong correlation between anxiety and the likelihood of developing internet addiction among university students. Feeling anxious or stressed can also be a trigger to elicit food addiction in humans (Parylak, Koob, & Zorrilla, 2011).

One suggestion to explain the effect of stress on addiction is the self-medication hypothesis (Khantzian, 1974; Khantzian, 1985; Khantzian, 1997), which indicates individuals tend to use the abused substance to manage negative feelings. In 1974, Khantzian reported five clinic cases and summarised those patients may become addicted to heroin because they have not successfully developed a way to deal with distress in the real world (e.g., social vacuum, unemployment, break up in a relationship). Later in 1985, Khantzian reported more clinical cases and argued that developing drug addiction was not only because the patients were using drugs to deal with stressors from the world around them, but also because they were using drugs to manage different mental health issues. The drug choice was based on the drug's psychopharmacological action. For example, opiates helped patients manage disorganisation and aggression, while cocaine helped patients relieve depression or mania. This further supported the self-medication hypothesis.

Another explanation of anxiety influencing addictive behaviour is that substance abuse or withdrawal can evoke many symptoms including anxiety, and addicts with high levels of anxiety experience more serious withdrawal symptoms. For example, smokers with a current anxiety disorder reported more severe tobacco withdrawal symptoms and smoking relapse compared with smokers without severe anxiety-related mood and physical symptoms (Leventhal et al., 2013, Weinberger, Desai, & McKee, 2010). Also, higher state and trait anxiety scores among abstinent alcoholics were positively correlated to a more frequent and intense craving for alcohol (Roelofs, 1985). A stressful environment induced negative effects, including anxiety, increased severity of withdrawal symptoms among abstinent alcoholics and the possibility of relapse in drinking (Breese et al., 2005).

1.9.2 Stress, Anxiety and PIT

It is possible that the phenomenon of stress/anxiety increasing addictive behaviour is mediated by stress/anxiety influencing PIT. Some studies examined the effect of stress on animals' performance on a Pavlovian instrumental transfer (PIT) task. For example, Morgado et al. (2012) put male rats in chronic unpredictable stress (CUS) paradigm and a specific PIT task. In the CUS, the rats received one out of five kinds of stressors (hot air stream, cold water, vibration, restraint, overcrowding) randomly every day for 28 days. In the specific PIT task, researchers used tone and white noise to be the two CSs, pellets and sucrose to be the two USs, and left and right levers to be the responses. In Pavlovian and instrumental training, the rats learned associations between S1-O1, S2-O2, R1-O1, and R2-O2. In the transfer test, researchers found that rats in the stress group gave few responses to S1, S2 which resulted in no specific effect observed. However, the control group showed a specific effect —— a CS selectively increased responding rates were paired with the same outcome as the CS. The response rates to the CS that were paired with the different outcomes as the CS were as low as the response rates in the stress group. They think this phenomenon may be because some brain areas affected by stress are also important regions of PIT. In addition, they found that chronic stress did not influence the rats' behaviour during Pavlovian training or instrumental training, and the PIT deficits recovered after 6-weeks of the absence of stress.

Instead of putting rats in an environment with stressors, researchers also gave rats microinjections to imitate the brain under stress. Peciña et al. (2006) conducted a PIT task with rats who received different microinjections in the caudal medial accumbens shell. The rats were arranged in the vehicle group, 250 nanograms (ng) corticotropin-releasing factor (CRF) group, 500ng CRF group, and amphetamine group. In their design, rats could get sucrose by responding to one of the levers, but not the other (R1-O, R2-nothing). The two stimuli were 30 seconds tone or clicker. In the transfer test stage, the rats in the 500 ng CRF and amphetamine group showed enhanced R1 (but not R2) when the CS+ was presented, but not when the CS- was presented. The researchers concluded that increased release of corticotropin, mediated by stress, fear, and anxiety, can elicit responses in PIT. This result is different from the one Morgado et al. (2012) reported; however, while Morgado applied specific PIT, it is difficult to say if the effect observed was specific or general in the study of Peciña et al. (2006).

Nevertheless, some experiments did not observe that stress can affect the PIT effect in rats. For instance, Pielock et al. (2013) studied whether acute stressors can change rats' behaviour on a single lever PIT task with two stimuli in the Pavlovian stage (CS+, CS-). They arranged rats into different groups: no stressors, a single stressor (acute restraint in a bright novel room) and multiple stressors (acute restraint in a bright novel room, loud music) in a dark cycle or a light cycle. The researchers found that stressors worked most effectively in the dark and partly worked in light. Also, the findings showed that neither single nor multiple acute stressors changed the PIT effect significantly, no matter whether it was in a light or dark cycle. However, the single, or multiple acute stressors reduced basal lever press rate in the dark.

Overall, in animal studies, the stress environment decreased the specific PIT (Morgado et al., 2012). In PIT task design, without knowing if it was a specific or general effect, employing microinjections to replicate the stressed brain's response enhanced the PIT effect (Peciña et al., 2006), but the stress environment did not affect the PIT effect significantly (Pielock et al., 2013).

Besides animals, human subjects have also been used. In 2017, Quail and colleagues explored the relationship between humans' performance on PIT and their scores on the Depression

Anxiety Stress Scales (DASS; Lovibond, & Lovibond, 1995). They used a computer-based standard appetitive PIT task with a background story of getting snacks from a vending machine. The stimuli were four different coloured lights, the rewards were three different kinds of snacks, the non-reinforcement outcome was the word 'empty', and the responses were two buttons. By using this task, they could demonstrate both specific and general PIT effects. By conducting correlations, the researchers found that scores on the combined anxiety and stress subscales negatively correlated to the general PIT effect, but not the specific PIT effect. In further analysis, participants were divided into two groups (9 participants in the low anxiety and stress group, and 8 participants in the high anxiety and stress group). The anxiety scores and stress scores in the high anxiety and stress group were significantly higher than those in the low anxiety and stress group. Then, they analysed the impact of combined anxiety and stress scores on the specific and general PIT effects in the two groups separately. Consistent with the results from the correlation, there was no difference in the size of the specific PIT effect between the two groups, but a difference in the magnitude of the general effect was observed. Specifically, a weaker general effect was observed in the high anxiety and stress group as participants gave more responses to S4 (the light colour paired to 'empty'): responses to S4 were significantly higher in the high anxiety and stress group than in the low anxiety and stress group, and responses to S3 were not significantly different between the two groups. Researchers thought this is because feeling stressed or anxious can decrease people's ability to inhibit.

Vogel et al. (2018) also explored the relationship between perceived stress and performance on a specific PIT task. In the Pavlovian stage, four abstract stimuli A, B, X, and Y, were presented on the screen. Participants learnt that A predicted gaming points; B predicted shopping points; X, Y were control stimuli. In the instrumental stage, participants learned that they could press the 'G' key to get gaming points and press the 'S' key to get shopping points. In the transfer test, researchers observed the specific gaming PIT effect. Stress was measured by using Perceived Stress Questionnaire (PSQ20; Levenstein et al., 1993). The stress scores could not predict the specific gaming PIT effect significantly. This indicates researchers did not find evidence that stress could influence the specific PIT.

Besides measuring participants' state by using scales, some researchers have used mood induction procedures to manipulate participants' state in further analysing how humans' mental state affects their performance on the PIT task. For example, in 2015, Pool and colleagues used a socially evaluated cold pressor test (SECPT) in the process of stress manipulation. In their experiment, a single lever paradigm was used in an appetitive PIT task. Participants learnt to get the reward of chocolate odour by squeezing a handgrip in the instrumental stage and learnt three stimuli (patterns look similar to a yellow circle, pink triangle, and green square) were paired to chocolate odour, odourless air and nothing in the Pavlovian stage. Then, in the stress induction stage, subjects were categorized into two groups (stress group, stress-free group). In the stress group, participants were encouraged to put their nondominant hands in cold water (0–2 °C) for as long as they could, while in the stress-free group, it was warm water (35–37 °C) for 3 minutes. At the end of the stress induction process, subjects' feeling of pleasure, stress, and pain was immediately recorded using a 0 (not at all) to 10 (extremely) scale. Scores on this scale showed that people felt a higher level of stress and pain and a lower level of pleasure than those in the stress-free group. Finally, in the transfer test, results showed that compared to participants in the stress-free group, subjects in the stress group gave more responses to the stimulus that was paired with chocolate odour than the stimulus that was paired with odourless air. This study evidenced that acute stress could increase humans' reactions to reward-paired cues (strengthen PIT effect), however, it was difficult to say if it was a specific or general PIT effect.

In addition, Steins-Loeber et al. (2020) doubted whether acute stress could change people's performance on PIT tasks. They tried to replicate Pool's result by using SECPT before the transfer test in a PIT task. In contrast to Pool's task, a cigarette was added as one more outcome, and instead of odour, researchers used chocolate and cigarette pictures as outcomes. In the Pavlovian stage, participants saw four stimuli (patterns like four different wheels) and learnt that one of the CSs was paired with pictures of chocolate, one with cigarettes, and the other two were control stimuli. In the instrumental stage, participants learnt that the red button was paired with chocolate and the purple button was paired with the cigarette. Both the smoking-specific effect and the chocolate-specific effect were observed in the transfer test. The size of PIT effects showed no differences between the stressed and non-stressed groups, although participants in the stress group reported higher stress levels in a visual analogue scale than non-stressed groups. This indicated that the phenomenon of stress affecting addictive behaviour might not be driven by drug-related cues promoting drug-seeking behaviour.

Other kinds of mood induction procedures were also used in studies that explored the same topic. Pritchard et al. (2018) enhanced stress levels by asking them to evaluate some aversive images, while the control group evaluated neutral pictures. Aversive pictures were images of dead or dying humans from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert,1997). Participants first learned the 'D' key and 'H' key was paired with water or chips separately in their experiment. Then, aiming to devalue the outcome of water, participants were asked to drink water until sick. After drinking, participants practised rating the aversive or neutral pictures. By pressing the left or right arrow key, participants decided which one out of the two pictures was more aversive in the negative group or more attractive in the neutral group. In the test stage, there were three phases: extinction, reacquisition, and PIT test. In the extinction phase, participants saw an aversive/neutral image on the screen first. Then they were instructed to get water or chip points by pressing the ‘D or H’ key and finally rate aversive/neutral pictures as they practised. In the reacquisition phase, the procedure was identical to the extinction phase except that the outcome pictures (water or chips) were presented after pressing the ‘D or H’ key. Finally, in the PIT test, the procedure was identical to the extinction phase except that at the beginning of each trial, an aversive/neutral image was presented with an outcome picture. Researchers found participants in the stress group reported more negative feelings (e.g., anxiety, depression, anger) in the profile of mood States (POMS; McNair, Lorr, & Droppleman, 1971) questionnaire than people in the control group, but their performance on the reacquisition test and specific PIT showed no differences between groups.

Overall, in human studies, the impact of stress on PIT has been explored by using scales or mood induction procedures. Quail et al. (2017), used DASS and found higher scores on combined anxiety and stress subscales decreased the general PIT effect but not the specific effect. Vogel et al. (2018) used PSQ20 and did not find evidence that stress can influence the specific PIT effect. SECPT was used as stress mood induction in two studies. Pool et al. (2015) reported that participants in the SECPT group gave more responses to the transfer test than in the stress-free group. However, it is difficult to say whether the PIT effect was specific or general. Steins-Loeber et al. (2020) failed to repeat this result when changing the Pool’s PIT task to a specific PIT task. This may indicate that the enhanced PIT effect by stress in Pool’s study was a more general effect than specific. Another study (Pritchard et al., 2018) used the process of evaluating aversive images as stress induction and failed to observe a significant impact on specific PIT tasks.

So far, the previous research observed inconsistent results in exploring how stress or anxiety can influence performance on PIT tasks. This may be because stress or anxiety can influence general PIT effects but not specific PIT effects. However, previous studies applied different types of PIT tasks —— some used PIT tasks with specific effects only, and some used PIT tasks for which it is difficult to say if the observed effects were specific or general. In this thesis, an avoidance-based PIT task was applied in measuring the relationship between anxiety and PIT effects in Experiments 3-7. In avoidance-based PIT tasks, participants responded to a CS that was paired with the same aversive outcome before to avoid the aversive feeling (i.e., specific effect). Also, participants respond to a CS that is paired with a different (in sensory) outcome as the R because the outcomes share the same motivational value (i.e., general effect). Anxious feelings can enhance the attention, memory, and expectancy of aversive outcomes, hence increasing the motivation to perform avoidance behaviour (Ellenbogen & Schwartzman, 2009; Terburg, Aarts & van Honk, 2012; Ly & Roelofs, 2009). In measuring a specific effect, researchers usually used the response rates to the same outcomes as the CSs paired (congruent condition) minus the response rates to the different outcomes as the CSs paired (incongruent condition). Specific effects depend on sensory values and motivational values. The motivational values of the outcomes in the congruent and incongruent conditions were the same and should be influenced by anxiety levels to a similar extent. In the general effect, responses to S3 should be increased as the motivational value of the outcome is enhanced. However, responses to S4 should not be influenced as S4 was paired with a non-reinforcement outcome, which has no motivational values. Therefore, if participants' motivation is enhanced, the general effect should be stronger as participants respond more to S3 but not S4 and left specific effects unaffected.

1.10.1 Impulsivity and Addiction

Impulsivity is generally considered as the tendency to act on a whim without considering the costs of the action (Moeller, et al., 2001). Barratt (1959) suggested three main sub-traits of impulsiveness: acting without thinking, making cognitive decisions quickly, and present-directed behaviour or a lack of considering the future. Additionally, Whiteside and Lynam (2001) argued that five characteristics could lead to impulsive behaviour (UPPS-P): positive urgency (tendency to act rashly under extreme positive emotions), negative urgency (tendency to act rashly under extreme negative emotions), sensation-seeking (tendency to seek out novel and thrilling experiences), lack of premeditation (tendency to act without thinking), and lack of perseverance (inability to remain focused on a task). Both Barratt's impulsiveness scale and UPPS-P impulsive behaviour scale have been widely used in self-assessment measurements.

Impulsivity is a personality trait that plays an important role in the behaviour of various types of addiction (Mulder, 2002), such as gambling, overeating or food addiction, alcohol dependency, and drug abuse (Meda, et al., 2009). For example, aiming to investigate whether the personality trait of impulsivity can predict severe levels of gambling disorders, Savvidou et al. (2017) used the UPPS-P impulsive behaviour scale for a large sample of the clinical population. By conducting regression analysis, they found that higher impulsivity scores significantly predicted more serious gambling disorder symptoms. Additionally, prospective research reported that impulsivity traits could strongly predict the acquisition of alcohol use (Clark, Vanyukov & Cornelius, 2002). Conversely, alcohol dependence can also cause impulsive behaviour (Goldstein & Volkow, 2002). In addition, by comparing participants with food addiction and non-clinical subjects, patients with an eating addiction reported higher impulsivity, measured by the Barratt Impulsiveness Scale. Results indicated impulsivity could be a risk factor for eating addiction (Brunault et al., 2018).

This phenomenon can be explained by suggesting that impulsivity can be influenced by the behavioural activation or inhibition system (BAS; BIS; Gray, 1970; Gray, 1987; McNaughton & Gray, 2000). BAS is used to adjust appetitive motivations which support responding toward appetitive outcomes. BIS is used to adjust aversive motivations which support moving away from aversive feelings. Highly impulsive individuals are more sensitive to the activation of BAS and are encouraged by the stimuli that can bring them rewards. BIS has been considered a model that animals' approach or avoid conflict goals, such as food being presented with electronic shock together (Gray & McNaughton, 2000). Low BIS individuals are less sensitive to risk and less thoughtful in approaching conflict goals (less behaviour inhibition). Therefore, highly impulsive individuals experience more reward attraction and less behaviour inhibition when the reward occurs with punishments. Overall, impulsivity is positively correlated to BAS and negatively correlated to BIS (Smillie & Jackson, 2006). This indicates highly impulsive people feel rewards (e.g., food, alcohol) are extremely attractive and difficult to limit intake, which results in a higher risk of developing and maintaining addiction (Aragues et al., 2011).

1.10.2 Impulsivity and PIT

Sommer et al. (2017) explored the relationship between impulsivity and performance on a PIT task by using alcohol-dependent patients. They used the PIT task reported by Garbusow et al. (2014; described in section 1.8). In the PIT task, participants learnt to collect a 'good shell' or leave a 'bad shell' to get money in the instrumental stage; learnt associations between CSs (background pictures) and outcomes (win or lose money) in the Pavlovian stage; collect or leave the shell while money CS or beverage stimuli (alcohol or water) present in transfer test. After completing the PIT task, participants were asked to perform a delay discounting task: they could choose to get a small amount of money immediately or a larger amount of money later. Participants exhibiting a preference for smaller immediate rewards demonstrated elevated levels of impulsivity. Researchers found that compared with healthy controls, high-impulsive alcohol-dependent patients, but not low-impulsivity alcohol-dependent patients, showed a stronger PIT effect no matter if the stimuli were alcohol-related. It indicates that high-impulsive alcohol-dependent patients can be influenced strongly by environmental cues and thus be prevented from reaching long-term goals. This study also showed that impulsivity can mediate alcohol-dependent patients' performance on PIT tasks. The PIT effects were not separated into specific PIT or general PIT when analysed.

Hinojosa-Aguayo and González (2020) reported that affect-driven impulsivity, especially negative urgency, influenced humans' performance on specific PIT effects, outcome devaluation, and the effect of outcome devaluation of specific PIT. In their first experiment, the participants first completed a standard Pavlovian instrumental transfer task used by Quail et al., (2017). In the PIT task, participants were encouraged to get different snacks from a vending machine. Then, participants experienced the outcome devaluation procedure (used by Morris et al., 2015): watching cockroaches run over snacks. To test the devaluation effect, participants had 120s to make responses freely. Finally, participants filled in an impulsive behaviour scale (short Spanish version UPPS-P, Cándido et al., 2012). Researchers found that both the magnitude of the specific PIT and outcome devaluation effects were negatively correlated to scores in the negative urgency subscale. In the second experiment, participants experienced a devaluation procedure before the transfer test (described in section 1.7). The researchers found that negative urgency scores negatively correlated to the devaluation effect on the specific effect —— while devaluation should decrease PIT effects, high negative urgency participants were immune to it. The devaluation effect on the general effect was not observed and its correlation with impulsivity was not measured.

However, some researchers did not find a significant relationship between impulsivity and PIT effects. For example, Vogel et al. (2018) explored the relationship between individual factors, including impulsivity, and performance on a specific PIT task (described in section 1.9.2). Subjective impulsive behaviour was measured by using Barratt Impulsiveness Scale (BIS-15; Meule et al., 2011). Results did not show any significant relationship between impulsivity and the specific effect.

So far, by using impulsivity scales, researchers reported either non-significant (Vogel et al., 2018) or negative correlations between impulsivity and specific PIT effects (Hinojosa-Aguayo & González, 2020). By separating participants into high and low impulsivity groups, researchers found the high impulsivity group showed a stronger PIT that is either general or specific (Sommer et al., 2017). Because reliable general PIT effects have been difficult to observe in humans, the relationship between general effects and impulsivity has not been investigated well. In addition, it is possible that Sommer et al. (2017) observed different results from other researchers because they applied a more general PIT effect and others used specific PIT only. Therefore, it is important to apply a PIT task which can study both specific and general effects. Based on previous findings, I predicted that impulsivity negatively correlated to specific effects but not general effects.

1.11 Aim of this Thesis

The experiments in this thesis aimed to explore how stress/anxiety or impulsivity can influence humans' behaviour on specific and general PIT tasks. To explore this, in Chapter II, I first conducted two novel standard PIT tasks, one an avoidance-based PIT, and the other an appetitive PIT. Both specific and general effects could be observed stably in both PIT tasks.

Then, in Chapter III, a series of studies were conducted to explore how stress/anxiety can influence humans' performance in an avoidance-based PIT task. Most of the previous studies did not separate specific and general effects clearly in their PIT task designs. Therefore, the PIT task with both specific and general effects was applied. To assess the anxiety levels, both scales, online mood induction and in-person mood induction were used in separate experiments. Anxiety scales included Depression Anxiety Stress Scales (DASS; Lovibond, & Lovibond, 1995), State Anxiety Scale in State subscale in State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983), and the Generalised Anxiety Disorder Assessment (GAD-7; Spitzer et al., 2006). I also used a mood induction procedure with music and pictures to enhance anxiety levels. The online mood induction procedure included unpleasant images and heavy metal music to enhance arousal levels. The in-person mood induction used a speech stress test to enhance stress levels. I predicted that high stress increases general PIT effects, but not specific PIT effects.

The experiments in Chapter IV explored relationships between impulsivity and PIT effects. The appetitive PIT task was applied, as well as added devaluation procedures. I used scales of Barratt Impulsiveness Scale Version 11 (BIS-11; Patton, Stanford & Barratt, 1995) and the UPPS-P Impulsive Behaviour Scale (Lynam, Whiteside, Smith, & Cyders, 2006; Cyders Littlefield, Coffey & Karyadi, 2014). I predicted that impulsivity negatively correlated to specific effects and positively correlated to general effects. Inspired by Hinojosa-Aguayo and González (2020), adding devaluation procedures before the transfer test can be a way to measure how impulsivity correlates to the change of outcome values in PIT effects. Based on the results of previous studies, I predict that individuals with higher levels of impulsivity are less sensitive to the devaluation effect on specific PIT.

Chapter II: Avoidance-based and Appetitive PIT tasks (Experiments 1-2)

It can be seen from the literature reviews that the inconsistent findings of relationships between anxiety or impulsivity and PIT effects may be because specific and general effects were not distinguished clearly in the previous PIT tasks. Therefore, experiments in this chapter aimed to develop two standard PIT tasks with both specific and general effects observed in humans.

2.1 An Avoidance-based PIT Task

The current experiment aimed to develop an effective avoidance-based PIT task and look for both specific and general effects in humans. The development of avoidance-based PIT can be traced back to 1967. LoLordo's dogs first learned to press a panel to avoid electric shock, then learned associations between S1 and electric shock, S2 and loud noise, S3 and nothing. Finally, in the extinction stage, the researchers observed that the dogs made more panel presses to S1 or S2 rather than S3. It showed a general effect (more response to S2 than S3) that dogs gave responses to a stimulus that was paired with another outcome with the same motivational value. A similar design has been used in an experiment on rats (Henderson, Patterson, & Jackson, 1980). The results of the study showed a general effect that rats made more lever responses to avoid shock in the presence of a CS paired with an airblast than the avoidance baseline.

In human studies, Paredes-Olay et al. (2002) observed specific effects in an avoidance-based PIT task. In their four experiments, participants were asked to play a video game to protect their country from navy and air force attacks. Two of the experiments shared the same design. Participants first learned that two keys were paired to two different outcomes (destruction of the ship, destruction of the plane) separately. Then, they learned associations between two stimuli and the two outcomes in the Pavlovian stage. Lastly, the stimuli were presented separately and the responses to the two keys were recorded. The results showed that participants pressed more on the key which shared the same outcome as the stimulus. The other two experiments used a similar design. The only difference was that the researchers added one more stimulus, which was paired with nonreinforcement outcomes (destruction of nothing), in Pavlovian learning as the 'control' condition. Results from one of the two experiments showed that participants responded more to the 'same' condition (respond to stimuli that share the same outcomes) than the 'control' condition, which showed no difference from the 'different' condition (respond to stimuli paired with different outcomes). Also, results from the other experiment showed that participants responded less to the 'different' condition than the 'control' condition, which showed no difference with the 'same' condition. Meanwhile, the researchers observed higher response rates to the 'same' condition than the 'different' condition in the four experiments. This indicated that specific effects can be firmly observed with avoidance instrumental response in a demonstration of PIT.

In 2011, Nadler et al. failed to observe general effects in two standard appetitive PIT tasks, then conducted a standard avoidance-based PIT task which showed both specific and general effects. The three PIT tasks shared the same design: participants formed R1-O1 and R2-O2 associations in the instrumental conditioning, and S1-O1, S2-O2, S3-O3, and S4-nothing in the Pavlovian conditioning. In the appetitive tasks, participants were encouraged to get coin, star, and key images in the computer game in Experiment 1a, and the outcomes changed to goblet, star, and moneybag (worth 25¢) images in Experiment 1b. The researchers observed specific effects (S1:R1>R2, S2:R2>R1) and failed to observe general effects (response rates to S3 and S4 were not different). The researchers argued this may be because the outcomes were not attractive enough to evoke general effects which require high motivation. Then, the researchers conducted an avoidance-based PIT task inspired by the design of Paredes-Olay et al. (2002). They observed both specific and general effects in this task with quasi-avoidance learning tasks in humans (Experiment 2). They used a similar cover story with images of different coloured squares as stimuli and pictures of warplanes, warships, and tanks as outcomes. The experiment used a standard PIT process to study both specific and general effects (same in Experiments 1a and 1b). Responses in the transfer test were recorded and showed both specific (S1: R1>R2; S2: R2>R1) and general effects (participants made more R1 and R2 when S3 was presented than S4 was presented). They thought that the reason that they observed a general effect in this avoidance-based task might be because the emotional features of the outcomes in avoidance-based PIT were more discriminable.

Then, Lewis et al. (2013) modified Nadler et al.'s (2011) task by including one more stimulus paired with a neutral outcome in the Pavlovian stage. They found that participants made few responses to the stimuli paired with the neutral outcome or nothing in the CS period, as few as in the CS-absent period. Both specific and general effects were observed in the avoidance-based PIT. Moreover, using fMRI, researchers found these effects triggered the activity of corticostriatal circuitry, including the striatum (bilateral putamen) and the cingulate cortex, which is similar to the neural mechanism underlying appetitive PIT. Further, the avoidance-based PIT process was suggested as a model to understand relapse in addiction. For example, an alcohol-related stimulus can evoke an aversive feeling during the withdrawal period and keeping drinking alcohol can avoid feelings of withdrawal (e.g., anxiety).

The studies above evidenced that avoidance responses can allow for a demonstration of PIT. Different from learning R-O association in the instrumental stage in appetitive PIT, in avoidance-based PIT, responses were made as anticipated outcome destroyed, R-noO. The noO was learnt by seeing the pictures of the dangerousness with the words that the dangerousness was destroyed. In this case, R-O was also formed while learning R-noO, and the S-O-R account can be used to explain avoidance-based PIT (Nadler et al, 2011). So far, some avoidance-based PIT task designs can detect both specific and general effects in humans. The current novel avoidance-based PIT task was inspired by previous ones.

Experiment 1

Introduction

After attempting to observe general effects in many types of appetitive PIT tasks, inspired by Nadler et al. (2011), I decided to conduct an avoidance-based PIT to study both specific and general effects. Nadler et al. conducted two appetitive PIT tasks and failed to get a general effect, but one avoidance-based PIT task showed both specific and general effects. They argue this may be because the emotional features of the outcomes in the avoidance-based PIT task were more discriminable. This may also be the reason that I did not get a general effect in the appetitive PIT tasks. Therefore, I decided to use an avoidance-based PIT task to enhance the level of emotional arousal produced by the outcomes. The current experiment aimed to develop a robust avoidance-based PIT task that is suitable for exploring individual differences in PIT.

Method

Design

This experiment used a standard PIT task design with a post-test assessment to check the knowledge of the Pavlovian stage (see Table 6). In this standard PIT task design, participants first experienced instrumental training. They formed associations between two responses and two outcomes separately. Then, in the Pavlovian training, participants learned that the four stimuli were each paired with one of four outcomes. Two of these four outcomes had been presented in the instrumental stage, the third was a new outcome, and the fourth was a non-reinforcement outcome. Finally, in the transfer test, the four stimuli were presented randomly, and responses were recorded.

Table 6
Design of Experiment 1.

Instrumental training	Pavlovian conditioning	PIT Transfer test	Post-test assessment
R1-O1	S1-O1	S1: R1, R2	S1
R2-O2	S2-O2	S2: R1, R2	S2
	S3-O3	S3: R1, R2	S3
	S4-nothing	S4: R1, R2	S4

Note: S: Stimuli, O: Outcomes, R: Responses.

Participant

All the participants were recruited via the Prolific online platform. Participants were adults with normal or corrected-to-normal vision and had undergraduate or graduate degrees. In total, 32 participants completed this experiment, and data from 8 participants were excluded during the data treatment procedure (see Results section). Finally, data from 24 participants were used, of which 5 did not report their sex and age. Among the remaining 19 participants, there were 7 males and 12 females with a mean age of 24.74 (*SD*=6.12, range 18–37).

Materials

This PIT task was conducted using PsychoPy software (Peirce, 2007). Participants completed the task on their own devices (laptop or computer). Responses were pressing the ‘z’ and ‘m’ keys on the keyboard. Stimuli (S1, S2, S3, S4) were coloured (red, yellow, blue, black) squares (see Figure 1). The outcomes (see Figure 2) in this task were pictures of bats with the words ‘bats destroyed’, rocks with the words ‘rocks destroyed’, arrows with the words ‘arrows destroyed’, and an empty cave with the word ‘no attack’. Both stimulus and outcome images were approximately 60 mm × 60 mm. The identity of the outcomes paired with each stimulus was counterbalanced across participants. Half participants had red and yellow squares as S1 and S2, and blue and black squares as S3 and S4. The rest had blue and black squares as S1 and S2, red and yellow as S3 and S4. When corresponding to positions of stimuli, red and yellow can be switched, and blue and black can be switched. This yielded eight counterbalancing conditions (see Appendix). In the post-test assessment, a question of ‘Was this image followed by? Please click on the link’ was used to assess knowledge. A continuous scale from 1 = ‘very unlikely’ to 7 = ‘very likely’ was prepared for participants to answer the question (see Figure 3).

Fig. 1. Stimuli used in the avoidance-based PIT task.

Fig. 2. Outcomes used in the avoidance-based PIT task.

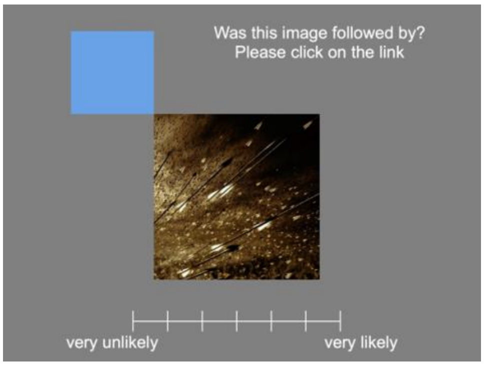

Fig. 3. Question used in the post-test assessment.

Procedure

The experiment received ethical approval (No. S1222) from the University of Nottingham School of Psychology Ethics Committee.

At the very beginning of the task, participants were told that they were exploring caves:

'Welcome to this adventure game!
You are going to explore a series of caves to collect some treasure; but the treasure is protected by cave spirits, and dangerous things will attack you on the way.

We prepared some defences for you to survive.
You can wear a helmet to protect yourself from falling rocks...

use a torch to drive the bats away...

or use a shield to protect yourself from arrows.'

Instrumental Training

Then, subjects were encouraged to protect themselves by pressing the 'z' key or 'm' key:

'As you enter the first cave you are going to be attacked, and you must defend yourself by pressing the keys on the main keyboard (z or m). One of these keys repels the bats, whereas the other shields you from the arrows. Because it is dark you do not know which button neutralises which kind of attack. Sometimes the defences will be successful, but often they will not. Now

you must try and survive the bats and arrows by using your defences. The sooner you discover the function of the keys the safer you will be.'

In this experiment, O1 was always 'bats destroyed', and O2 was always 'arrows destroyed'. Outcomes were delivered according to a variable ratio (VR) 5 schedule (i.e., on average one out of five responses was reinforced). For R1, the reinforced outcome was a picture of bats presented for one second in the centre of the screen and the words 'bats destroyed' below. For R2, the reinforced outcome was a picture of arrows presented for one second in the centre of the screen and the words 'arrows destroyed' below. This stage finished after participants had earned at least 50 O1 and 50 O2.

Pavlovian Conditioning

In the Pavlovian training stage, participants were asked to observe the relationships between the four stimuli and four outcomes passively:

'You have done good work and have survived the first cave - and now your friend has come to help. Your friend has special glasses and can see the attacks coming to you.
They will now send you a code of coloured squares to warn you whether an attack is coming, and if so what it is. Your mission in this part of the game is to learn which coloured box indicates whether there is an attack, and what type it is.'

S1 and S2 were respectively paired with O1 and O2, the same outcomes used in the previous instrumental stage, while S3 was paired with a new outcome, O3. S4 was paired with a picture of an empty cave with the words 'no attack'. There were four trials in each block. Each type of stimulus and the outcome paired with it was presented once in a random order in each block. In each trial participants were presented with a fixation cross in the centre of the screen for one second, after which the stimulus was presented in the centre of the screen for two seconds, followed by the outcome picture presented in the centre of the screen for two seconds. There were 10 blocks in total.

PIT Transfer Test

In this step, participants were told that:

'Now you will enter the final cave that contains the treasure! Your friend will keep sending you signals to alert you to the type of attack you are facing.
You are now asked to press the keys (z or m) to help fend off the attacks, so you can reach the treasure.'

In each trial, a stimulus was presented for two seconds with a two-second preCS period before, and a two-second ITI post afterwards. Participants were allowed to press the 'z' or 'm' keys, while the four different stimuli were presented randomly as in the Pavlovian stage, with four trials, one with each stimulus, per block. This phase ended after 24 trials (6 blocks) of testing.

Post-test Assessment

In this step, participants were told that:

'Now you will be tested on your knowledge about the different signals. Use the mouse to click on the line to indicate confidence in your answer.'

One out of the four stimuli was presented in the upper left corner, together with one of the four outcomes presented in the centre of the screen (see Figure 3). Participants needed to indicate if the two pictures matched, by clicking on the scale at the bottom of the screen. Once participants had made their ratings, the next question appeared immediately. Each of the four stimuli was presented with each of the four outcomes once, giving 16 stimulus-outcome pairs, and these were randomly presented.

Results

In this thesis, data were analysed by using the Shapiro-Wilk test (for multivariate normality), independent t-tests, chi-square, correlations, and mixed analysis of variance (ANOVA). In ANOVAs, interactions were explored with simple main effects (using the pooled error term for interactions involving a between-subjects factor), and posthoc tests using Holm-Bonferroni *p* values to control for the family-wise error rate. Statistical analyses were two-tailed with a critical *p-value* of 0.05. Partial eta squared (η_P^2) was used as a measure of effect size for significant main effects and interactions. All the analysis was completed in JASP (JASP Team, 2019).

Data Treatment

In the post-test assessment stage, the rating scores were recorded. Participants were expected to give a high score (5.5-7) to each of the four correct stimulus-outcome pairs and a low score (1-2.5) to each of the 12 incorrect pairs. Scores not in this range were considered mistakes. A performance criterion was applied, such that participants making two or more mistakes were excluded, as this would indicate poor learning in the Pavlovian stage. According to this criterion, 24 participants were left (three people for each of the eight conditions).

In the transfer test, responses on each key were classified into four conditions (congruent, incongruent, S3, and S4). In the congruent condition, participants made the response that signalled the same outcome as was predicted by the stimulus (R1-S1, R2-S2). In the incongruent condition, participants made the response that had signalled the other outcome that had appeared in the instrumental stage but had not been paired with the stimulus (R1-S2, R2-S1). In the S3 condition, the total response rates (R1+R2) to S3 were recorded, while in the S4 condition, responses to S4 were summed (R1+R2). Then, the response rates were separated according to whether they occurred during the preCS periods (fixation cross presented) or the CS periods (a stimulus presented) first. In the preCS or CS periods, the response rates in each condition were averaged in each four-trial block. The data in the first three blocks were analysed and the data in the last three blocks was not included in analysis. Afterwards, difference scores were computed by subtracting the response rates in the preCS period from that during the CS period, for each of these four conditions. Finally, the results during preCS period, CS period, and CS-preCS (difference scores) period in each condition were converted to responses per minute.

Specific Effect

The difference scores (response per minute; rpm) in the congruent and incongruent conditions are presented in Figure 4. The figure suggests that difference scores in the congruent condition were greater than in the incongruent condition. This impression was supported by results of a conditions (congruent, incongruent) x blocks within ANOVA, which showed a significant main effect of conditions, F (1,23) = 51.161, p< .001, MSE = 13915.149, η_P^2 = .690. The main effect of blocks, F (2,46) = .183, p= .833, MSE = 8309.443, and the interaction between conditions and blocks, F (2,46) =.801, p= .455, MSE = 13494.497, were not significant. This suggests that the difference scores in the congruent condition were consistently higher than in the incongruent condition across blocks.

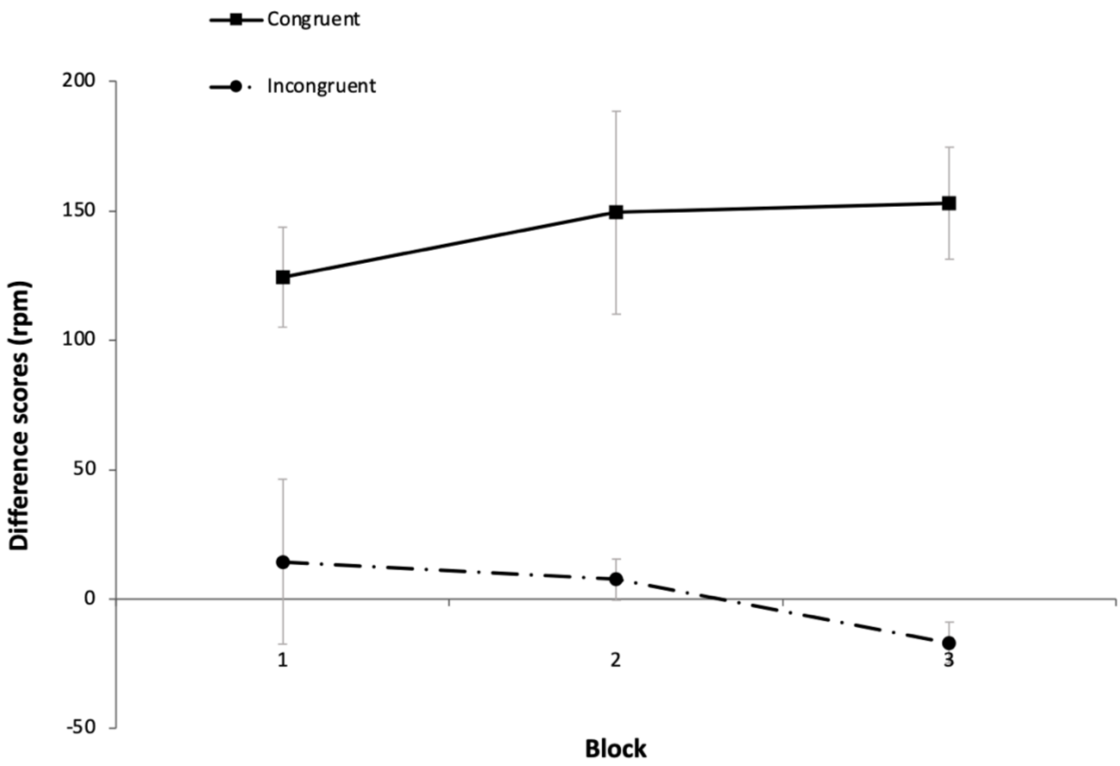

Fig. 4. Mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 1. Error bars represent standard errors.

PreCS response rates (Table 7) were analysed by using a conditions (congruent, incongruent) x blocks repeated measures ANOVA. Neither the main effect of conditions, F (1,23) =1.632, p= .214, MSE = 1609.171, nor the main effect of blocks, F (2,46) =1.547, p= .224, MSE = 1194.633, or the interaction F (2,46) =2.760, p= .074, MSE = 730.774, were significant. This suggests before the stimuli were presented, the response rates in the congruent and the incongruent conditions were not different.

Table 7

conditions	block1	block2	block3
Congruent	6.25(3.82)	9.38(6.87)	16.25(8.70)
Incongruent	28.75(13.96)	6.25(3.24)	22.5(10.22)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 1. Standard deviations are shown in brackets.

General Effect

The difference scores in the S3 and S4 conditions are presented in Figure 5. The figure implies that difference scores in the S3 condition were greater than in the S4 condition. This suggestion was supported by results from a conditions (S3, S4) x blocks within-subjects ANOVA: the main effect of conditions was significant, F (1,23) =5.289, p= .031, MSE = 3256.997, η_P^2 = .187; however, the main effects of blocks, F (2,46) = .109, p= .897, MSE = 2412.976, and the interaction between conditions and blocks, F (2,46) = 1.277, p= .289, MSE = 1589.470, were not. These results suggest that the difference scores in the S3 condition were consistently larger than in the S4 condition over blocks. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (23) = .485, p = .632.

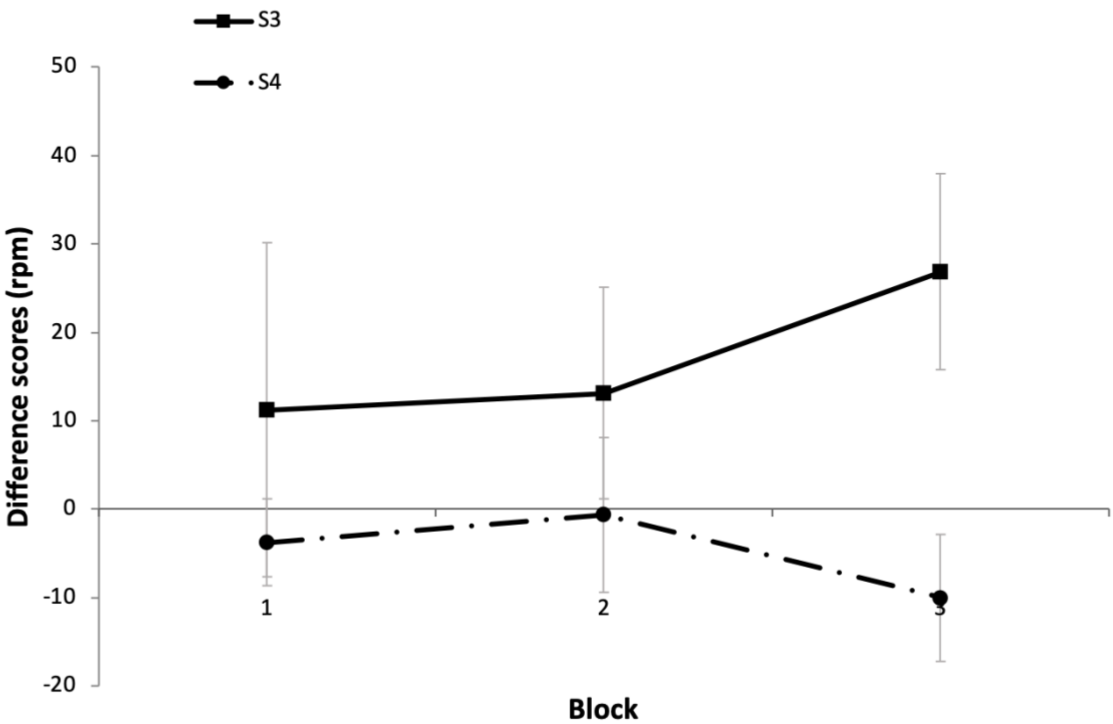

Fig. 5. Mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 1. Error bars represent standard errors.

PreCS response rates (Table 8) were analysed by using a conditions (S3, S4) x blocks within-subjects ANOVA. Neither the main effect of conditions, F (1,23) =.793, p= .382, MSE = 868.410, or the main effect of blocks, F (2,46) = .208, p= .813, MSE = 998.573, nor the interaction between conditions and blocks, F (2,46) =1.242, p= .298, MSE = 77.649, were significant. This suggests before the stimuli were presented, there were no differences between the response rates for S3 and S4 over blocks. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (23) = -1.827, p = .081.

Table 8

conditions	block1	block2	block3
S3	27.5(11.01)	16.25(8.61)	15.00(9.07)
S4	11.88(5.99)	15.00(8.02)	18.75(9.78)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 1. Standard deviations are shown in brackets.

Discussion

The aim of this experiment was to develop an effective avoidance-based PIT task to study both specific and general effects. From the results above, it can be seen that both specific and general effects can be observed in the current PIT task. The difference scores (CS-preCS) in the congruent condition were higher than in the incongruent condition. This phenomenon is in line with the former research that the specific effect can be observed in humans in avoidance-based PIT tasks (Nadler et al., 2011; Lewis et al., 2013). Also, the difference scores (CS-preCS) in the S3 condition were higher than in the S4 condition in the transfer test. This result is consistent with the previous study and indicated that outcomes with aversive emotional characteristics, such as ‘panic’ or ‘danger’, are able to motivate participants (Nadler et al., 2011). The response rates showed no difference in the preCS stage between the congruent and incongruent conditions or between S3 and S4 conditions. In this experiment, both of the PIT effects presented stability throughout the transfer test.

Compared to the previous study (Nadler et al., 2011), the current study put more effort into distinguishing sensory features among outcomes. The bats, arrows, and rocks look different from the pictures and give different feelings when being attacked by them: people are bitten by bats, stabbed by arrows (sharp instrument injury), and crushed by rocks (blunt instrument injury). Therefore, in this study, the boundaries between general and specific effects should be clear. A limitation of this study was that the outcomes in the instrumental stage were not counterbalanced. Pictures of bats and arrows were always O1 and O2 which were paired with R1 and R1. This issue was addressed in later experiments (Experiments 3-7).

2.2 An Appetitive PIT Task

An appetitive type of PIT task was conducted to be able to repeat previous research (Hinojosa-Aguayo & González, 2020) in exploring the relationship between impulsivity and PIT in Experiments 8-10. In previous research, two appetitive PIT tasks which used the standard design (R1-O1, R2-O2 in the instrumental conditioning; S1-O1, S2-O2, S3-O3, S4-nothing in the Pavlovian conditioning) and demonstrated specific and general effects in humans were reported by Quail et al. (2017) and Watson et al. (2014). However, results from studies showed that it was not easy to observe reliable general PIT effects in humans.

The PIT task conducted by Quail et al. has been described in section 1.9.2. Their results showed that presenting S1 and S2 increased responses to the stimuli that were paired with the same outcomes but not the different outcomes. Also, presenting S3 increased responses more than presenting S4. These results indicated that specific and general effects have been observed. However, Hinojosa-Aguayo and González (2020) employed Quail's PIT task and did not perceive a clear general effect as the number of responses to S3 did not surpass the baseline.

The PIT task conducted by Watson et al. (2014) has been described in section 1.7. Although the researchers added a devaluation procedure before the transfer test, they reported that both specific and general effects were observed without being influenced by the devaluation. The data they used to measure the effects was the percentage of pressing on R1/(R1+R2). During the period with no cue presented, the number was 50%, which indicated an equal number of responses to R1 and R2. The participants responded more to S3 than S4, but the difference was numerically small — a mean of 9.7 (*SD*=3.5) key presses to S3; a mean of 9.4 (*SD*=3.6) key presses to S4. As the researchers mentioned, this may be because of the devaluation procedure added, but it is still uncertain if the size of the general effect can be larger without devaluation added.

To be able to observe reliable specific and general effects in humans in an appetitive PIT task, a novel appetitive PIT task was conducted in the current experiment. The appetitive PIT task was transferred from the avoidance-based type of PIT in the last experiment.

Experiment 2

Introduction

Experiment 2 aimed to conduct a novel appetitive PIT task, a version that shares the same cover story as the avoidance PIT task in the last experiment. This idea was inspired by the thought process that Nadler et al. (2011) described in their paper. Nadler et al. (2011) argued that their success in observing general effects in avoidance-based but not appetitive PIT tasks may be because aversive outcomes have stronger emotional features than rewards, which enhanced motivation. However, the outcome pictures were not the only part they changed that may influence motivation between the appetitive and avoidance-based tasks. Their cover story of appetitive PIT was to ask participants to finish this computer game to get coupons for a bookstore or cafe, however, in the avoidance-based one, participants were asked to play a leadership role in an army to protect their country from enemy attack. The protecting country story might present a stronger emotional feature than getting coupons. Therefore, the appetitive PIT in the current experiment kept the same cover story as the avoidance-based PIT task that I conducted.

The outcome pictures in the current PIT task changed from hazards in caves to the tools that can protect people in caves. It was expected that the tools — rewards in a dangerous situation — have strong emotional features to evoke general effects and distinguishable perceptual features to evoke specific effects. Changing avoidance-type training to positive reinforcement training, participants needed to press keys indicating using the tools instead of destroying hazards.

Method

Design

Same as Experiment 1, this experiment used a standard PIT task design with a post-test assessment to check the knowledge of the Pavlovian stage. There were some differences between this appetitive PIT task and the last avoidance-based PIT task. In the instrumental stage of the avoidance-based PIT task, participants gave responses to avoid aversive outcomes. However, in the appetitive PIT task, participants were instructed to get tools instead of destroying danger. The reinforcement outcomes were appetitive (the tools can help them survive); participants gave responses to get the outcomes. Also, in the Pavlovian stage, instead of aversive outcomes (pictures of danger) in the avoidance-based PIT task, participants saw appetitive outcomes (pictures of tools) paired with stimuli in the appetitive PIT task.

Participant

The participants' recruitment process was the same as in Experiment 1. In total, 24 participants completed this study. There were 11 males and 13 females. Subjects' ages ranged from 22 to 43 years old (*Mean* = 28.29, *SD* = 5.16).

Materials

The materials used in this task were identical to Experiment 1, except for the outcomes (Figure 6).

Fig. 6. Outcomes Used in the Appetitive PIT Task

Procedure

Identical to Experiment 1 except that the participants were told that pressing keys means they were using the tools:

Instrumental Training

'As you enter the first cave you are going to be attacked, and you must defend yourself by pressing the keys on the main keyboard (z or m). For example, pressing one of these keys means you are using a torch, whereas the other key is a way to use a shield. Because it is dark you do not know which button indicates which kind of defences. Sometimes the defences will be successful, but often they will not. Now you must try and survive by using your defences. The sooner you discover the function of the keys the safer you will be.'

After participants pressed the keys, they saw outcome pictures presented for one second in the centre of the screen.

Results

Data Treatment

The data treatment procedure was the same as that employed for Experiment 1.

Specific Effect

The difference scores in the congruent and incongruent conditions are presented in Figure 7. The figure suggests the difference scores in the congruent condition were greater than in the incongruent condition. This impression was supported by results of a conditions (congruent, incongruent) x blocks within-subjects ANOVA, which showed a significant main effect of conditions, F (1,23) = 16.664, $p < .001$, MSE = 190398.302, $\eta_P^2 = .420$. The main effect of blocks was not significant ($F<1$). The interaction between conditions and blocks was significant, F (2,46) = 3.578, $p = .036$, MSE = 26565.693, $\eta_P^2 = .135$, and simple main effects analysis revealed that the congruent and incongruent conditions showed differences in all the blocks (largest $p = .019$). This suggests that the difference scores in the congruent condition were consistently higher than in the incongruent condition across all first three blocks. Numbers on different blocks fluctuated in the incongruent condition.

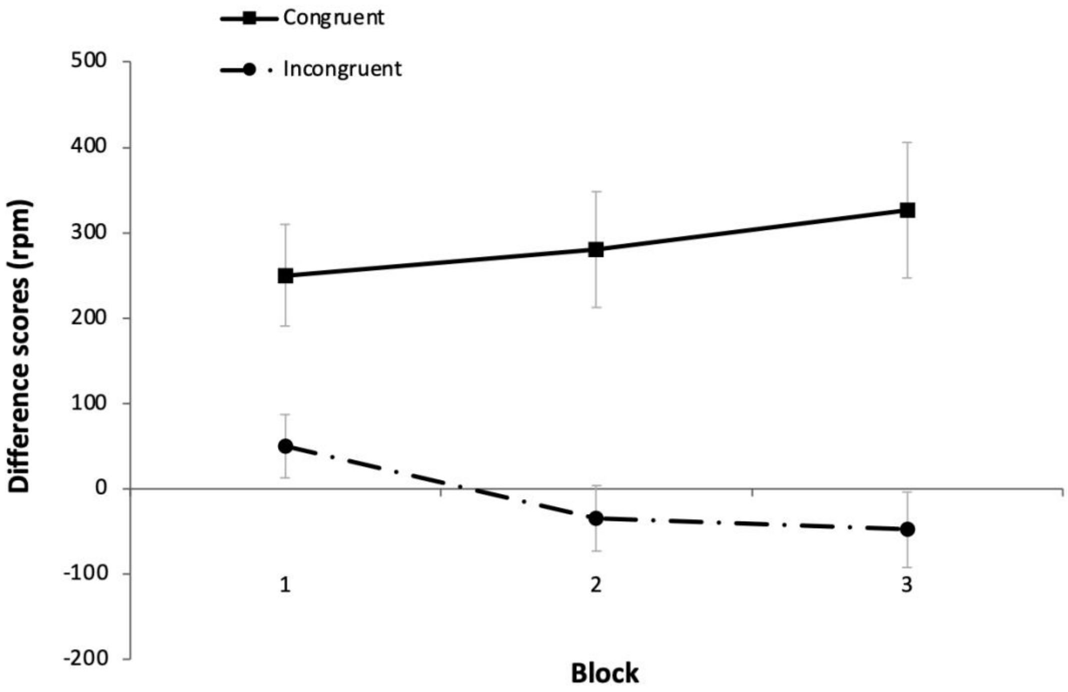

Fig. 7. Mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 2. Error bars represent standard errors.

PreCS response rates (Table 9) were analysed by using a conditions (congruent, incongruent) x blocks repeated measures ANOVA. Neither the main effects of conditions, F (1,23) = .218, p= .645, MSE = 130.343, blocks, F (2,46) = .803, p= .454, MSE = 68.612, or the interaction, F (2,46) =1.983, p= .149, MSE = 81.407, were significant. This suggests before the stimuli were presented, there were no differences between the response rates in congruent and incongruent conditions over blocks.

Table 9

conditions	block1	block2	block3
Congruent	76.25(41.49)	58.13(26.25)	55.00(19.75)
Incongruent	26.25(11.85)	98.75(39.63)	104.38(42.43)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 2. Standard deviations are shown in brackets.

General Effect

The difference scores in the S3 and S4 conditions are presented in Figure 8. The figure shows that difference scores in the S3 condition were greater than in the S4 condition. This idea was supported by results from a conditions (S3, S4) x blocks within ANOVA. The main effect of conditions, F (1,23) = 4.710, p= .041, MSE = 46903.261, η_p^2 = .170, was significant, but not the main effect of blocks, F (2,46) = 2.647, p= .082, MSE = 9370.856, or the interaction between conditions and blocks, F (2,46) = 1.104, p= .340, MSE = 7307.541. These results suggest that the difference scores in condition S3 were significantly higher than in condition S4. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (23) = 1.573, p = .129.

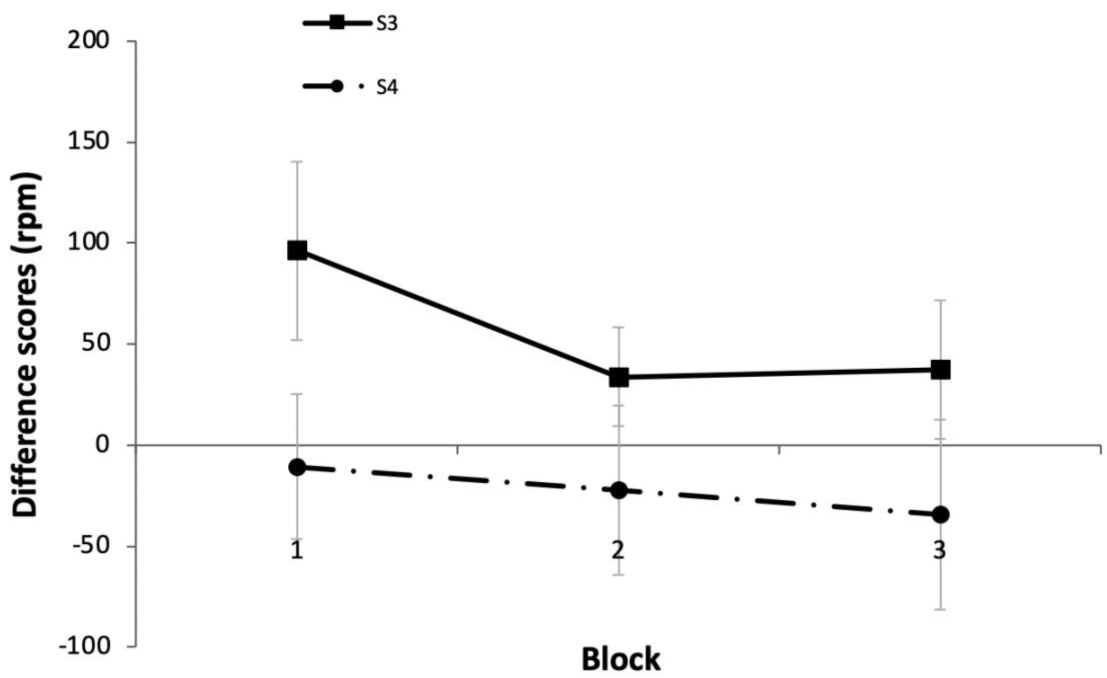

Fig. 8. Mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 2. Error bars represent standard errors.

PreCS response rates (Table 10) were analysed by using a conditions (S3, S4) x blocks within-subject ANOVA. The results showed that neither the main effect of conditions, *F* (1,23) = 2.401, *p*=.135, *MSE* = 189.589, blocks *F* (2,46) = 1.643, *p*= .205, *MSE* = 25.376, nor the interaction between conditions and blocks (*F*<1) were significant. This suggests before the stimuli were presented, there were no differences between the response rates for S3 and S4 on any block. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, *t* (23) = -1.473, *p* = .154.

Table 10

conditions	block1	block2	block3
S3	34.38(13.35)	52.50(21.95)	61.25(23.16)
S4	85.63(40.84)	112.50(44.34)	110.00(43.01)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 2. Standard deviations are shown in brackets.

Discussion

The aim of this experiment was to conduct an appetitive PIT task with both specific and general effects. The results above clearly showed robust specific and general effects. The difference scores (CS-preCS) in the congruent condition were higher than in the incongruent condition, in the S3 condition were higher than in the S4 condition in the transfer test. This phenomenon is in line with the former research that the specific and general effects can be observed in appetitive PIT tasks in humans (Quail et al., 2017). Neither of the effects appeared in the preCS stage — the response rates showed no difference in the preCS stage between the congruent and incongruent conditions or between S3 and S4 conditions. This indicated the cues changed participants' instrumental responses. Both of the PIT effects were stable throughout the transfer test, and this phenomenon could still be observed when the number of participants increased to 48 or 96 in later experiments (Experiments 8-10).

To my knowledge, this is the first appetitive PIT task that is based on an avoidance-based PIT task. Compared to the avoidance-based PIT task, the appetitive one used positive reinforcement training in instrumental conditioning and appetitive outcomes in Pavlovian conditioning. With minimal changes between the two types of the PIT task, the successful transfer may dispel Nadler's et al. (2011) doubts about whether using avoidance training instead of positive training resulted in the success of the general PIT effect. Also, in real-world situations, individuals' addictive behaviour may aim to both approach happiness and avoid negative feelings (Lewis et al. 2013). The values of the outcomes in the two PIT tasks are based on the situation introduced by the cover story. The learning procedures used symbolic outcomes in the tasks mirrored Pavlovian conditioning successfully in observing both specific and general PIT effects. With the outcomes, PIT tasks can be used to study the learning procedures in addiction in general.

A limitation of this study was that the outcomes in the instrumental stage were not counterbalanced. Pictures of fire torch and shield were always the O1 and O2 which paired to R1 and R1. This was addressed in later experiments (Experiments 8-10).

General Discussion

The aim of Chapter II was to develop PIT tasks that can study both specific and general PIT effects in humans. The two experiments in this chapter showed that two standard PIT tasks were developed, one was an appetitive PIT, and the other was an avoidance-based PIT. The results of the experiments showed that stable specific and general effects can be observed from the two types of PIT tasks. These two novel PIT tasks are prepared for later experiments in measuring relationships between anxiety/impulsivity and PIT effects.

Chapter III: Stress/Anxiety and Avoidance-based PIT (Experiments 3-7)

This chapter aimed to explore the impact of anxiety/stress on human performance in PIT. Former research reported inconsistent results in exploring how stress or anxiety can influence PIT. For example, Quail et al. (2017) used a standard PIT task and reported higher levels of anxiety and stress decreased the general PIT effect but not the specific effect. Vogel et al. (2018) did not find stress can influence the specific PIT effect. Pool et al. (2015) reported that participants who experienced stress mood induction of the cold pressure task showed a larger size of PIT effect than in the stress-free group. However, it is difficult to say whether the PIT effect was specific or general in the single-lever PIT task. Steins-Loeber et al. (2020) failed to repeat the results that stress enlarges PIT effects when changing the Pool's PIT task to a specific PIT task. This may indicate that the enhanced PIT effect by stress in Pool's study was a more general effect than specific. Another study (Pritchard et al., 2018) reported that stress mood induction (evaluating aversive images) did not influence specific PIT significantly. These results were different may be because different PIT tasks (standard, specific and single lever PIT tasks) were applied. However, specific and general effects can be affected differently. Therefore, a standard PIT task, which can study both specific and general effects, was applied in this chapter. Anxiety/stress levels were measured by scales or induced by mood induction.

3.1 Anxiety Scales and PIT

Experiment 3

Introduction

This experiment explored the correlation between PIT effects and stress/anxiety levels. Anxious feelings can enhance attention to, memory and expectancy of aversive outcomes, hence evoking avoidance behaviour (Ellenbogen & Schwartzman, 2009; Terburg, Aarts & van Honk, 2012; Ly & Roelofs, 2009). Participants responded to a CS paired with the same outcome as the R based on the fact that the outcomes share sensory properties. However, participants respond to a CS that is paired with a different (in sensory) outcome as the R because the outcome shares the same motivational value as the outcome the R is paired with.

In measuring a specific PIT effect, researchers usually used the response rates to the same outcomes as the CSs paired (congruent condition) minus the response rates to the different outcomes as the CSs paired (incongruent condition). Thus, specific effects depend on both sensory and motivational values of the outcomes and are measured as difference scores in congruent and incongruent conditions. The motivational values of the outcomes in the congruent and incongruent conditions were equivalent and should be influenced at similar levels by stress. In the general effect, S3 is paired with a novel outcome that shares the same motivational values as the outcomes that responses are paired with, and S4 is paired with a non-reinforced outcome with no motivational value. Therefore, if participants' motivation is enhanced, the general effect should be stronger as participants respond more to S3 but not S4. I predict that enhanced stress levels will not affect specific PIT effects but can strengthen general PIT effects.

Method

Design

The design of the PIT task was the same as the task in Experiment 1. To improve the avoidance-PIT task in Chapter II, in this task, I counterbalanced the instrumental stage and there were 48 conditions in total (see Appendix). Three scales were used. They were Anxiety and stress subscales in Depression Anxiety Stress Scales (DASS; Lovibond, & Lovibond, 1995), State Anxiety Scale in State subscale in State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), the Generalised Anxiety Disorder Assessment (GAD-7; Spitzer et al., 2006). This study was conducted online, and participants did it by using their own devices.

Participant

In total, 70 adults completed this study. Data from 22 participants were excluded since they failed the post-test check, the remaining 48 subjects provided valid data for this study. Among them, there were 23 males and 23 females. Two participants did not report their sex. The subjects' mean age was 27.13 (*SD* = 5.05, ranging from 18 to 39 years old). One participant's age was unknown.

Material

PIT task

To improve on the task from Experiment 1, in this task, the instrumental stage was counterbalanced. In the instrumental stage in Experiment 1, R1 was always paired with bats and R2 was always paired with arrows. However, in this experiment, R1 paired with one out of three reinforcement outcomes, and R2 paired with one out of the remaining two reinforcement outcomes. Combined with the counterbalancing in Pavlovian conditioning, this task had 48 counterbalancing conditions in total (see Appendix).

Personality scales

To measure stress or anxiety levels, after completing the PIT task, participants answered the scales below:

Anxiety and stress subscales in Depression Anxiety Stress Scales (DASS)

The DASS (Lovibond, & Lovibond, 1995) is a self-report questionnaire to measure individuals' emotional states of depression, anxiety, and stress over the past week. There were 42 questions in total and 14 questions for each subscale. In this experiment, only DASS-Anxiety and DASS-Stress subscales were used. The DASS-A evaluates the severity level of nervousness's physical symptoms, feelings, and subjective experiences. The DASS-S assesses a few aspects of continuing general arousal, such as feeling upset easily, becoming over-reactive, and lacking patience. A 4-point (score 0 to 3) rating scale was used to indicate the extent to which the participants agree with the statements. Higher scores correlate with stronger negative emotions.

State subscale in State-Trait Anxiety Inventory (STAI)

State Anxiety Scale (S-Anxiety) in STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) was used to measure how participants felt at the moment. The 20 questions include statements about feeling tension, nervousness, worry, and physical symptoms. The total score range is 20 to 80, rated on a 4-point scale (score 1 to 4). Higher scores indicate greater anxiety.

Generalised Anxiety Disorder Assessment (GAD-7)

The Generalised Anxiety Disorder Assessment (GAD-7; Spitzer et al., 2006) is a self-report questionnaire to evaluate the severity of generalised anxiety disorder. There are seven statements in total, and each statement described a state of feeling in the past two weeks. For example, one statement is 'Feeling nervous, anxious, or on edge.' The response categories of "not at all," "several days," "more than half the days," and "nearly every day," with responding scores of 0, 1, 2, and 3, correspondingly. The score ranges from 0 to 21—higher scores correlating with more severe generalised anxiety symptoms.

The scales were answered in the order of STAI, DASS, and GAD-7.

Results

PIT

Data Treatment

The data treatment procedure was the same as that employed for Experiment 1.

Specific Effect

The difference scores in the congruent and incongruent conditions are presented in Figure 9. The figure suggests that participants had greater difference scores in the congruent condition than in the incongruent condition. This impression was supported by results of a conditions (congruent, incongruent) x blocks within ANOVA, which showed a significant difference in the main effect of conditions, F (1,47) =41.242, $p< .001$, MSE = 7118.201, η_P^2 = .467. The main effect of blocks, F (2,94) = .521, p= .596, MSE = 763.477, and the interaction between conditions and blocks, F (2,94) = 1.466, p= .236, MSE = 1371.439, were not significant. This suggests that the difference scores in the congruent condition were consistently higher than in the incongruent condition across the first three blocks.

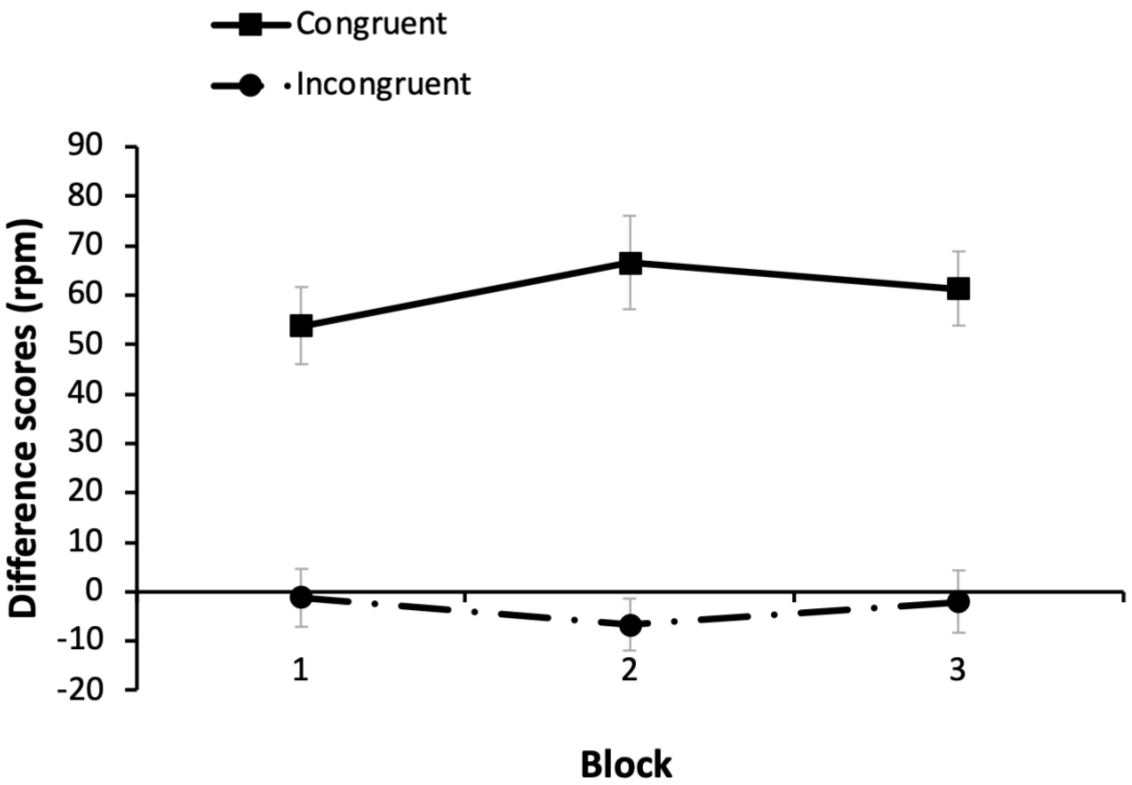

Fig. 9. Mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 3. Error bars represent standard errors.

The mean response rates in the congruent and incongruent conditions during the preCS periods are shown in Table 11. Response rates in the preCS stage were analysed by using a conditions (congruent, incongruent) x blocks within ANOVA. The main effects of conditions, F (1,47) = 3.300, p= .076, MSE = 568.467, and blocks (F<1) were not significant. Neither was the interaction between conditions and blocks, F<1. This suggests before the stimuli were presented, there were no differences between the response rates in congruent and incongruent conditions over the first three blocks.

Table 11

conditions	block1	block2	block3
Congruent	13.75(3.76)	11.25(4.04)	12.66(4.74)
Incongruent	15.78(4.91)	22.34(5.96)	14.84(5.10)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 3. Standard deviations are shown in brackets.

General Effect

The difference scores per minute in the S3 and S4 conditions are presented in Figure 10. The figure shows that participants had greater difference scores in the S3 condition than in the S4 condition. The difference scores were analysed by a conditions (S3, S4) x blocks within ANOVA. The main effect of conditions, F (1,47) =24.180, p< .001, MSE = 917.350, η_p^2 = .340, was significant. The main effect of blocks and the interaction between conditions and blocks were not significant, Fs< 1. This suggests that the difference scores in the S3 condition were consistently higher than in the S4 condition across the first three blocks. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (47) = - .574, p = .569.

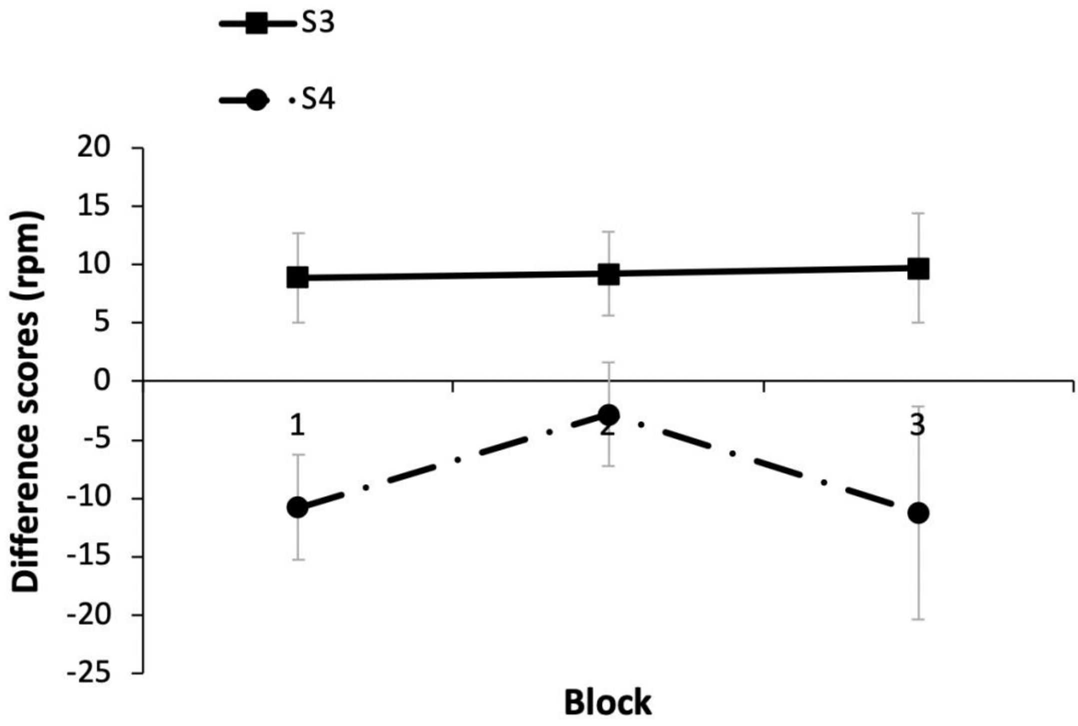

Fig. 10. Mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 3. Error bars represent standard errors.

The mean response rates in the S3 and S4 conditions during the preCS periods are shown in Table 12. The preCS response rate was analysed by using a conditions (S3, S4) x blocks within ANOVA. Neither the main effect of conditions, or the main effect of blocks, nor the interaction between conditions and blocks was significant, $Fs<1$. This suggests before the stimuli were presented, there were no differences between the response rates for S3 and S4 conditions. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (47) = .295, p = .769.

Table 12

conditions	block1	block2	block3
S3	11.88(3.36)	13.75(4.19)	18.13(4.29)
S4	15.63(4.92)	12.66(3.98)	21.09(10.42)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 3. Standard deviations are shown in brackets.

PIT Effects and Personality

Scores that were derived as a measure of the specific effect were equal to the average response rates in the congruent condition minus the average response rates in the incongruent condition. Scores that were derived as a measure of the specific effect were equal to the average response rates in the S3 condition minus the average response rates in the S4 condition. Since the sample size was small (n = 48), a Shapiro-Wilk test for multivariate normality was used in choosing an appropriate statistical method. The results showed that the distribution departed significantly from normality (W = .802, p < .001). Based on this outcome, Kendall's tau-b correlation was used, and the median with the interquartile range was used to summarize the anxiety scales: S-STAI (*Median* = 35.50, *IQR* = 12.50), the sum of anxiety and stress subscales in DASS (*Median* = 12.00, *IQR* = 19.25), GAD-7 (*Median* = 10.00, *IQR* = 7.25). Kendall's tau-b correlations among specific effect, general effect, and scores from three scales were conducted (Table 13). There was a significant positive correlation between the score in GAD-7 and the general effect, τ_b = .275, p = .009. Other correlations between an effect and a score from a scale were not significant. Correlations among scales were all significant.

Table 13

Correlations among effects and scores from anxiety scales

Variable	Specific effect	General effect	STAI	a/s-DASS	GAD-7
1. Specific effect	—				
2. General effect	0.137	—			
3. STAI	-0.034	0.076	—		
4. a/s-DASS	0.129	0.174	0.425 ***	—	
5. GAD-7	0.161	0.275 **	0.367 ***	0.756 ***	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Discussion

This study aimed to explore the correlation between anxiety levels and PIT effects in an avoidance-based PIT task. The results indicated that the size of the general effect, but not the specific effect, was positively correlated with anxiety levels in GAD-7. In this experiment, both specific and general effects were observed. This result is in line with the previous research that humans show significant effects on both response selection (specific) and reaction motivation (general) in avoidance-based PIT tasks (Nadler et al., 2011; Lewis et al., 2013). Results from this study also replicated the findings of the previous experiment (Experiment 1). With counterbalancing of both outcomes in the instrumental stage, and the responses across the two outcomes, this avoidance-based PIT task is more reliable.

In addition, the current experiment used three different scales to measure subjects' anxiety or stress levels both at the moment and at a longer time (in the past one week or two weeks). The positive correlation between the general effect and self-report anxiety level in GAD-7 showed in this experiment was different to the results reported by Quail et al. (2017). Specifically, high anxiety state participants showed abnormal motivation to respond to S4 in Quail's research, however, subjects in the high anxiety group showed vigour to respond to S3 in this experiment. It seems the different results we got were not due to the dissimilar anxiety or stress levels of our subjects. Both of us used subscales of anxiety and stress in DASS. Participants' anxiety and stress level in their study (anxiety: *Mean*=6.667, *SD*=5.231; stress: *Mean*=10.583, *SD*=6.990) was very close to the current results (anxiety: *Mean* = 5.583, *SD* = 4.915; stress: *Mean* = 11.375, *SD* = 9.240). Quail and colleagues explained their results by arguing that high anxiety and stress lead to abnormal cue-driven behaviour in humans. However, the number of 17 participants was arguably rather small, raising the possibility that the result may be underpowered to generate reliable and generalisable results. Since the correlation in the current experiment appeared to be weak (τ_b = .275), the next experiment was conducted to see if the results were repeatable with another analysis applied, and reliable with depression scales included.

Experiment 4

Introduction

This experiment repeated Experiment 3 by using scales about both anxiety and depression. To be able to compare results with the last experiment and Quail's study, the same scales were used. The Generalised Anxiety Disorder Assessment (GAD-7; Spitzer et al., 2006) was kept, full short-version of Depression Anxiety Stress Scales (DASS; Lovibond, & Lovibond, 1995) was applied, while STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) was deleted. Also, Patient Health Questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001) in measuring depression was added to test the reliability of the correlation between anxiety and PIT.

Method

Design

The design of the PIT task was the same as in Experiment 3. The scales changed to GAD-7, a full short version of DASS and PHQ-9.

Participant

The data collection procedure was the same as in previous experiments. 58 adults finished this study. Data from 10 participants were excluded since they failed the training in the Pavlovian stage. In total, 48 subjects provided valid data for this study. Among them, there were 29 males, 18 females and one unknown. The subjects' mean age was 27.13 (*SD* = 5.05, range 21-51).

Material

PIT task

Same as the one used in Experiment 3. The scales were answered in the order of DASS, GAD-7, and PHQ-9.

Personality scales

Depression Anxiety Stress Scales (DASS), short version

This experiment used DASS-21, which is a short version of DASS with 42 items (Lovibond, & Lovibond, 1995). This scale includes 21 questions in total — seven questions for each subscale. In this experiment, all the subscales were kept. The depression subscale assesses individuals' subjective feelings of hopelessness, devaluing life, lack of interest, and other symptoms related to depression. An example question is that 'I felt that life was meaningless.' A 4-point (score 0 to 3) rating scale was used to indicate the extent to which the participants agree with the statements. Higher scores correlate with stronger negative emotions.

Patient Health Questionnaire (PHQ-9)

PHQ-9 (Kroenke, Spitzer, & Williams 2001) is used to measure the severity of depression. It has 9 questions asking about individuals' symptoms in the last two weeks. An example question is 'Little interest or pleasure in doing things?'. For each question, the answers can be scored from '0' (not at all) to '3' (nearly every day). The score range is from 0 to 27. Higher scores indicate more serious illness.

Results

PIT

Data Treatment

The data treatment procedure was the same as that employed for Experiment 1.

Specific Effect

The difference scores in the congruent and incongruent conditions are presented in Figure 11. The figure suggests that participants had greater difference scores in the congruent condition than in the incongruent condition. This impression was supported by results of a conditions (congruent, incongruent) x blocks within ANOVA, which showed a significant difference in the main effect of conditions, F (1,47) =23.060, p< .001, MSE = 245.546, η_P^2 = .329. The main effect of blocks, F (2,94) = 1.430, p= .245, MSE = 26.979, was not significant. Neither was the interaction between conditions and blocks, F<1. This suggests that the difference scores in the congruent condition were consistently higher than in the incongruent condition across all first three blocks.

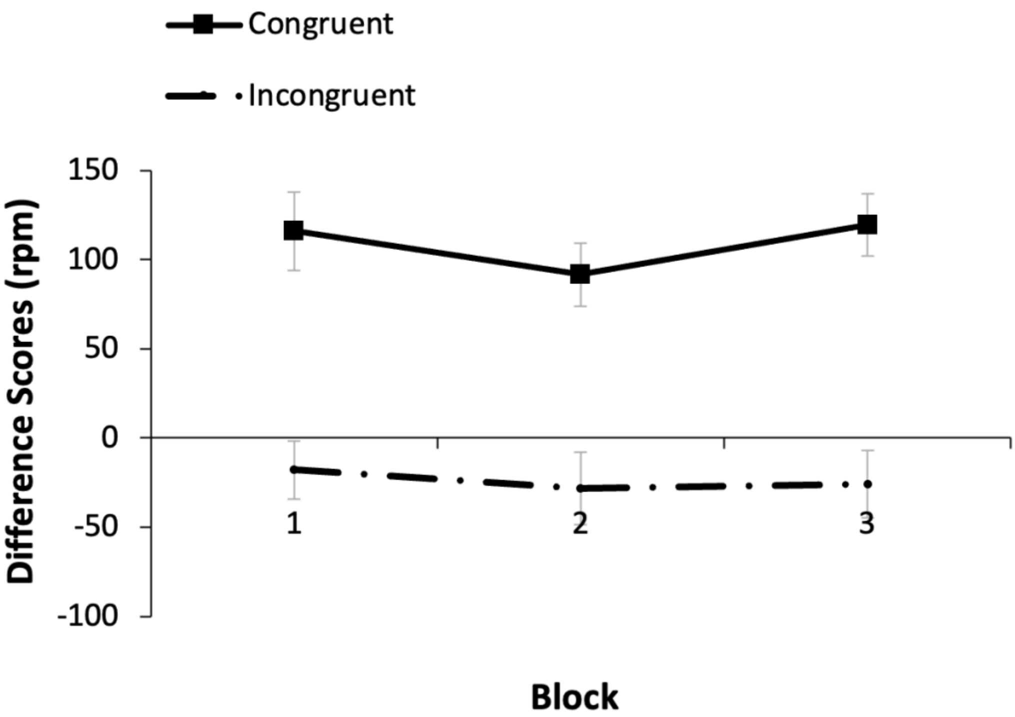

Fig. 11. Mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 4. Error bars represent standard errors.

The mean response rates in the congruent and incongruent conditions during the preCS periods are shown in Table 14. Response rates in the preCS stage were analysed by using a conditions (congruent, incongruent) x blocks repeated measures ANOVA. The main effects of conditions, F (1,47) = 3.960, p= .052, MSE = 133.705, and blocks, F <1, were not significant. Neither was the interaction between conditions and blocks, F <1. This suggests before the stimuli were presented, there were no differences between the response rates in congruent and incongruent conditions over blocks.

Table 14

conditions	block1	block2	block3
Congruent	8.91(4.27)	13.13(6.78)	5.47(2.87)
Incongruent	42.19(16.41)	54.53(25.38)	52.81(24.35)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 4. Standard deviations are shown in brackets.

General Effect

The difference scores per minute in the S3 and S4 conditions are presented in Figure 12. The figure shows that participants had greater difference scores in the S3 condition than in the S4 condition. The difference scores were analysed by a conditions (S3, S4) x blocks within ANOVA. The main effect of conditions, F (1,47) =13.624, p< .001, MSE = 27.497, η_P^2 = .225, was significant. The main effect of blocks was not significant, F<1. Neither was the interaction between conditions and blocks, F (2,94) =1.584, p=.211, MSE = 8.605. This suggests that the difference scores in the S3 condition were consistently higher than in the S4 condition across blocks. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (47) = - .026, p = .979.

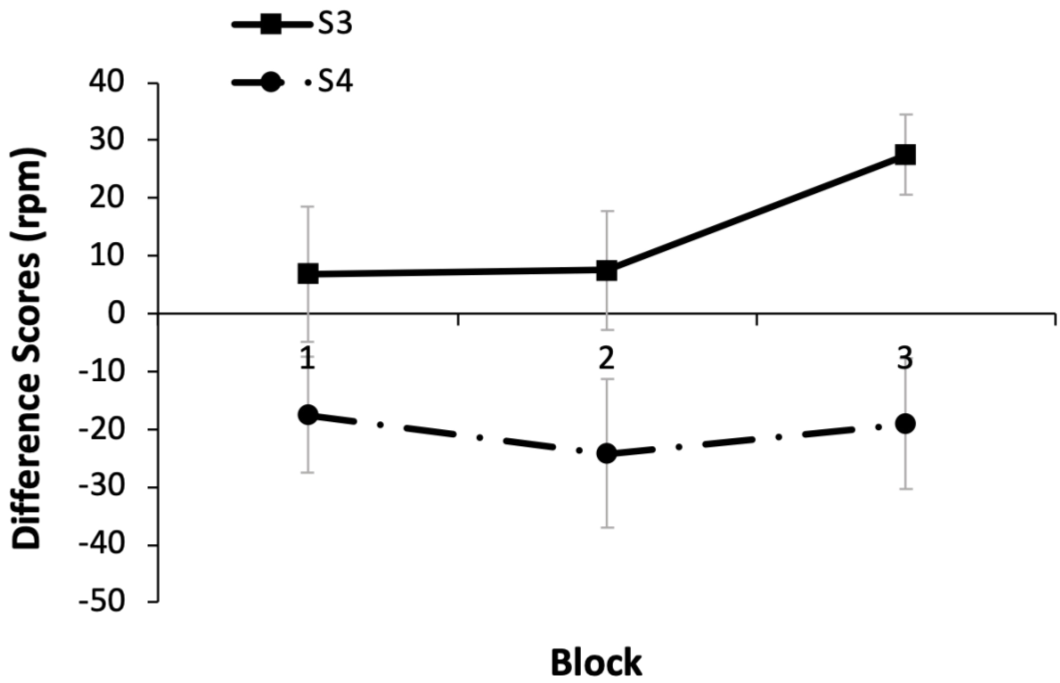

Fig. 12. Mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 4. Error bars represent standard errors.

The mean response rates in the S3 and S4 conditions during the preCS periods are shown in Table 15. The preCS response rate was analysed by using a conditions (S3, S4) x blocks within ANOVA. The main effect of conditions, F (1,47) = 5.256, p= .026, MSE = 15.364, η_P^2 = .101 was significant. Neither the main effect of blocks nor the interaction between conditions and blocks, Fs <1, was significant. This suggests before the stimuli were presented, the response rate for S4 was higher than S3. This may enlarge the general effect observed by analysing difference scores. Therefore, the response rate in CS presenting period was analysed to check if there was a general effect. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (47) = .678, p = .501.

Table 15

conditions	block1	block2	block3
S3	30.31(15.13)	35.16(15.11)	15.78(10.62)
S4	39.84(16.09)	46.41(17.50)	42.66(16.98)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 4. Standard deviations are shown in brackets.

The mean response rates in the S3 and S4 conditions during the CS periods are shown in Table 16. By conducting a conditions (S3, S4) x blocks within ANOVA, it can be seen the main effect of conditions, F (1,47) = 8.185, p= .006, MSE = 13.141, η_P^2 = .148 was significant. Neither the main effect of blocks nor the interaction between conditions and blocks, Fs <1, were significant. This suggests that the response rates in the S3 condition were consistently higher than in the S4 condition across blocks. The significant main effect of conditions that appeared in difference scores indicated the general effect that appeared in the CS stage was strong enough to overcome the high response to S4 in the preCS stage. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (47) = .881, p = .383.

Table 16

conditions	block1	block2	block3
S3	37.19(9.51)	42.66(11.40)	43.28(11.77)
S4	22.34(8.96)	22.19(10.84)	23.59(11.40)

Note. Mean CS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 4. Standard deviations are shown in brackets.

PIT and Personality

Since the sample size was small (n = 48), a Shapiro-Wilk test for multivariate normality was used in choosing an appropriate statistical method. The results showed that the distribution departed significantly from normality (W = 0.694, p < .001). Therefore, the median with the interquartile range was used to summarize the variables: DASS-21 (*Median* = 18.50, *IQR* = 14.50), the sum of anxiety and stress subscales in GAD-7 (*Median* = 15.00, *IQR* = 7.50), PHQ-9 (*Median* = 18.00, *IQR* = 10.00).

A Bayesian correlation was conducted as it is more suitable for complex models than the frequentist test. Correlations among specific effect, general effect, and scores from three scales were presented in Table 17. The default prior option was used (stretched beta prior width was 1). A positive correlation was expected between PIT effects and anxiety levels. However, it can be seen from Table 17 that the BF_{01}s range 3.00-10.00 between a PIT effect and a score of anxiety scale, which showed substantial evidence to support H0, according to Jeffreys (1961). The results indicated that the data of this experiment did not show effects and scores from scales were correlated.

Table 17

Bayesian Correlation

Variable		Specific Effect	General Effect	DASS-21	GAD-7	PHQ-9
1. Specific Effect	BF_{01}	—				
2. General Effect	BF_{01}	4.536	—			
3. DASS-21	BF_{01}	5.332	4.105	—		
4. GAD-7	BF_{01}	5.339	3.985	6.695×10^{-12}	—	
5. PHQ-9	BF_{01}	5.277	3.389	3.780×10^{-8}	7.623×10^{-9}	—

Note: BF_{01}> 3: substantial evidence for H0, BF_{01}> 10: strong evidence for H0, BF_{01}> 30: very strong evidence for H0. BF_{01}<0.33: substantial evidence for H1, BF_{01}< 0.1: strong evidence for H1, BF_{01}<0.03: very strong evidence for H1.

Discussion

This study aimed to explore the correlation between anxiety levels and PIT effects in an avoidance-based PIT task by repeating Experiment 3. In this experiment, to improve the analytical method, a Bayesian correlation, which is suitable for small number sizes, was applied. I expected that anxiety levels positively correlated to general effects based on the results from Experiment 3 — the general effect positively correlated with scores in GAD-7. However, the results above did not show that there was a correlation between anxiety or depression and any PIT effect. This may be because the positive results observed in the last experiment were weak (τ_b = .275), which may not be robust to be repeated. Also, although anxiety and depression are the two most common mental health issues among people, depression may not be a good factor to add. As reported, symptoms of anxiety and depression are difficult to distinguish because of their high incidence of co-occurrence (Clark & Watson, 1991; Watson et al., 1995). Further research can apply scales that measure other aspects of individual differences. In addition, as the participants were from non-clinical populations, the range of anxiety levels was not large. A limited range of anxiety levels may be the reason that the relationship between anxiety and PIT was not observed. With this idea, mood induction procedures were applied in Experiments 5-7 to enlarge the range of anxiety levels.

3.2 Stress Mood Induction Procedure (MIP) and PIT Experiment 5

Introduction

Experiments 3 and 4 used participants from the general population in normal states which may limit the variability of the anxiety level. Therefore, mood induction procedures were applied in Experiments 5-7 to enlarge the difference in anxiety levels among individuals. In the previous research, Pool et al. (2015) reported that human participants in the cold pressure group showed a stronger transfer effect than the no-stress group by using a single lever press PIT task. It is difficult to classify the enhanced PIT effect as a specific or general effect. Steins-Loeber et al. (2020) failed to repeat the results when applying Pool's task as a specific PIT task. Pritchard et al. (2018) used aversive images to enhance stress levels and did not observe a significant impact on specific PIT tasks. The different reported results could be because previous studies which used stress mood induction procedures did not separate or include both specific and general effects in their task design. Therefore, an avoidance-based PIT task with both effects and stress mood induction procedures was applied in the current experiment.

Both watching images and listening to music have been used as mood-induction procedures to influence people's emotional states (Siedlecka & Denson, 2019). Using pictures to influence participants' states, Lang (1979) reported participants had higher heart rates when seeing pictures with fear content compared to seeing pictures with action content, and had more muscle tension when seeing pictures with action content than seeing pictures with fear content. It can be explained as the pictures can increase individuals' arousal levels as stressors, and vice versa, people with high anxiety levels can be more concentrated on negative pictures (Ellenbogen & Schwartzman, 2009). Applying PIT tasks, pictures of dead bodies have been shown to change stress levels effectively in the mood induction procedure (Pritchard et al., 2018). The images in the International Affective Picture System (IAPS) have been used as standardized stimuli that can produce consistent physical and emotional reactions from human participants (Lang et al., 1993). Not only pictures, but music can also evoke emotions effectively (Juslin & Sloboda 2001). For example, listening to exciting music can increase people's heart rate, respiratory rate, and blood pressure (Koelsch, & Jäncke, 2015). College students who are heavy metal/hard rock music listeners reported significantly higher anxiety levels than non-listeners (Shafron & Karno, 2013).

Therefore, in Experiment 5, the mood induction procedure was applied online by asking participants to watch the aversive pictures selected from IAPS and listen to heavy metal music.

Method

Design

Compared with Experiment 3, the design in the current experiment included a mood induction procedure before the transfer test (see Table 19). In the stress condition, participants listened to heavy metal music and watched wounded or dead body pictures. In the neutral condition, participants listened to café background voice and watched pictures of objects. A questionnaire measured participants' feelings at moment immediately after the transfer test. The hypothesis is that the general effect, but not the specific effect, can be enlarged under stress.

Table 19
Design of Experiment 5.

Instrumental training	Pavlovian conditioning	Mood Induction Procedure	PIT Transfer Test (music/voice on)	Questionaries	Post-test assessment
R1-O1	S1-O1	Heavy metal music + wounded body pictures	S1: R1, R2	I feel: bad arousal	S1
R2-O2	S2-O2	OR	S2: R1, R2	sad anxious annoyed	S2
	S3-O3	Café background voice + pictures of objects	S3: R1, R2		S3
	S4-nothing		S4: R1, R2		S4

Note: S: Stimuli, O: Outcomes, R: Responses.

Participant

In total, 58 adults completed this study. Data from 10 participants were excluded since they failed the Pavlovian stage, and data from 48 subjects (24 in the stress group, 24 in the neutral group) were used to analyse. In the stress group, there were 8 males and 16 females, aged from 22 to 37 years old (*Mean* = 26.75, *SD* = 4.21). In the neutral group, there were 9 males, 14 females, and one participant reported 'non-binary'. Participants age range was from 21 to 40 years old (*Mean* = 28.79, *SD* = 5.54).

Material

Mood Induction Procedure

Pictures

In the stress group, unpleasant pictures were images of wounded or dead animals or humans were used (see examples in Figure 13). In the neutral group, pictures of objects were used (see examples in Figure 14). The 12 unpleasant pictures and 12 neutral pictures were selected from Open Affective Standardized Image Set (OASIS; Kurdi, Lozano, & Banaji, 2017). The chosen pictures were — Aversive images: animal carcass 1, 2, 5; dead bodies 1, 2, 3; injury 1, 2, 4; severed finger 1; tumour 1; miserable pose 3. The mean arousal level score of these aversive images reported by OASIS was 4.22 (*SD*=2.02). Neutral images: bottle 1; keyboard 2; office supplies 2; office supplies 4; paintbrush 1; paper 3; phone 3; rocks 4; roofing 4; sidewalk 3; socks1; yarn 4. The mean arousal level score of these neutral images reported by OASIS was 2.12 (*SD*=1.37).

Fig. 13. Examples of pictures in the stress group

Fig.14. Examples of pictures in the neutral group.

Sounds

In the *stress* group, a 98-s clip from a heavy metal instrumental piece called ‘Fire’ was used (copyright-free, Key E minor, Alt Key 9A, BPM 140), which was played repeatedly in a loop. In the *neutral* group, a recording of café background voice was used as a neutral sound. Indistinct sounds of people talking, walking, cups clashing can be heard in the recording.

Questionnaires

A short scale in measuring participants' mood state at the moment should be applied to quickly test the mood induction procedure's effectiveness to minimize its influence on the transfer test. Therefore, a 5-item Visual Analogue Scale (VAS; Delgado et al., 2018) was applied. It is a self-report scale in measuring the intensity and frequency of different symptoms. The scale in this experiment assessed levels of negative moods including feeling bad, anxious, aroused (specified as sweating, increased heart rate, or feeling tense), sad or annoyed. For each statement, participants give ratings from 1 to 5, where a higher score indicates stronger negative feelings.

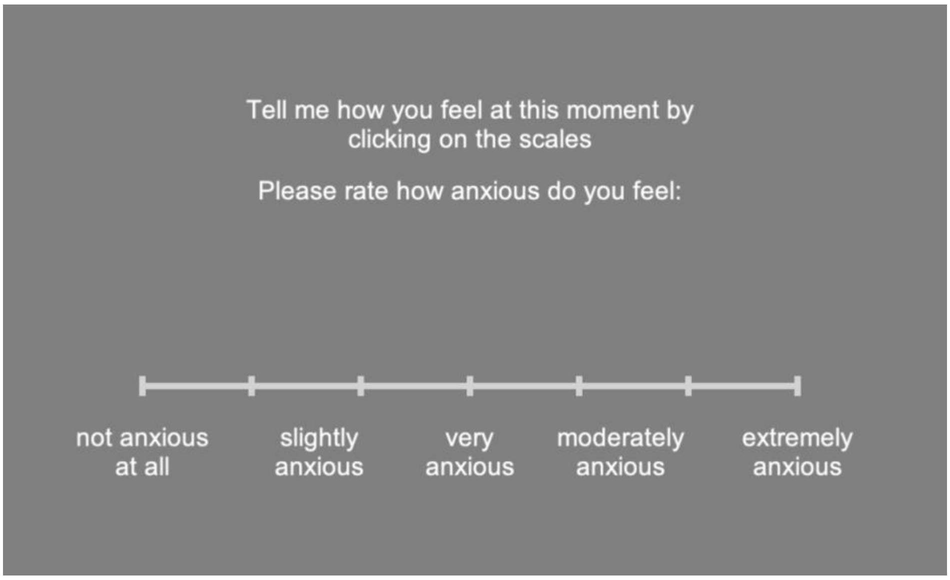

Fig. 15. Example question of the questionnaire.

Procedure

The procedure of the PIT task was identical to the one in Experiment 3. The main difference was that this experiment included a mood induction procedure before and during the transfer test, and the anxiety check scale immediately after the transfer test:

Mood Induction Procedure

In this stage, participants were told that:

'Before enter the final cave:
People who have been here before shared fragments of their memories with you.
There are some pictures in their memory. If some pictures make you feel very uncomfortable, remember that you can withdraw by closing the window.
There is also some sound in their memory. Please turn on the sound.'

To check if participants could hear the sound, they were asked:

'What kind of sound you can hear?
click on the scale'

Participants could choose '*a hubbub of voices*' or '*heavy metal music*'.

In each trial of this procedure, a fixation cross was presented in the centre of the screen for one second, followed by a picture presented in the centre of the screen for three seconds. There were 36 trials in total, the 12 pictures were repeated three times. During the whole procedure, the music/voice was on. The whole procedure lasted 144 seconds.

PIT Transfer Test

Identical to the PIT transfer test in previous experiments. The only difference was that the music/voice was on.

Questionnaires

In this step, participants were told:

'Tell me how you feel at this moment by clicking on the scales'

Then they answered the five questions separately below:

'Please rate how bad do you feel:'

'Please rate how anxious do you feel:'
'Please rate your arousal level (Do you experience sweating, and increase in heart rate, or feel tense)'
'Please rate how sad do you feel:'
'Please rate how annoyed do you feel:'

For each question, the answers had five levels:

'Not bad/anxious/aroused/sad/annoyed at all'
'Slightly bad/anxious/aroused/sad/annoyed'
'Very bad/anxious/aroused/sad/annoyed'
'Moderately bad/anxious/aroused/sad/annoyed'
'Extremely bad/anxious/aroused/sad/annoyed'

This procedure finished when participants answered all five questions by clicking on the scales.

Results

Data Treatment

All of the participants gave correct answers to the sounds they heard (i.e., heavy metal music in the stress group, café background voice in the neutral group). The data treatment procedure was the same as that employed for Experiment 1.

Mood Induction Procedure

The mean scores of self-reported questionnaires are shown in Figure 16. The figure suggests that participants in the stress group gave higher scores for all kinds of negative moods than participants in the neutral group. Five independent t-tests were conducted. The results showed that participants in the stress group reported significantly stronger feelings of bad t (46) = - 2.84, p = .007, arousal, t (46) = - 4.312, p < .001, and sadness, t (46) = - 2.875, p = .006; but not anxiety, t (46) = - 1.994, p = .052, or annoyance, t (46) = - 1.052, p = .298. This suggests that participants in the stress group felt worse than the participants in the neutral group, but this was not specific to anxiety or arousal.

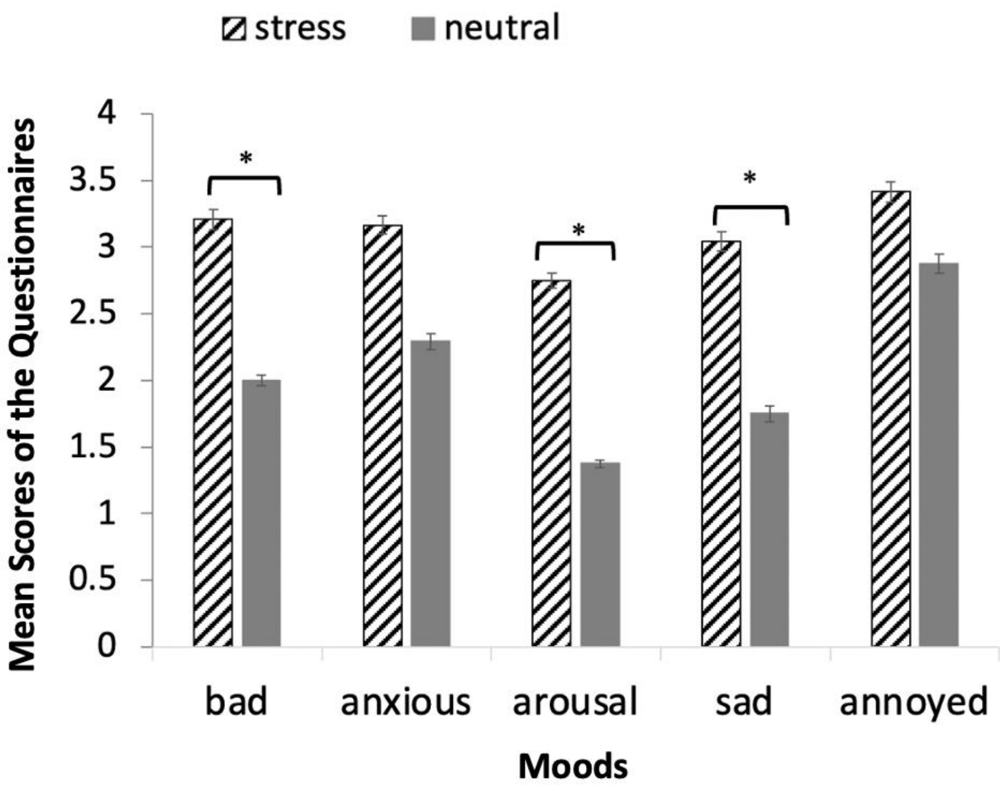

Fig.16. Mean scores of the mood questionnaires in the two groups (stress, neutral) were presented. Error bars presented standard errors.

PIT

Specific Effect

Difference Scores

The difference scores in the congruent and incongruent conditions are presented in Figure 17 and suggest that congruent difference scores were higher than incongruent, and this congruent/incongruent difference appeared slightly larger in the stress group; however, this proved not to be reliable. A condition (congruent, incongruent) x blocks x groups (stress, neutral) mixed ANOVA, showed the main effect of condition, F (1,46) = 24.244, p < .001, *MSE* = 23502.242, η_P^2 = .345 was significant, as was the interaction between blocks and groups, *F* (2,92) = 4.232, *p*= .017, *MSE* = 4080.477, η_P^2 = .084. The interaction between conditions and groups was not significant, *F* (1,46) = 1.915, *p* = .173, *MSE* = 23502.242, BF_{excl} = 1.325. Nothing else was significant (the largest *F* (2,92) = 2.733, *p*= .070, *MSE* = 4080.477, for the main effect of blocks). Post hoc tests (Holm) showed that the score in block 3 in the stress group was higher than in block 1 in the stress group. Nothing else in the post-hoc tests was significant, smallest *p*=.053. This suggests there was a specific PIT effect, and that this was of a similar size in the two groups.

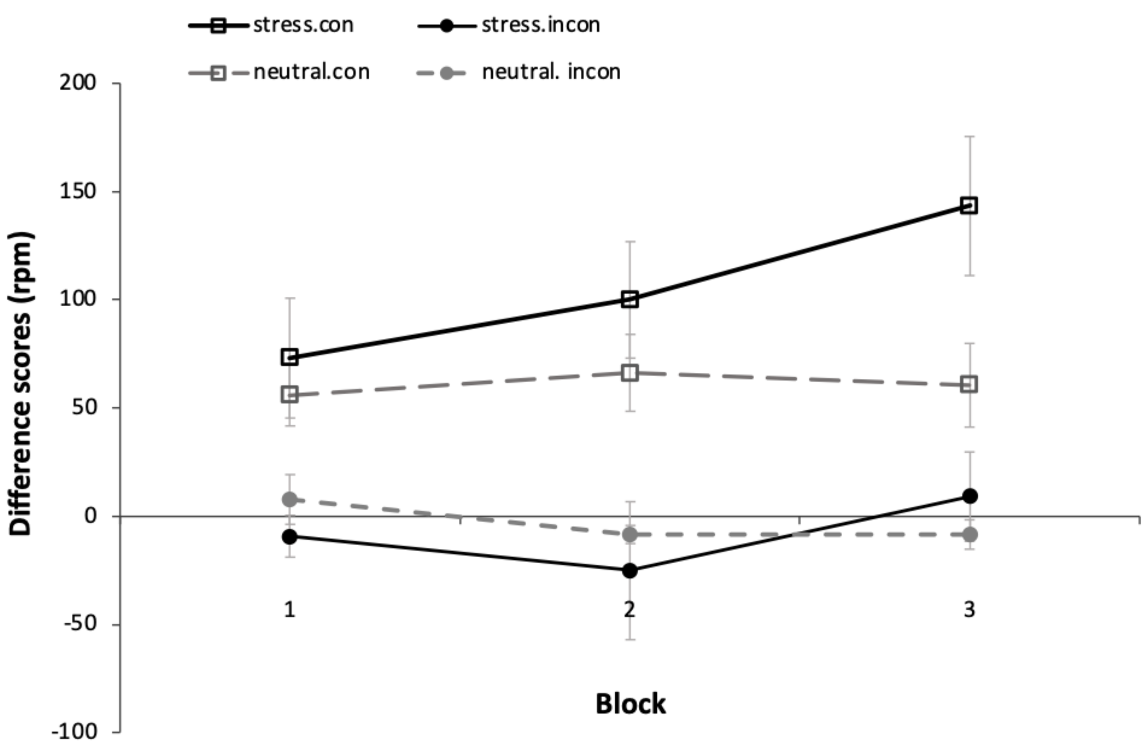

Fig.17. Group mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 5. Error bars represent standard errors.

preCS

The group mean preCS response rates in the congruent and incongruent conditions are shown in Table 20. A condition (congruent, incongruent) x blocks x groups (stress, neutral) mixed ANOVA showed a main effect of condition, F (1,46) = 4.672, p= .036, MSE = 14.360, η_P^2 = .092. The incongruent preCS rates were higher than congruent; nothing else was significant (largest F (2, 92) = 1.552, p= .217, MSE = 11.727, for the main effect of blocks). Since higher preCS rates in the incongruent condition could enlarge the specific PIT effect by analysing difference scores, an analysis of response rates in the CS stage was conducted.

Table 20

conditions	block1	block2	block3
stress.congruent	16.9(7.0)	27.5(16.7)	27.5(17.0)
stress.incongruent	35.0(17.3)	62.2(32.0)	33.1(17.6)
neutral.congruent	4.7(2.3)	8.4(4.2)	16.6(6.9)
neutral.incongruent	11.9(8.1)	21.9(7.0)	24.4(10.7)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 5. Standard deviations are shown in brackets.

CS

The group mean CS response rates in the congruent and incongruent conditions are shown in Table 21. A condition (congruent, incongruent) x blocks x groups (stress, neutral) mixed ANOVA showed the main effect of condition, F (1,46) = 23.795, p< .001, MSE = 74.598, η_P^2 = .341, the main effect of blocks, F (2,92) = 10.016, p< .001, MSE = 8.102, η_P^2 = .179, and the interaction between blocks and groups, F (2,92) = 5.903, p= .004, MSE = 8.102, η_P^2 = .114, were significant. The interaction between conditions and groups was not significant, F (1,46) = 1.716, p = .197, MSE = 74.598, BF_{excl} = 0.736. Nothing else was significant (the largest F (1,46) = 3.557, p= .066, MSE = 134.361). Post hoc tests (Holm) for blocks showed that the response rates in block 3 were higher than in block 2 p=.047 or block 1 p< .001, and the response rates in block 2 were higher than in block 1 *p*=.047. Post hoc tests (Holm) for groups and blocks interaction showed response rates in block 3 in the stress group were higher than the rates in block 1 in the neutral group (*p*=.047) or stress group (*p*<.001). This suggests there was a specific PIT effect, and that this was of a similar size in the two groups.

Table 21

conditions	block1	block2	block3
stress.congruent	90.0(27.2)	127.5(32.1)	170.9(36.8)
stress.incongruent	25.6(9.7)	37.19(14.1)	42.2(20.5)
neutral.congruent	60.6(14.4)	74.7(17.2)	77.2(17.5)
neutral.incongruent	19.7(8.8)	13.4(5.6)	15.9(7.4)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 5. Standard deviations are shown in brackets.

General Effect

Difference Scores

The difference scores for S3 and S4 are presented in Figure 18. The figure shows that scores were higher for S3 than S4 in both groups. A conditions (S3, S4) x blocks x groups (stress, neutral) mixed ANOVA showed only a significant main effect of conditions, *F* (1,46) = 9.438, *p*= .004, *MSE* = 2863.655, η_P^2 = .170. The interaction between conditions and groups was not significant, *F* (1,46) = .039, *p*= .844, *MSE* = 2863.655, BF_{excl} =10.586. Nothing else was significant (the largest *F* (2,92) = 2.067, *p*=.132, *MSE* = 1919.327 for the interaction between blocks and groups). This suggests there was a general PIT effect that did not differ between the two groups. Results in Rs (R1, R2) x groups (stress, neutral) ANOVA did not suggest a difference between the number of responses to R1 and R2 in the stress or neutral groups. The largest *F* (1,46) = .707, *p*=.405, *MSE* = 241.395 for the interaction of Rs and groups.

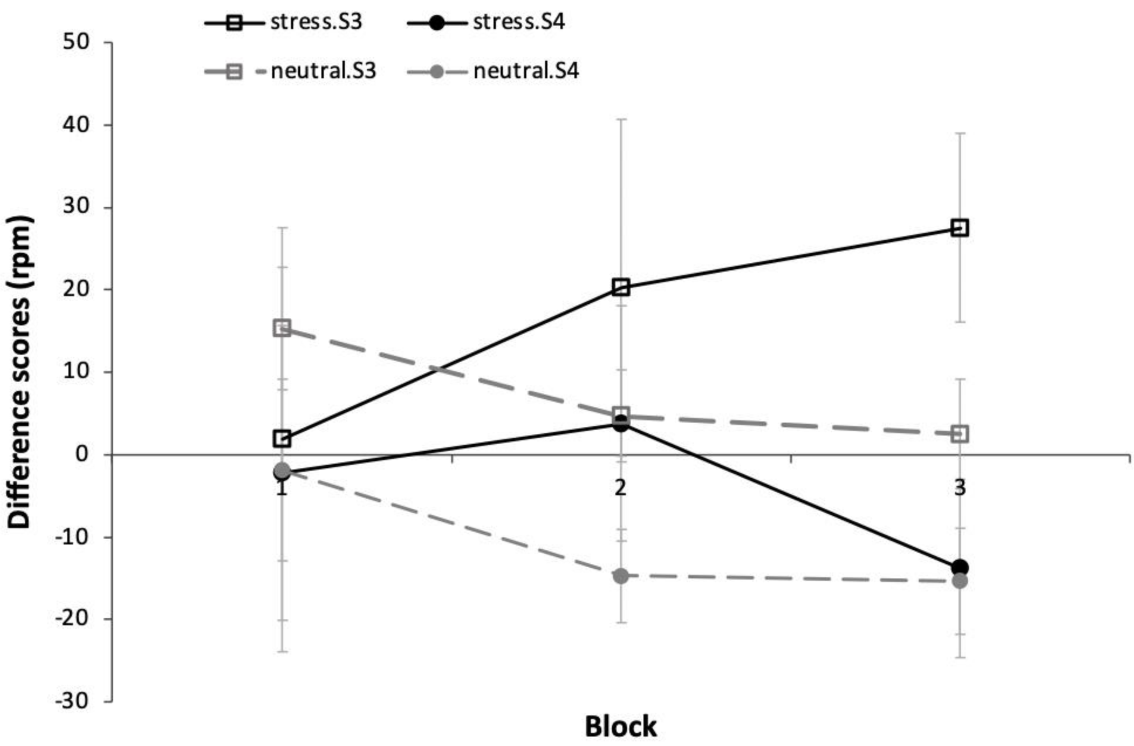

Fig.18. Group mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 5. Error bars represent standard errors.

preCS

The group mean preCS response rates in S3 and S4 are shown in Table 22. A conditions (S3, S4) x blocks x groups (stress, neutral) mixed ANOVA revealed nothing significant, largest F (1,46) = 3.116, p= .084, MSE = 118.770, for the main effect of groups. Results in Rs (R1, R2) x groups (stress, neutral) ANOVA did not suggest a difference between the number of responses to R1 and R2 in the stress or neutral groups. The largest F (1,46) = 3.116, p=.084, MSE = 1425.244 for the main effect of groups.

Table 22

conditions	block1	block2	block3
stress.S3	51.3(28.5)	63.4(27.2)	45.9 (20.4)
stress.S4	46.3(21.9)	38.1(18.0)	55.9 (23.4)
neutral.S3	6.9(2.7)	13.8(5.9)	20.0 (7.0)
neutral.S4	15.3(6.1)	20.9(7.2)	20.0(8.0)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 5. Standard deviations are shown in brackets.

Discussion

The aim of this study was to explore how anxiety levels induced by stress mood induction procedures can influence humans' performance on PIT effects. The results of this experiment showed that the size of the PIT effects did not differ between the stress group and the neutral group. Compared with using scales, applying stress mood induction should be able to enlarge the variety of anxiety levels. However, the mood induction did not show a statistically significant effect. The participants in the stress group reported higher scores in feeling bad, aroused, or sad – but not anxious, which directly measures the stress emotion. Therefore, the fact that stress mood induction did not influence the size of any PIT effect is difficult to interpret. The mood induction did not influence PIT may be because we applied the procedure after the instrumental conditioning and the Pavlovian conditioning. The stress related to addictive behaviour in practice can be more chronic. Therefore, it is possible that performance in the transfer test changes resulting in stress can affect learning in instrumental conditioning (Valenchon et al., 2017) or Pavlovian conditioning (Stelly et al., 2020). To give a possibility to let it happen, the stress mood induction should be placed before Pavlovian and instrumental conditioning. This issue was addressed in the later experiments (Experiments 6 and 7) by placing the mood induction procedure before PIT tasks.

Experiment 6

Introduction

Stress can affect participants' performance in transfer tests in a way of influencing learning outcomes in Pavlovian or instrumental conditionings before the transfer test. Therefore, the design of the last experiment can be improved by placing the mood induction procedure at the beginning of the task. The learning in Pavlovian conditioning was evaluated in post-test assessment. The learning in instrumental conditioning was not assessed since participants were unlikely to fail to learn only two associations after earning 50 of each outcome. The self-reported questionnaire applied was a 6-item STAI (used in Sayette et al., 2001) which was effective in testing stress mood induction. It can be a better choice than the novel scale used in Experiment 5.

Method

Design

Compared with the design in Experiment 5, the mood induction procedure in Experiment 6 moved to the beginning of the PIT task, and the post-test assessment was presented after Pavlovian conditioning immediately. The self-reported questionnaire, 6-item STAI, was presented three times: at the beginning of the experiment, immediately after MIP and at the end of the experiment (see Table 23 below). In addition to the stress and neutral conditions used in Experiment 5, the current Experiment 6 also added a positive group. Participants in this condition looked at positive pictures and listened to a piece of calm classical music.

Table 23

Design of Experiment 6.

STAI 1st	Mood Induction Procedure	STAI 2nd	Instrumental training	Pavlovian conditioning	Post-test assessment	PIT Transfer Test (music/voice on)	STAI 3rd
	Heavy metal music		R1-O1	S1-O1	S1	S1: R1, R2	
	+ wounded body pictures						
	OR		R2-O2	S2-O2	S2	S2: R1, R2	
	Classical music +						
	pictures of baby animals						
	OR			S3-O3	S3	S3: R1, R2	
	Café background voice +						
	pictures of objects			S4-nothing	S4	S4: R1, R2	

Note: S: Stimuli, O: Outcomes, R: Responses.

Participant

In total, 72 adults completed this study (24 in each of the three groups). In the stress group, there were 13 males and 11 females, with a mean age of 26.33 (*SD* = 4.51, range 21-37). In the positive group, there were 12 males and 12 females with a mean age of 24.88 (*SD* = 3.06, range 21-36). In the neutral group, there were 15 males and 9 females with a mean age of 25.38 (*SD* = 3.06, range 22-33).

Material

Mood Induction Procedure

Pictures

A new group of 12 positive pictures of cute animals, selected from the Open Affective Standardized Image Set (OASIS; Kurdi, Lozano, & Banaji, 2017), was used (see examples in Figure 19). These were cat (4, 5, 9, 10), chipmunk (1), dog (4, 5, 6, 12, 14), and bird (3, 4). The average mean arousal level scores of these positive images were 3.69 (*SD*=1.58).

Fig. 19. Examples of positive pictures.

Sounds

A piece of music — Canon in D (by Johann Pachelbel), was used for the positive condition.

Procedure

Differing from Experiment 5, in the current experiment, the participants experienced a mood induction procedure at the beginning of the experiment.

Mood Induction Procedure (MIP)

MIP was the same as Experiment 5, the only difference included a positive group, therefore, to check if participants could hear the sound, participants could choose among '*a hubbub of voices*', '*heavy metal music*' or '*classical music'*.

Questionnaires (6-item STAI):

1. *I am upset*
2. *I am worried*
3. *I am frightened*
4. *I am calm*
5. *I am secure*
6. *I am self-confident*

Participants clicked on the scale with words 'not at all', 'somewhat', 'moderately so', and 'very much so' to indicate how they feel at the moment. This procedure ended when participants answered the 6 questions separately by clicking on the scales on the screen (see Figure 20). The next question started immediately after participants clicked on the scale:

Fig. 20. Example questions from STAI.

Results

Data treatment

All of the participants gave correct answers to the sounds they heard (i.e., heavy metal music in the stress group, café background voice in the neutral group, classical music in the positive group). Using the same criteria as in Experiment 1, five participants learned poorly in the stress group, seven in the positive group, and three in the neutral group. No participants were excluded. The relation between groups and the learned outcome was not significant, $\chi^2(2, N = 72) = 2.021$, $p = .364$. All other aspects of data treatment were identical to those employed in the previous experiment.

Mood Induction Procedure (MIP)

Figure 21 below illustrated self-reported scores of STAI. Participants in the three groups reported similar scores both at the beginning of the experiment and at the end of the experiment.

However, participants in the stress group reported notably higher scores after the MIP than the participants in the positive or neutral groups.

By conducting a groups (stress, positive, neutral) x times mixed ANOVA, The results showed a significant main effect of groups, F (2,69) = 8.812, p< .001, MSE = 20.148, η_P^2 = .203 and time points, F (2,138) = 4.548, p= .012, MSE = 5.754, η_P^2 = .026 and a significant interaction between these factors, F (4,138) = 14.726, p< .001, MSE = 5.754, η_P^2 = .299. Simple main effects analysis revealed the group effect was different on the 2nd time point, p< .001, but not on other time points (*ps* > .142), and post-hoc tests (Tukey) showed that scores were higher for the stress group than the neutral or positive group (*ps*< .001); scores in the positive and neutral group did not differ. This suggests the mood induction procedure was effective in enhancing anxiety in the stress group, but this effect did not persist until the end of the experiment.

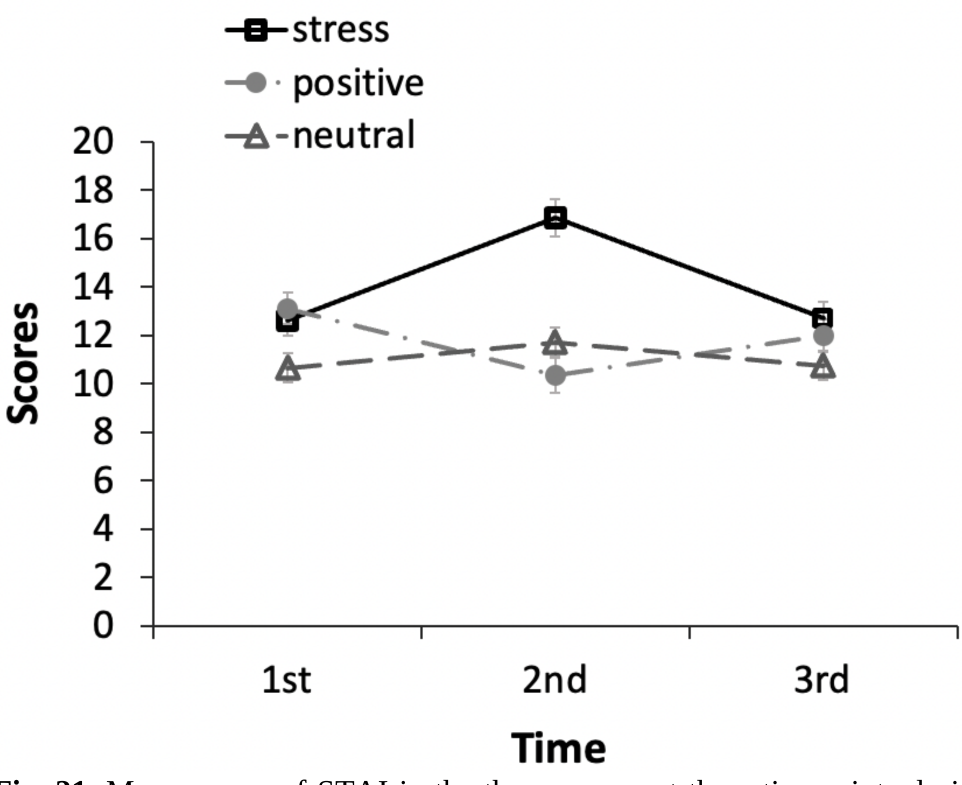

Fig. 21. Mean scores of STAI in the three groups at three timepoints during the experiment were presented. Error bars presented standard errors.

PIT

Specific Effect

Difference Scores

The difference scores for the congruent and incongruent conditions are presented in Figure 22, which indicates congruent scores were higher than incongruent conditions in all three groups, and across the first three blocks, but that the groups did not differ in their pattern of responding. The impression was supported by the results of a conditions (congruent, incongruent) x blocks x group (stress, positive, neutral) mixed ANOVA, which showed a significant main effect of condition, F (1,69) = 17.884, p< .001, *MSE* = 478.154, η_P^2 = .206, and of blocks, F (2,138) = 7.006, p= .001, *MSE* = 51.181, η_P^2 = .092. The interaction between conditions and groups was not significant, F (2,69) = .087, p= .917, *MSE* = 478.154, BF_{excl} = 2.458. Nothing else was significant, largest F (2,69) = 2.300, p= .108, *MSE* = 287.920. Post-hot tests (Holm) for the main effect of blocks showed that the difference scores in block 3 were higher than in block 2 (p=.004) or block 1 (p=.004).

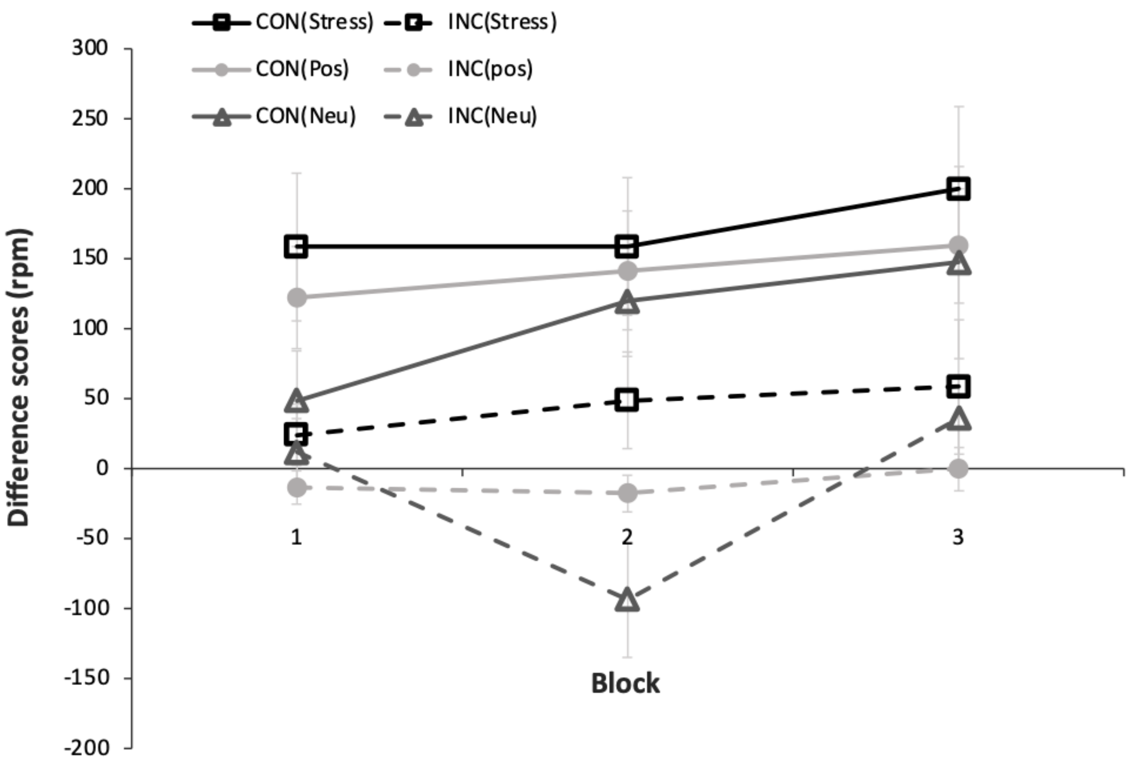

Fig.22. Group mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 6. Error bars represent standard errors.

preCS

The mean response rates in the congruent and incongruent conditions during the preCS period are shown in Table 24. A conditions (congruent, incongruent) x blocks x groups (stress, positive, neutral) mixed ANOVA showed nothing significant, largest F (2,138) = 1.988, p= .141, MSE = 85.302, η_P^2 = .028, for the main effect of blocks.

Table 24

conditions	block1	block2	block3
stress. congruent	31.3(12.3)	38.1(14.8)	46.3(18.1)
stress. incongruent	40.6(13.3)	56.2(23.5)	35.6(11.8)
positive.congruent	43.1(17.1)	78.8(38.6)	53.8(38.3)
positive.incongruent	108.8(52.7)	78.1(39.7)	71.9(39.9)
neutral. congruent	103.1(70.9)	152.5(66.2)	163.1(65.2)
neutral. incongruent	82.5(43.6)	183.1(64.8)	56.9(37.5)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 6. Standard deviations are shown in brackets.

General Effect

Difference Scores

The difference scores in the S3 and S4 conditions are presented in Figure 23. Scores for S3 were greater than for S4 condition in all three groups and across most of the test blocks. This impression was supported by the results of a conditions (S3, S4) x blocks x groups (stress, positive, neutral) mixed ANOVA, which showed a significant main effect of condition, F (1,69) = 9.751, p= .003, MSE = 86.896, η_P^2 = .124, which did not interact with group (BF_{excl} =14.940), or group and block, Fs < 1. Nothing else was significant (largest F (2,138) = 2.895, p= .059, MSE = 47.982, for the main effect of blocks). Thus, there was a general PIT effect that did not differ among the groups. Results in Rs (R1, R2) x groups (stress, neutral, positive) ANOVA did not suggest a difference between the number of responses to R1 and R2 in any group. The largest F (1,69) = 1.930, p=.169, MSE = 363.769, for the main effect of Rs.

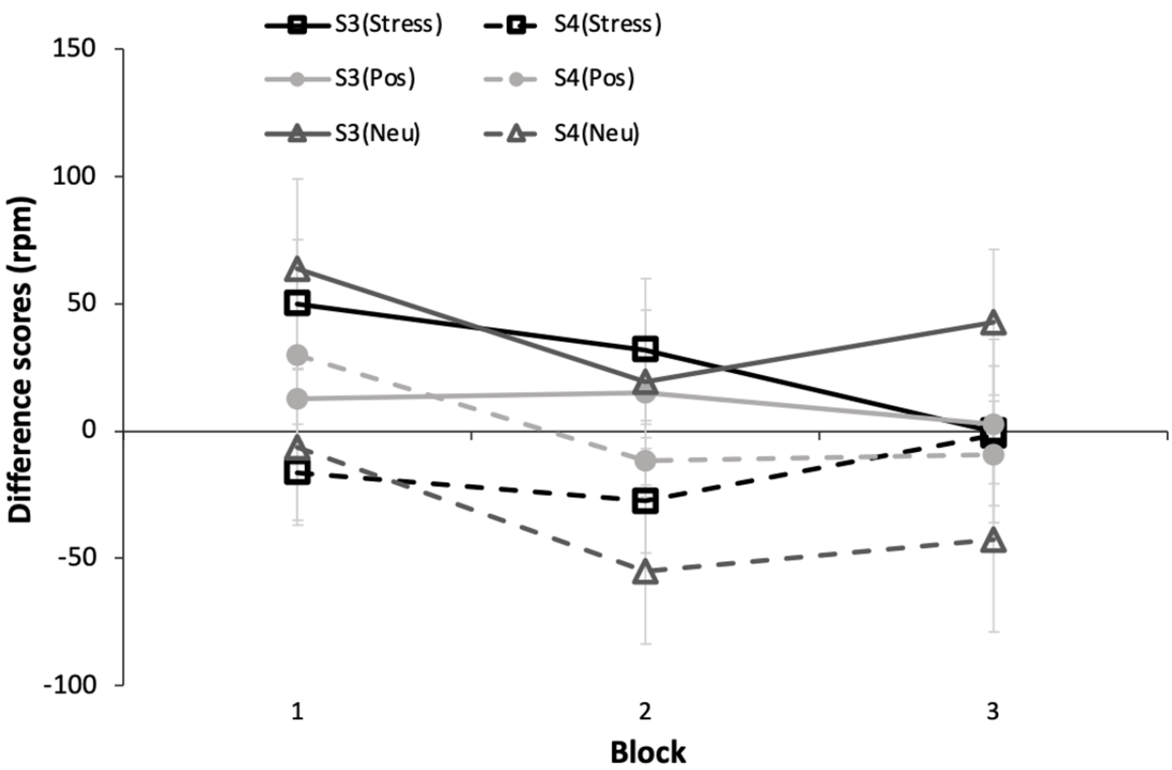

Fig.23. Group mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 6. Error bars represent standard errors.

preCS

The mean preCS response rates in S3 and S4 are shown in Table 25. A conditions (S3, S4) x blocks x groups (stress, positive, neutral) mixed ANOVA showed that the main effect of blocks, F (2,138) = 4.757, p= .010, MSE = 115.768, η_P^2 = .064, was significant. The interaction of conditions and groups was significant, F (2,69) = 3.459, p= .037, MSE = 59.242, η_P^2 = .091. Nothing else was significant, largest F (2,69) = 3.493, p= .066, MSE = 59.242, for the main effect of conditions. Post-hoc tests (Holm) for the main effect of blocks showed that response rates in block 3 were higher than in block 1, p=.010. Post-hoc tests (Holm) for the group and conditions interaction showed that the responses for S4 were higher than for S3 in the neutral group, p=.029. Nothing else was significant, smallest p=.599. This indicated there was no general effect in the preCS stage. However, the general effect in the neutral group might be enlarged. Results in Rs (R1, R2) x groups (stress, neutral, positive) ANOVA did not suggest a difference between the number of responses to R1 and R2 in any group. The largest $F(1,69) = 1.056$, $p=.308$, $MSE = 1597.765$, for the main effect of Rs.

Table 25

conditions	block1	block2	block3
stress.S3	19.4(10.3)	53.1(16.3)	98.8(40.3)
stress.S4	59.4(17.5)	63.8(20.9)	50.0(15.9)
positive.S3	18.8(12.3)	63.1(38.4)	79.4(38.7)
positive.S4	20.6(8.4)	64.4(38.0)	75.0(38.7)
neutral.S3	15.0(7.2)	89.4(42.9)	103.1(44.4)
neutral.S4	92.5(43.0)	142.5(61.2)	158.8(61.8)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 6. Standard deviations are shown in brackets.

Discussion

The aim of this study was to explore how anxiety levels induced by online mood induction procedures in stress, neutral and positive groups can influence humans' performance on PIT effects. The specific and general PIT effects were observed in all three groups, but the effects did not differ among the groups. This may be because although the mood induction in the stress group worked immediately, it did not last long enough till the end of the experiment. The influence of mood induction did not last long may be because, as Experiment 5, the current

Experiment 6 was an online study. This indicates participants did the experiment in a familiar environment which limited the effects of mood manipulations. Also, the unknown factors in different environments may influence PIT effects. In order to enhance the effect of mood inductions and maximize the difference in stress levels among groups, Experiment 7 was conducted in person with different mood induction procedures applied.

Experiment 7

Introduction

In this experiment, an in-lab experiment was conducted with in-person mood induction procedures applied. In the stress group, a speech stress test was used. This stress mood induction was modified from the one used in the study of Sayette et al. (2001): participants were told that they would have to give a speech about what they liked and disliked about their bodies in front of a camera at the end of the experiment. The speech would be filmed and analysed by psychologists. A strong photography light is on during the whole experiment for the filming later. Also, light conditions can influence humans' stress state. It has been reported that adults exposed to bright light significantly increased their stress hormone levels more than adults exposed to dim white light (Petrowski et al., 2020). In the neutral group, participants were asked to read magazines. In the relax group, a relaxation technique was applied, as experiencing short relaxation practice can significantly decrease individuals' heart rate and blood pressure (Pal et al., 2014). participants in the relax group completed the whole experiment under dim light.

Method

Design

The design of this in-lab experiment was the same as the design in Experiment 6, except there was a short reminder added to keep the participants' mood state before the transfer test (see Table 26).

Participant

In total, 72 students studying at the University of Nottingham completed this study (24 in each of the three groups), mean age of 22.45 (*SD* = 4.09), aged from 18 to 35 years old, including 44 females, 27 males and one person did not report sex. In the stress group, there were 6 males, 17 females, and one did not report sex, aged from 18 to 29 years old (*Mean* = 20.92, *SD* = 3.19). In the neutral group, there were 9 males and 15 females, with an age range of 19-35 (*Mean* = 22.54, *SD* = 4.06). In the relax group, there were 12 males and 12 females, aged from 18 to 33 years old (*Mean* = 23.79, *SD* = 4.55).

Table 26

Design of Experiment 7.

STAI 1st	Mood Induction I	STAI 2nd	Instrumental training	Pavlovian conditioning	Post-test assessment	Mood Induction II	PIT Transfer Test	STAI 3rd
	Speech Stressor Task		R1-O1	S1-O1	S1	reminders	S1: R1, R2	
	OR		R2-O2	S2-O2	S2		S2: R1, R2	
	Read Magazines							
				S3-O3	S3		S3: R1, R2	
	OR							
	Relaxation Techniques			S4-nothing	S4		S4: R1, R2	

Note: S: Stimuli, O: Outcomes, R: Responses.

Material

PIT

Materials used in the PIT task were the same as the ones used in Experiment 6.

Mood Induction Procedure (MIP)

<u>*Speech Stressor Task*</u>

A Panasonic GS250 Camcorder, a camera tripod, and a Vivanco videoleuchte (300 Watt) were used in the stress group.

<u>*Read Magazines*</u>

The magazine used in the neutral group named 'National Geographic – Lost cities' was sold in November 2021.

<u>*Relaxation Techniques*</u>

A small night light, and a five-minute calm music with guided relaxation practise.

Procedure

Participants were asked to read the information sheet, sign the consent form before, finish the first STAI questionnaire before going into the lab.

Mood Induction Procedure (MIP) I

<u>*Speech Stressor Task*</u>

A modified version of the speech stressor task conducted by Sayette et al. (2001) was applied to the stress group. At the beginning of the experiment, participants were told by researchers that they will give a short speech about what they liked or disliked about their body or physical appearance at the end of the task. They were asked to be as open as possible and acknowledged about defences people usually use to avoid facing the truth:

'After doing the computer task, you will be asked to give a speech about what you like and dislike about your body and physical appearance. You will need to sit in the chair behind you, so we can have the white wall to be the background, look at and talk to this camera (a camera was set about two meters away from the seat). I will turn on this photography light before I leave the room, please do not turn it off. In the speech, you will need to talk about what you like and dislike about your body for at least 3 minutes. Please try to be as open and as honest as possible. A therapist will rate the videotaped speech later. The therapist will rate your openness by analysing how often and in what ways you were defensive. Some common defences include:

Denial: Sometimes people may deny something because the truth is hard to accept. Facing reality can be too painful and stressful. For example, when children break things, they often cover their eyes with their hands. Sometimes people refuse to believe that loved ones are passed away.

Suppression: When experiencing some pain, people consciously try not to think about it. This reduces the psychological contact with the injury. For example, after a mother lost her child in a car accident, she would quickly change the topic when people mention something about driving. She may also quickly turn the page when she read some news about a car accident in the newspaper.

Rationalization: To give an unacceptable emotion, or action some seemingly rational explanation. This is the most common defence people use to cover up their pain or failures to maintain peace of mind. For example, if your friend is mean to you, you may rationalise it as them having a bad day rather than letting yourself be hurt by their words.

Humour: Sometimes people use humorous language or behaviour to cope with stressful situations, and express aggression or desires. For example, jokes about sex, death, and attack are the most popular.

These are some examples. In your speech later, we hope you can be as open and honest as possible. Now, if you are ok with it, please sign this consent form to agree to be videoed.'

This procedure was about five minutes. Then, participants started doing the PIT task in strong light.

Read Magazines

Participants in the neutral group were asked to read the magazine for five minutes. Then, participants started doing the PIT task in normal light.

Relaxation Techniques

Participants in the relax group were asked to follow the instruction and do the relaxation practice. The practice lasted five minutes in dark with a small night light on. Then, participants started doing the PIT task in dim light.

PIT

The PIT task applied was the same as the one used in Experiment 6.

Mood Induction Procedure (MIP) II

In this procedure, one sentence is present on the screen to remind the participants what they should do. The sentences in the different groups were:

Speech Stressor Task

'Reminder: you will give the speech in about five minutes…'

Read Magazines

'Reminder: you will read the magazine in about five minutes…'

Relaxation Techniques

'Relax …'

STAI

Participants answered the STAI by using a pen and questionnaire printed on paper for the first time and answered the STAI by clicking on the scales on the screen the second and the third time.

Results

Data treatment

Four participants in the stress group, three in the relax group and four in the neutral group did not pass the criterion for learning in the Pavlovian stage. The relationship between group and learning outcome was not significant, $\chi^2(2, N = 72) = .709, p = .701$.

Mood Induction Procedure

The STAI scores for the three groups (stress, relax, neutral) at the three different timepoints of the experiment are shown in Figure 24. The scores from the stress group appeared to increase over the course of the experiment, while those from the neutral group remained steady; scores from the relax group were lower than those of the other two groups. A group (stress, relax, neutral) x time points mixed ANOVA revealed significant main effects of groups, F (2,69) = 3.169, p= .048, MSE = 13.017, η_P^2 = .084, and of time points, F (2,138) = 5.968, p= .003, MSE = 2.738, η_P^2 = .080; the interaction was not significant, F (4,138) = 1.907, p= .113, MSE = 2.738. Post-hoc (Holm) tests on time points showed scores at times 1 and 2 were lower than those at time 3 (p = .013 and .006 respectively); scores at times 1 and 2 did not differ, p= .688. Post-hoc (Holm) tests on the group showed scores in the stress group were higher than those in the relax group, p = .042. The neutral group did not differ from the other two groups, ps= .416. The lack of a group x condition interaction raises the possibility that these group differences were present before the imposition of the mood induction procedure; however, a one-way ANOVA performed on the scores at the first time point revealed no differences among the three groups, $F < 1$.

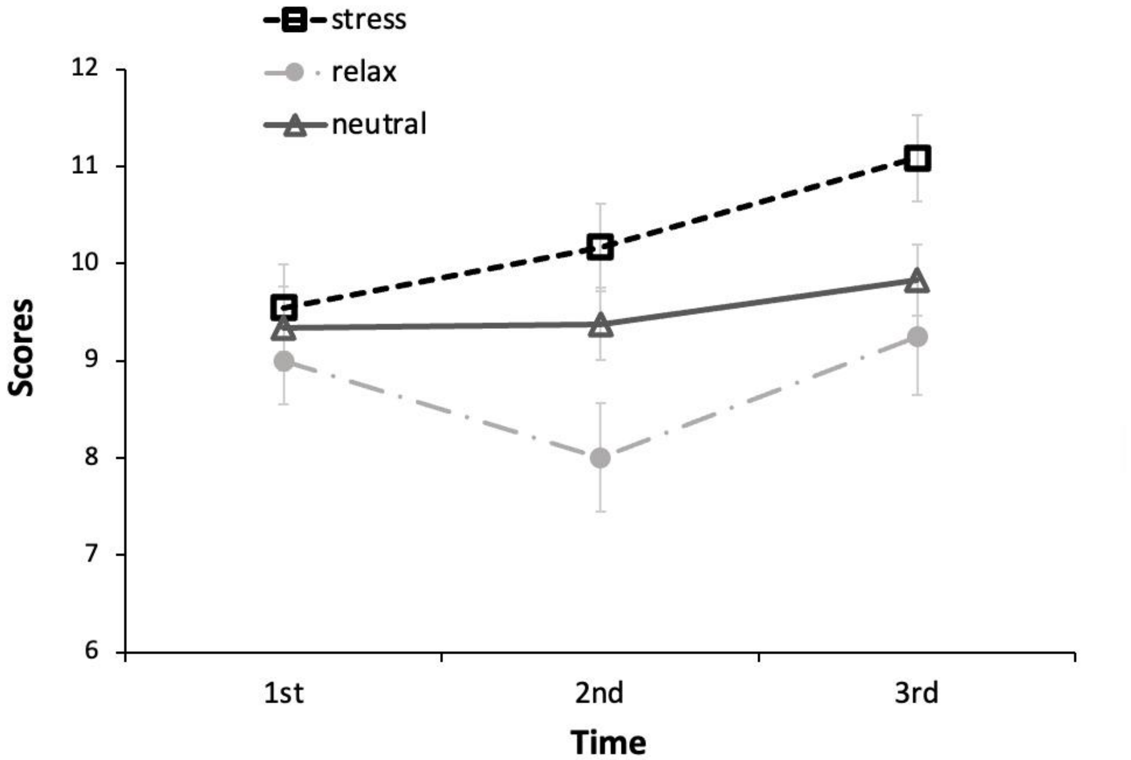

Fig.24. Mean scores of STAI in the three groups (stress, relax, neutral) three times during the experiment were presented. Error bars presented standard errors.

PIT

Specific Effect

Difference Scores

The difference scores for the congruent and incongruent conditions are presented in Figure 25. Scores in the congruent condition appeared greater than those in the incongruent condition, and this difference seemed consistent across both groups and blocks. This impression was supported by the results of a condition (congruent, incongruent) x blocks x group (stress, relax, neutral) ANOVA. The results showed a significant main effect of conditions, F (1,69) = 38.623, p< .001, MSE = 65.323, η_P^2 = .359, which did not interact with groups (BF_{excl} =87.557), or groups and blocks, Fs < 1. Nothing else was significant (largest F (2,138) = 1.379, p= .255, MSE = 8.383 for the main effect of blocks). This suggests that the specific PIT effect did not differ among the three groups.

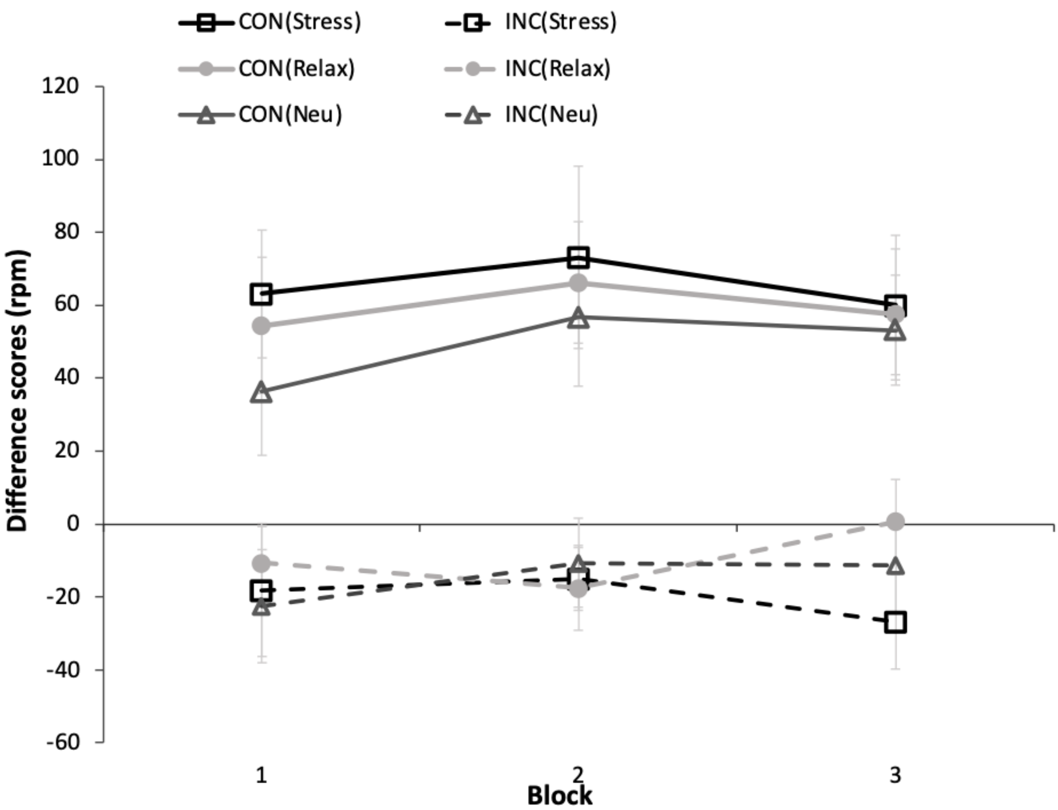

Fig.25. Group mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 7. Error bars represent standard errors.

PreCS

The group mean preCS response rates in the congruent and incongruent conditions across the first three blocks are shown in Table 27. A conditions (congruent, incongruent) x blocks x groups (stress, relax, neutral) mixed ANOVA was conducted. The results showed no significant main effects or interactions, largest F (2,69) = 1.326, p= .272, MSE = 7.513 for the interaction of conditions and groups.

Table 27

conditions	block 1	block 2	block 3
stress.congruent	46.3(13.0)	57.5(19.2)	48.8(15.9)
stress.incongruent	69.4(19.2)	48.1(16.7)	66.3(19.1)

relax.congruent	51.3(13.0)	66.9(21.1)	60.0(18.2)
relax.incongruent	46.9(12.5)	65.0(18.0)	51.3(16.4)
neutral.congruent	51.9(10.1)	56.3(16.0)	62.5(16.5)
neutral.incongruent	65.0(17.6)	61.9(15.3)	60.6(15.7)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 7. Standard deviations are shown in brackets.

General Effect

Difference Scores

The difference scores for the S3 and S4 conditions are presented in Figure 26. The figure suggests that rates during S3 were higher than those during S4 and that this difference was similar in the three groups. This impression was supported by the results of a condition (S3, S4) x blocks x group (stress, relax, neutral) ANOVA, which showed a significant main effect of condition, F (1,69) = 18.595, p< .001, MSE = 18.645, η_P^2 = .212; this did not interact with the group (BF_{excl} =10.032), or group and block, Fs < 1, and nothing else was significant (largest F (2,138) = 2.894, p= .059, MSE = 5.561 for the interaction between conditions and blocks). This suggests stable general effects in all the groups were observed and were not differ among groups. Results in Rs (R1, R2) x groups (stress, neutral, relax) ANOVA did not suggest a difference between the number of responses to R1 and R2 in any group. The largest F (1,69) = 3.282, p=.074, MSE = 77.200, for the main effect of Rs.

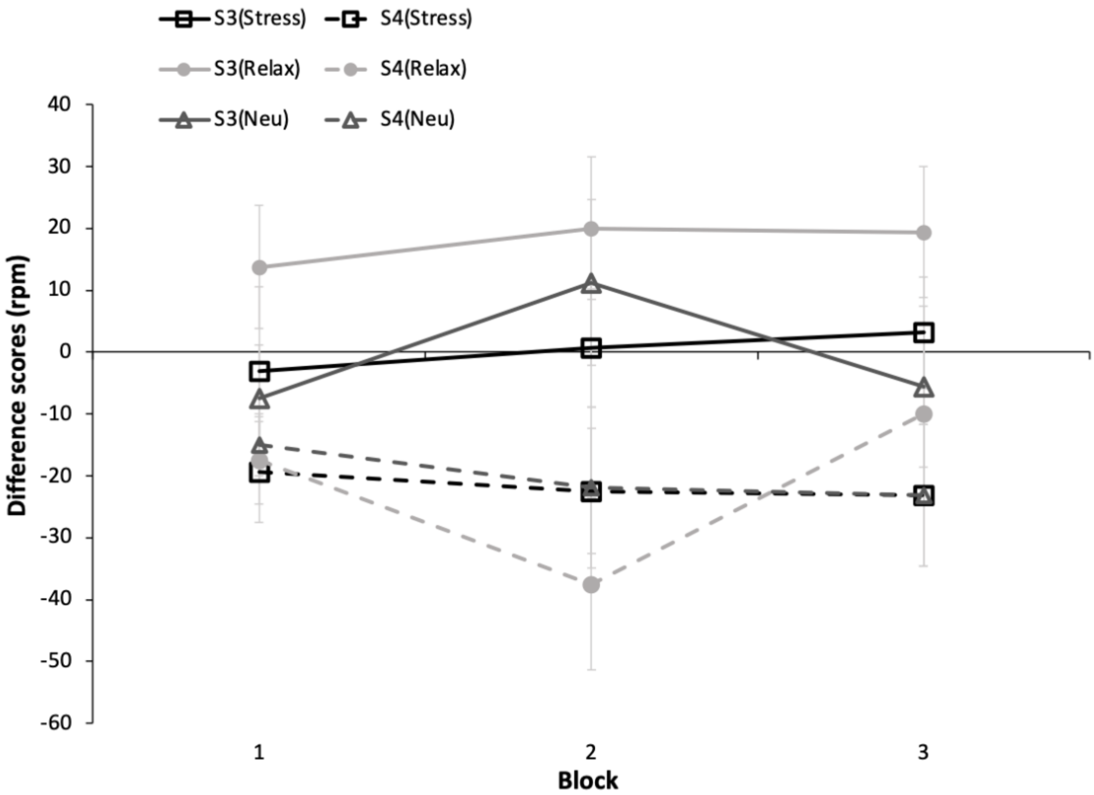

Fig.26. Group mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 7. Error bars represent standard errors.

PreCS

The mean preCS response rates in the S3 and S4 conditions are shown in Table 28. A conditions (S3, S4) x blocks x groups (stress, relax, neutral) ANOVA showed no significant main effects or interactions, largest F (4,138) = 1.503, p= .205, MSE = 7.304 for the interaction of conditions, blocks and groups. This suggests that the preCS response rate did not differ between groups or conditions on any of the test blocks. Results in Rs (R1, R2) x groups (stress, neutral, relax) ANOVA did not suggest a difference between the number of responses to R1 and R2 in any group. The largest F (1,69) = 2.264, p=.112, MSE = 73.020, for the main effect of Rs.

Table 28

condition	block 1	block 2	block 3

stress.S3	72.5(18.1)	53.1(15.6)	39.4(12.7)
stress.S4	57.5(13.1)	59.4(14.7)	56.3(15.3)
relax.S3	51.9(16.3)	61.3(16.9)	55.0(17.4)
relax.S4	61.9(15.6)	71.3(18.9)	40.6(13.1)
neutral.S3	60.6(14.5)	53.1(16.2)	59.4(17.1)
neutral.S4	54.4(14.5)	62.5(15.9)	63.8(17.2)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 7. Standard deviations are shown in brackets.

Correlations between STAI and PIT effects (combine Experiments 6 & 7)

Since the response rates from online studies were much higher than from in-person studies, to be able to combine Experiments 6 and 7, the ratio of specific effects (congruent/ (congruent + incongruent)) and general effects (S3/ (S3 + S4)) in CS stage were used. After this calculation, 21 out of 144 participants had the denominator be zero in either specific or general effect ratios. The 21 participants were excluded, leaving data from 123 participants to be analysed. A Bayesian correlation was conducted to see correlations between STAI scores at three timepoints and both effects ratios (see Table 29). The results indicated that the data of this experiment did not show PIT effects and anxiety levels were correlated.

Table 29

Correlations between STAI scores and PIT effects ratios

Variable		ratio. specific	ratio. general	STAI.1st	STAI.2nd	STAI.3rd
1. ratio. specific	BF_{01}	—				
2. ratio. general	BF_{01}	4.029×10^{-7}	—			
3.STAI.1st	BF_{01}	5.262	2.864	—		
4.STAI.2nd	BF_{01}	4.802	5.935	5.790×10^{-16}	—	
5.STAI.3rd	BF_{01}	3.909	5.447	6.423×10^{-10}	7.946×10^{-11}	—

Note: $BF_{01}> 3$: substantial evidence for H0, $BF_{01}> 10$: strong evidence for H0, $BF_{01}> 30$: very strong evidence for H0. $BF_{01}<0.33$: substantial evidence for H1, $BF_{01}< 0.1$: strong evidence for H1, $BF_{01}<0.03$: very strong evidence for H1.

Discussion

The aim of this study was to explore how anxiety levels induced by in-person mood induction procedures in stress, neutral and relax groups can influence humans' performance on PIT effects. In the results above, it can be seen stress levels in the stress group were significantly higher than in the relax group immediately after the mood induction till the end of the experiment. Both the specific and general effects can be observed, but the effects did not differ among the three groups. Moreover, the number of participants who did not learn well in the Pavlovian stage was similar among groups. This indicated that stress did not affect learning about the Pavlovian associations, although the four associations were easy to learn and the test may be insensitive to detect a difference. In addition, after combining data from Experiments 6 and 7, the ratios of PIT effects were not correlated to anxiety scores. Overall, therefore, there was no evidence that the state of stress influenced the magnitude of the specific and general PIT effects.

General Discussion

The aim of the experiments in Chapter III was to explore the relationship between anxiety and PIT effects. The results from a series of experiments did not show evidence that there is a relationship between anxiety and PIT. There were five experiments in this Chapter III. Both specific and general effects were observed in the novel avoidance-based PIT task in all the experiments.

Experiments 3 and 4 measured correlations between PIT effects and anxiety by applying self-report questionnaires. Classical correlation in Experiment 3 showed that the general effect was positively correlated to anxiety levels reported by GAD-7. However, the correlation was weak, and the results could not be repeated in Experiment 4 with Bayesian correlation applied. Therefore, the results did not support that anxiety correlated to PIT effects. This may be because the range of anxiety levels was not large. To address this issue, stress mood induction procedures were applied to enlarge the range of anxiety levels among participants in the next three experiments.

Experiments 5, 6, and 7 aimed to measure how stress mood induction can influence the size of PIT effects. In Experiment 5, the online stress mood induction procedure (MIP) was applied after instrumental and Pavlovian conditioning, and before the transfer test. The fact that the size of PIT effects between the stress and neutral groups did not show differences might be because the stress MIP did not influence self-reported scores in anxiety. Also, anxiety may influence performance in the transfer test by way of affecting learning in the Pavlovian and instrumental stages. Therefore, in Experiments 6 and 7, the stress mood induction procedures were placed before PIT tasks. Experiment 6 used online mood induction which was the same as the one in Experiment 5 with a positive group added. The PIT effects did not differ among the three groups. This may be because although the mood induction in the stress group worked immediately, it did not last long enough till the end of the experiment. Also, for the two online studies, participants did the experiments in a place that they are familiar with, which was difficult to arouse anxious feelings. All the online experiments were done out of necessity during the Covid pandemic lockdown. To improve the study, in Experiment 7, an in-lab mood induction procedure was applied. The stress levels in the stress group were significantly higher than in the relax group immediately after the mood induction till the end of the experiment. However, the PIT effects did not differ among the three groups. In addition, after combining data from Experiments 6 and 7, the ratios of PIT effects were not correlated to anxiety scores.

In conclusion, the five experiments in Chapter III did not support that anxiety correlated to or can affect PIT effects. Since the previous inconsistent results may be due to applied different PIT tasks, it was important to have the current experiments conducted with standard PIT tasks, which can study both specific and general effects, applied. The results of the current experiments observed may be because the mood induction procedures did not exert maximum effects. Further research can apply more effective stress mood induction.

Chapter IV: Impulsivity and Appetitive PIT (Experiments 8-10)

This chapter aimed to explore the impact of impulsivity on humans' performance in PIT. It may be that previous findings on this topic were inconsistent because researchers applied different types of PIT tasks, and specific and general effects can be affected differently. By applying specific PIT tasks, researchers reported either non-significant (Vogel et al., 2018) or negative correlations between impulsivity levels and the effect (Hinojosa-Aguayo & González, 2020). By using a PIT task that is difficult to classify as specific or general, researchers found that participants with higher impulsivity showed stronger PIT (Sommer et al., 2017), which is opposite to the results reported by Hinojosa-Aguayo and González (2020). The different results may be because the PIT effect in Sommer et al (2017) is more general and PIT effects in others are specific only. Also, the relationship between general PIT and impulsivity has not been explored. Therefore, a standard PIT task, which can study both specific and general effects, was applied in this chapter. Impulsivity levels were measured by scales.

4.1 Impulsivity and PIT

Experiment 8

Introduction

Hinojosa-Aguayo and González (2020) used healthy young women to be their participants. In their first experiment, the participants first completed a Pavlovian instrumental transfer task (PIT; Quail et al., 2017). Then, participants experienced outcome devaluation procedures (Morris et all, 2015) and finally filled in an impulsive behaviour scale (short Spanish version UPPS-P, Cándido et al., 2012). They found that both the specific effect and outcome devaluation were negatively correlated to negative urgency scores. In the second experiment, participants experienced the devaluation procedure before the transfer test. Researchers found that participants with higher negative urgency scores were less sensitive about the outcome devaluation effect on specific PIT. However, in their experiment, the general effect was reported to be a partial effect as presenting S3 did not evoke more responses than the period when no stimuli were presented although more than presenting S4. The correlation between the devaluation-affected general PIT and impulsivity was not explored.

The experiments below aimed to repeat Hinojosa-Aguayo and González (2020) with a novel appetitive PIT task which can study both specific and general effects. Derived from Hinojosa-Aguayo and González's findings, there was expected to be a negative correlation between levels of impulsivity and specific effects, as well as between impulsivity and the devaluation effects of specific effects in the current experiment.

Method

Design

An appetitive PIT task with impulsivity scales at the end was applied (see Table 30). The design of the appetitive PIT task was the same as the task in Experiment 2. To improve the PIT task in Chapter II, in this task, I counterbalanced the instrumental stage. Any two out of three outcomes were selected and associated with R1 and R2 switchable. This six times the original eight conditions resulted in 48 conditions in total (see Appendix).

Table 30
Design of Experiment 8.

Instrumental training	Pavlovian conditioning	PIT Transfer test	Post-test assessment	Personality scales
R1-O1	S1-O1	S1: R1, R2	S1	UPPS-P
R2-O2	S2-O2	S2: R1, R2	S2	
	S3-O3	S3: R1, R2	S3	
	S4-nothing	S4: R1, R2	S4	

Note: S: Stimuli, O: Outcomes, R: Responses.

Participants

In total, 62 adults completed this study. Data from 14 participants were excluded since they failed the Pavlovian stage, and data from 48 subjects were used for analysing. Among them, there were 9 males, 37 females, one reported ‘non-binary’, and one did not report their sex, aged from 21 to 37 years old (*Mean* = 25.83, *SD* = 3.93).

Materials

PIT task

To improve the task in Experiment 2, in this task, the instrumental stage was counterbalanced. In the instrumental stage in Experiment 2, R1 was always paired with bats and R2 was always paired with arrows. However, in this experiment, R1 was paired with one out of three reinforcement outcomes, and R2 was paired with one out of the remaining two reinforcement outcomes. Combined with the counterbalancing in Pavlovian conditioning, this task had 48 counterbalancing conditions in total (see Appendix).

Personality scales

UPPS-P Impulsive Behaviour Scale

Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, (UPPS-P) Impulsive Behavior Scale (Lynam, Smith, Whiteside, & Cyders, 2006) contains 59 items with 10-14 items in each subscale. A four-point (score 1-4) rating scale was used to indicate the extent to which the participants agree with the statements. In the negative or positive urgency subscale, a higher score indicates participants tend to act rashly when experiencing extreme negative or positive emotions. In the lack of premeditation subscale, a higher score indicates participants are more likely to act without thinking. In the lack of perseverance subscale, a higher score indicates participants feel difficult to concentrate on a task. In the sensation-seeking subscale, a higher score indicates participants tend to seek experiences that make them feel excited.

Procedure

Personality scales

After the PIT task, participants completed the full version of the UPPS-P scale. Questions were presented separately in the centre of the screen. Participants answered questions by clicking on the scale on the screen. The next question started immediately after they answered on the scale.

Results

PIT

Data Treatment

The data treatment procedure was the same as that employed for Experiment 1.

Specific Effect

The difference scores per minute in the congruent and incongruent conditions are presented in Figure 27. The figure suggests that participants had greater difference scores in the congruent condition than in the incongruent condition. This impression was supported by results of a conditions (congruent, incongruent) x blocks within ANOVA, which showed a significant difference in the main effect of conditions, F (1,47) = 11.136, p= .002, MSE = 99848.920, η_P^2 = .192. The main effect of blocks and the interaction between conditions and blocks, Fs<1, were not significant. This suggests that the difference scores in the congruent condition were consistently higher than in the incongruent condition across the first three blocks.

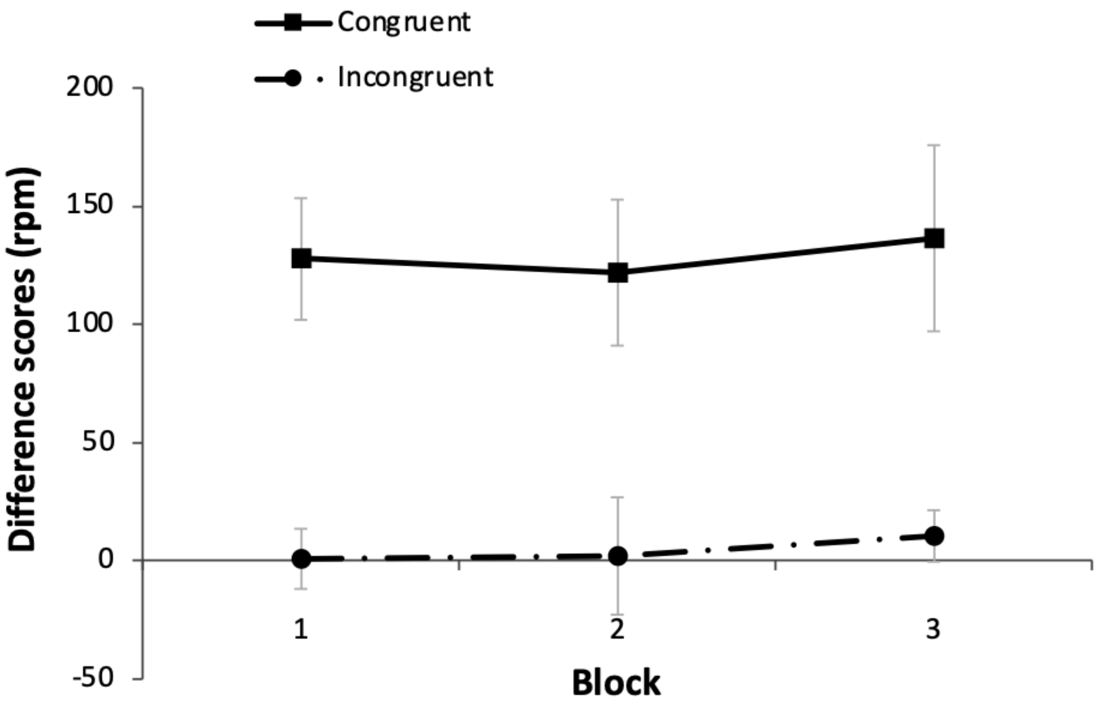

Fig.27. Mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 8. Error bars represent standard errors.

The mean response rates per minute in the congruent and incongruent conditions during the preCS period are shown in Table 31. Response rates in the preCS stage were analysed by using a conditions (congruent, incongruent) x blocks repeated measures ANOVA. The main effects and the interaction were not significant, *Fs* <1. This suggests before the stimuli were presented, the response rate in the congruent and the incongruent conditions was not different.

Table 31

conditions	block1	block2	block3
Congruent	67.19(30.59)	65.63(30.92)	59.06(21.80)
Incongruent	54.69(13.59)	70.31(19.16)	64.69(22.42)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 8. Standard deviations are shown in brackets.

General Effect

The difference scores per minute in the S3 and S4 conditions are presented in Figure 28. A conditions (S3, S4) x blocks within ANOVA showed that the main effect of conditions was significant, *F* (1,47) = 12.100, *p*= .001, *MSE* = 11443.467, η_P^2 = .205. The main effects of blocks, *F*<1 was not significant. Neither was the interaction of conditions and blocks, *F* (2,94) = 1.578, *p*= .212, *MSE* = 8500.814. The results above suggest that the difference scores in the S3 condition were higher than in the S4 condition. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, *t* (47) = 1.597, *p* = .117.

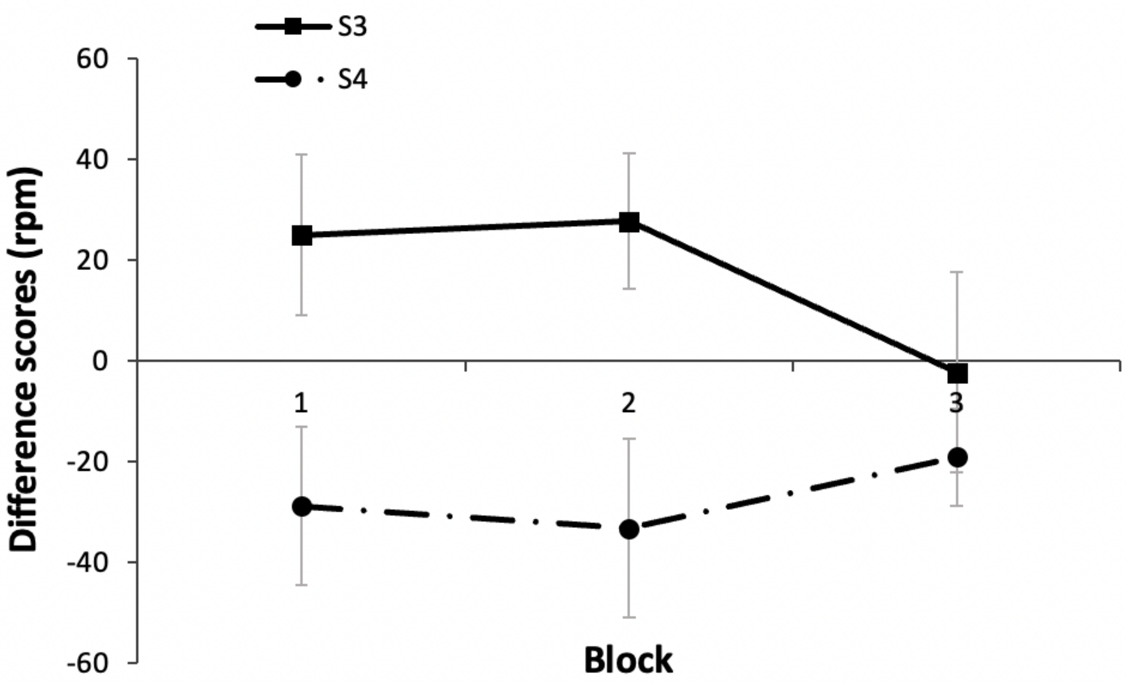

Fig.28. Mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 8. Error bars represent standard errors.

The mean response rates per minute in the S3 and S4 conditions during the preCS period are shown in Table 32. The preCS response rate was analysed by using a conditions (S3, S4) x blocks within ANOVA. Neither the main effect of conditions, *F* (1,47) =2.362, *p*= .131, *MSE* = 2503.175, or the main effect of blocks, *F* <1, nor the interaction between conditions and blocks, *F* (2,94) =1.476, *p*= .234, *MSE* = 8608.394, was significant. This suggests before the stimuli were presented, there were no differences between the response rates for S3 and S4 over blocks. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, *t* (47) = - 1.796, *p* = .079.

Table 32

conditions	block1	block2	block3
S3	45.00(20.42)	49.38(17.58)	83.75(25.78)
S4	55.62(17.72)	80.63(24.16)	69.06(22.83)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 8. Standard deviations are shown in brackets.

PIT and Personality

Shapiro-Wilk test for multivariate normality was used in choosing an appropriate statistical method. The results showed that the distribution departed significantly from normality (*W* = 0.826, *p* < .001). Therefore, the median with the interquartile range was used to summarize the impulsivity subscales: negative urgency (*Median* = 30.00, *IQR* = 9.50), lack of premeditation (*Median* = 22.50, *IQR* = 8.00), lack of perseverance (*Median* = 21.00, *IQR* = 6.25), sensation seeking (*Median* = 32.00, *IQR* = 11.75), positive urgency (*Median* = 28.50, *IQR* = 16.50).

Bayesian correlations among specific effect, general effect and scores from subscales of UPPS-P were conducted. The results indicated that the data of this experiment did not show PIT effects and impulsivity levels were correlated. Some correlations appeared among subscales (see Table 33). The interscale correlations are in an acceptable range (< 0.6).

Table 33
Correlations among PIT effects and scores in UPPS-P

Variable		Specific effect	General effect	Negative urgency	Premeditation (lack of)	Perseverance (lack of)	Sensation Seeking	Positive urgency
1. Specific effect	BF_{01}	—						
2. General effect	BF_{01}	0.363	—					
3. Negative urgency	BF_{01}	5.313	3.020	—				
4. Premeditation (lack of)	BF_{01}	5.268	4.279	0.029	—			
5. Perseverance (lack of)	BF_{01}	5.325	4.655	0.143	0.009	—		
6. Sensation Seeking	BF_{01}	1.105	0.675	2.491	3.237	5.069	—	
7. Positive urgency	BF_{01}	3.071	3.500	1.060×10^{-7}	1.020×10^{-4}	0.005	0.767	—

Note: BF_{01}> 3: substantial evidence for H0, BF_{01}> 10: strong evidence for H0, BF_{01}> 30: very strong evidence for H0. BF_{01}<0.33: substantial evidence for H1, BF_{01}< 0.1: strong evidence for H1, BF_{01}<0.03: very strong evidence for H1.

Discussion

This experiment was trying to explore how impulsivity may be correlated to specific or general PIT effects with a novel appetitive PIT task. The results of this experiment showed that impulsivity was neither correlated to specific effects nor general effects. This is different from the results that Hinojosa-Aguayo and González (2020) reported in their Experiment 1: negative urgency and positive urgency were negatively correlated to the specific effect. It may be because although there was a significant correlation reported in their results (negative urgency, p= .039; positive urgency, p= .017), the correlation did not appear to be very strong (negative urgency, r= - .26; positive urgency, r= - .30). Besides, the scores from the scale in the current experiment were not normally distributed, therefore, a two-tailed Kendall's tau-b was applied instead of the one-tailed Pearson's coefficient applied in their analysis.

In addition, Hinojosa-Aguayo and González (2020) argued their general effect was partial as the difference score to S3 was below zero. However, in the current experiment, a general effect can be observed clearly. Therefore, this PIT task was used in later experiments to repeat experiments reported by Hinojosa-Aguayo and González (2020) with devaluation procedures included.

4.2 Impulsivity, PIT and devaluation after PIT

Experiment 9

Introduction

Compare with Experiment 8, in the current experiment, a devaluation procedure was added after the transfer task. This procedure was the same as Experiment 1 in Hinojosa-Aguayo and González (2020), with a PIT task that can observe both specific and general effects applied following a devaluation procedure in the current study. If the devaluation effect can be observed, the devaluation procedure would be added before the transfer test in the next experiment. Based on results from Hinojosa-Aguayo and González (2020), I expected higher impulsivity indicating weaker devaluation effects. Also, instead of the long version of UPPS-P, the short version was applied to be consistent with the method in the study of Hinojosa-Aguayo and González (2020).

Method

Design

The design of the PIT task in the current Experiment 9 is the same as in Experiment 8. A devaluation was added after the transfer test, see Table 34.

Table 34
Design of Experiment 9.

Instrumental training	Pavlovian conditioning	PIT Transfer test	Devaluation	Devaluation test	Post-test assessment	Scales
R1-O1	S1-O1	S1: R1, R2		R1?	S1	S-UPPS-P
R2-O2	S2-O2	S2: R1, R2		R2?	S2	
	S3-O3	S3: R1, R2			S3	BIS
	S4-nothing	S4: R1, R2			S4	

Note: S: Stimuli, O: Outcomes, R: Responses.

Participants

In total, 48 participants provided valid data for this study. Among them, there were 19 males and 29 females. Subjects' mean age was 27.0 (*SD* = 5.40, range 20-42).

Materials

PIT task

The procedure of the PIT task was the same as in Experiment 8. Compare with Experiment 8, pictures of devalued outcomes were added in the stage of Devaluation (Figure 29).

Fig.29. Outcomes in devaluation.

Personality Scales

S-UPPS-P

In this task, UPPS-P short version (S-UPPS-P; Cyders et al., 2014) was used. There are 20 items in the short version UPPS-P with 4 items in each subscale.

Barratt Impulsiveness Scale

Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995) contains 30 items to describe an impulsive personality. An example statement is 'I do things without thinking'. A 4-point scale (score 1-4) was used for participants to rate how often they have the stated behaviours, thoughts, or feelings. A higher score indicates stronger impulsiveness.

Procedure

PIT task

Devaluation

In this stage, participants were told that:

‘Well done! in the final cave:
Your friend cannot help you anymore.
It will be super dark, and you won’t see anything.
Please press the keys (z or m) to use the defences, so you can protect yourself in the next two minutes.
Good luck!’

On the next slide, participants were informed that one of the outcomes paired with responses before was broken. The picture of the broken outcome was presented in the centre of the screen. For example:

‘Oh, NO!! Oh, NO!!!!!!!!!
The torch is broken!’

At the same time, a picture of the devalued outcome was presented in the centre of the screen. Then, participants were asked that:

‘*If the original torch is 100% effective, how effective do you think the broken one is? click on the line with your mouse*’

Ratings on a 0% to 100% scale were recorded. As soon as participants answered this question, the devaluation test started. Participants can press the ‘z’ or ‘m’ keys freely for 120 seconds with a fixation cross presented in the centre of the screen. The response rates to each key from participants were recorded.

Personality Scales

After the PIT task, participants first completed the S-UPPS-P scale, and then answered BIS. Questions were presented separately in the centre of the screen. Participants answered questions by clicking on the scale on the screen. The next question started immediately after they click on the scale. This stage finished after the 20 questions in S-UPPS-P and 30 questions in BIS had been answered.

PIT

Data Treatment

The data treatment procedure was the same as that employed for Experiment 1.

Specific Effect

The difference scores in the congruent and incongruent conditions are presented in Figure 30. The figure suggests that participants had greater difference scores in the congruent condition than in the incongruent condition. This impression was supported by results of a conditions (congruent, incongruent) x blocks within ANOVA, which showed significant difference in main effect of conditions, F (1,47) = 29.681, p< .001, MSE = 146846.742, η_P^2 = .387. The main effect of blocks, F <1, and the interaction between conditions and blocks, F (2,94) = 1.751, p= .179, MSE = 25113.364, were not significant. This suggests a specific effect has been observed across all first three blocks.

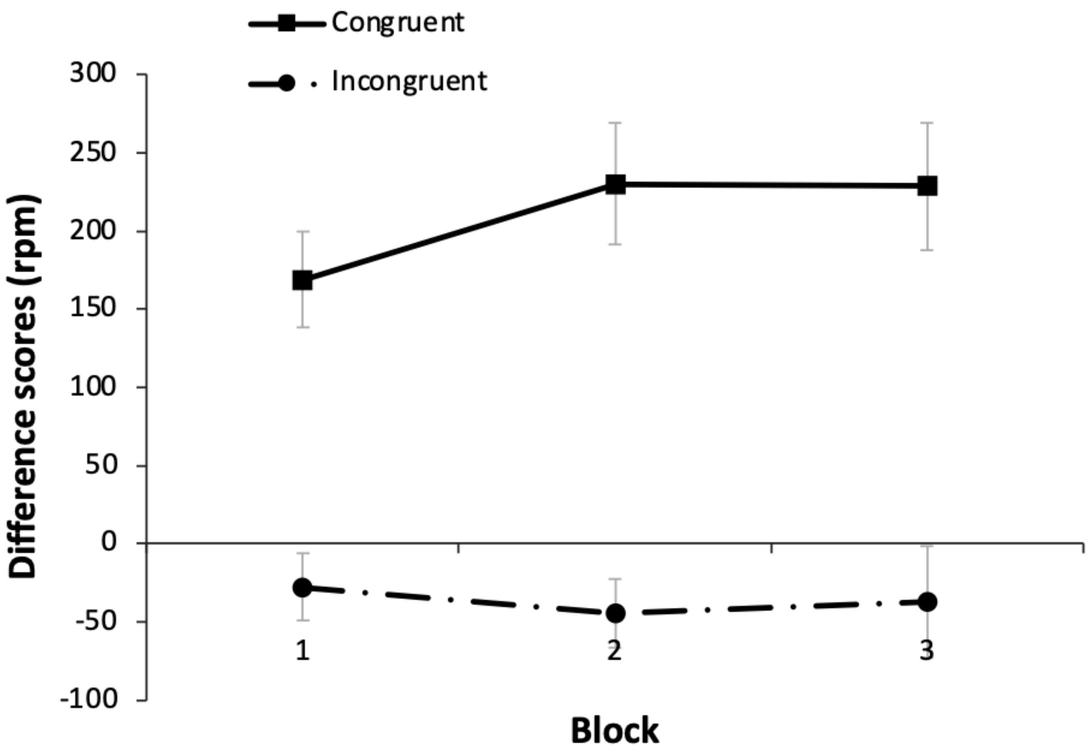

Fig.30. Mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 9. Error bars represent standard errors.

The mean response rate per minute in the congruent and incongruent conditions during the preCS period is shown in Table 35. Response rates in the preCS stage were analysed by using a conditions (congruent, incongruent) x blocks repeated measures ANOVA. The main effect of conditions, F (1,47) = 3.077, p= .086, MSE = 27984.309, η_P^2 = .061, was not significant. Neither was the main effect of blocks, or the interaction between conditions and blocks, Fs<1.

Table 35

conditions	block1	block2	block3
Congruent	68.75(22.58)	50.31(25.29)	38.44(17.96)
Incongruent	104.38(33.07)	72.50(24.61)	84.38(29.99)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 9. Standard deviations are shown in brackets.

General Effect

The difference scores per minute in the S3 and S4 conditions are presented in Figure 31. The figure implies that participants had greater difference scores in the S3 condition than in the S4 condition. This suggestion was supported by results from a conditions (S3, S4) x blocks within ANOVA: the main effect of conditions was significant, F (1,47) = 5.632, p= .022, MSE = 39261.436, η_P^2 = .107, and it interacted with blocks significantly, F (2,94) = 3.477, p= .035, MSE = 27333.095, η_P^2 = .069. However, the main effect of blocks, F (2,94) = 1.564, p= .215, MSE = 12862.882, was not significant. The Post-hoc tests (Holm) showed the score in the incongruent condition in block 2 was lower than other scores (incongruent in block 1, p=.032, congruent in block 2, p=.032, congruent in block 3, p=.036). Nothing else was significant (smallest p= .655). The results above suggest that the difference scores in the S3 condition were larger than in the S4 condition. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (47) = .251, p = .803.

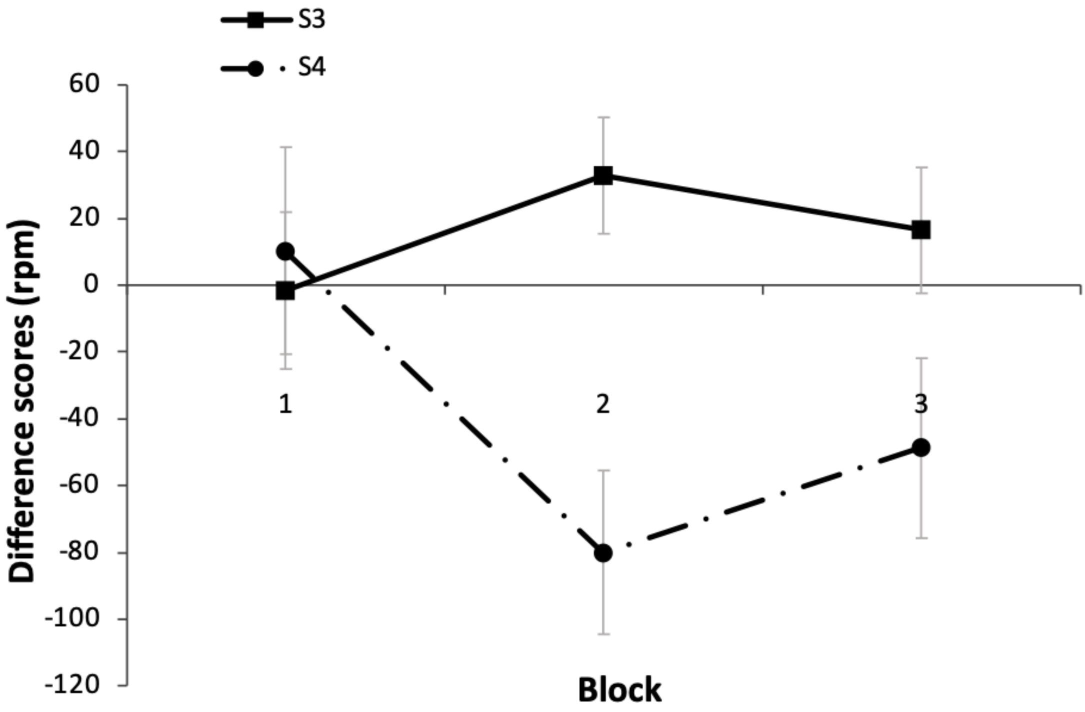

Fig.31. Mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 9. Error bars represent standard errors.

The mean response rate per minute in the S3 and S4 conditions during the preCS period is shown in Table 36. The preCS response rate was analysed using conditions (S3, S4) x blocks within ANOVA. Neither the main effect of conditions, F (1,47) = 1.016, p= .319, MSE = 36196.260, or the main effect of blocks, F (2,94) = .149, p= .862, MSE = 13753.923, nor the interaction between conditions and blocks, F (2,94) =2.318, p= .104, MSE = 27927.660, was significant. This suggests before the stimuli were presented, there were no differences between the response rates for S3 and S4 over blocks. Results in a paired sample t-test showed that the number of responses to R1 and R2 was not different, t (47) = 1.692, p = .097.

Table 36

conditions	block1	block2	block3
S3	84.06(28.55)	40.63(11.86)	61.25(22.82)
S4	56.25(25.27)	116.56(32.95)	80.94(27.02)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 9. Standard deviations are shown in brackets.

PIT and Personality

In the devaluation procedure, most of the participants (36 out of 48) showed the correct direction in the devaluation effect (devalued R < non-devalued R). Because this study aimed to explore how impulsivity correlated to the devaluation effect, the participants who did not learn the devaluation procedure well (devalued R >= non-devalued R) were excluded, leaving data from 36 participants. Since the sample size was small (n = 36), a Shapiro-Wilk test for multivariate normality was used in choosing an appropriate statistical method. The results showed that the distribution departed significantly from normality (W = 0.842, p < .001). Therefore, the median with the interquartile range were used to summarize the impulsivity scales: S-UPPS-P (*Median* = 43.50, *IQR* = 7.25), BIS (*Median* = 63.00, *IQR* = 12.50).

A Bayesian correlation was conducted among specific effect, general effect, devaluation effect and scores from two scales were presented in Table 37. The default prior option was used (stretched beta prior width was 1). It can be seen from Table 37 that Bayes factors (BF_{01}) ranged 1-5 between an effect (specific or general or devaluation) and the score from a scale (S-UPPS-P or BIS), which showed weak to substantial evidence to support H_0, according to Jeffreys (1961). This result indicated there was no relationship between any of the effects and impulsivity scores from subscales of UPPS-P or BIS. However, there was strong evidence that supported the specific effect and the devaluation effect is positively correlated (τ_b = 0.345, BF_{01} = 0.067). Some correlations among subscales appeared. The interscale correlations are in an acceptable range (< 0.6).

Table 37

Correlations among PIT effects and impulsivity scores

Variable		Specific effect	General effect	devaluation	negative urgency	positive urgency	sensation seeking	lack of premeditation	lack of perseverance	attention	cognitive instability	motor	perseverance	self-control	cognitive complexity
1. Specific effect	BF_{01}	—													
2. General effect	BF_{01}	1.176	—												
3. devaluation	BF_{01}	0.067	3.688	—											
4. negative urgency	BF_{01}	4.276	3.853	1.995	—										
5. positive urgency	BF_{01}	4.099	2.850	3.605	2.046	—									
6. sensation seeking	BF_{01}	4.630	4.458	4.383	4.508	4.609	—								
7. lack of premeditation	BF_{01}	4.619	4.630	4.072	4.506	0.038	4.399	—							
8. lack of perseverance	BF_{01}	2.289	1.427	2.411	4.368	0.057	0.728	0.002	—						
9. attention	BF_{01}	4.563	4.604	4.509	3.356	3.308	0.456	0.763	2.658	—					
10. cognitive instability	BF_{01}	3.644	2.761	1.109	4.306	0.648	4.566	0.195	0.076	0.258	—				
11. motor	BF_{01}	1.969	4.564	3.516	4.102	0.036	2.893	1.511	3.934	0.054	0.180	—			
12.perseverance	BF_{01}	3.500	4.450	4.471	0.930	3.820	3.528	4.060	4.473	0.313	3.187	0.060	—		
13. self-control	BF_{01}	4.337	3.978	3.503	4.344	0.034	4.087	0.120	0.742	0.078	4.577	1.182	0.264	—	
14. cognitive complexity	BF_{01}	4.594	2.671	4.585	2.481	3.490	1.191	4.322	4.350	2.578	2.992	0.860	0.049	0.729	—

Note: $BF_{01} > 3$: substantial evidence for H0, $BF_{01} > 10$: strong evidence for H0, $BF_{01} > 30$: very strong evidence for H0. $BF_{01} < 0.33$: substantial evidence for H1, $BF_{01} < 0.1$: strong evidence for H1, $BF_{01} < 0.03$: very strong evidence for H1.

Discussion

The aim of this experiment was to explore correlations between impulsivity and PIT or devaluation effects. The results of this experiment showed that impulsivity was neither correlated to PIT effects nor the devaluation effect. In this experiment, a devaluation procedure after the PIT task was piloted and most (36 out of 48) of the participants showed a devaluation effect. The strong positive correlation between the specific effect and the devaluation effect indicated that participants who show stronger specific effects were the ones who were more sensitive about the values of the outcomes.

The results did not show any correlation between any PIT effect and any subscale scores in impulsivity. This was the same as the results in the last Experiment 8. The devaluation effect did not show a correlation with impulsivity. This is different from what Hinojosa-Aguayo and González (2020), reported in their Experiment 1— the devaluation effect was negatively correlated to negative urgency while the specific effect was negatively correlated to both negative and positive urgency. This may be because a one-tail Pearson's coefficient was applied in their analysis while the current experiment used a two-tailed Kendall's tau-b. However, the correlations were not significant when applying the same analysis to the data from the current experiment. Also, although significant correlations were observed in their study, the correlation appeared to be weak (r = - .29 between devaluation and negative urgency; r = - .26 between specific effect and negative urgency; r = - .30 between specific effect and positive urgency). Overall, the results of this experiment did not show evidence that impulsivity correlated to PIT effects or the devaluation effect.

4.3 Impulsivity and Devaluation Effects on PIT Effects

Experiment 10

Introduction

So far, specific PIT effects, general PIT effects, and devaluation effects were all observed in previous experiments. To measure the changed size of PIT effects by devaluation (devaluation effect on PIT effects), in Experiment 10, a devaluation procedure was placed before the transfer tests. Therefore, the correlations between impulsivity and devaluation effects on both PIT effects could be analysed. The design of this experiment was the same as Experiment 2 in Hinojosa-Aguayo and Gonzalez (2020). Aiming to improve their task, male participants were included, the age range of participants was widened, a PIT task with proper specific and general effects was applied, and a devaluation effect on general PIT was expected to be observed. The correlations between impulsivity levels and the devaluation effect on PIT effects were analysed.

Method

Design

The design of the appetitive PIT task in the current Experiment 10 was the same as the one in Experiments 8 and 9. Different from Experiment 9, a devaluation procedure was placed after instrumental conditioning and Pavlovian conditioning, before the transfer test (see Table 38 below). In the devaluation procedure, one of the two outcomes used in the instrumental stage was devaluated and counterbalanced among conditions.

Table 38
Design of Experiment 10.

Instrumental training	Pavlovian conditioning	Devaluation	PIT Transfer test	Post-test assessment	Personality scales
R1-O1	S1-O1	O1 devalued	S1: R1, R2	S1	S-UPPS-P
R2-O2	S2-O2		S2: R1, R2	S2	
	S3-O3		S3: R1, R2	S3	BIS
	S4-nothing		S4: R1, R2	S4	

Note: S: Stimuli, O: Outcomes, R: Responses.

Participants

All the participants were recruited via the Prolific online platform. Participants were adults with normal or corrected-to-normal vision and have undergraduate or graduate degrees. In total, 123 participants completed this experiment, data from 9 participants were excluded since they failed the Pavlovian learning stage, and data from 18 participants were excluded since they failed devaluation learning (see Results section). Finally, data from 96 participants were used. Among them, there were 28 males, 67 females and one did not report sex. The mean age was 27.81 (*SD*=5.33) ranging from 21 to 45 years old.

Materials

Same as Experiment 9.

Procedure

PIT task

The only difference with Experiment 9 was that the devaluation procedure was before the transfer test.

Devaluation Procedure

After instrumental training and Pavlovian conditioning, participants were told that:

'Oh, NO!! Oh, NO!!!!!!!!!!
The shield is broken! It cannot protect you anymore!'

In the meantime, a picture of devalued outcome was presented in the centre of the screen.

Then the transfer test started immediately.

Results

Data Treatment

To make sure that an instrumental devaluation effect can be observed in this experiment, data from participants who gave more devalued responses than non-devalued responses in CS + preCS stage were deleted. Finally, 96 participants, two in each condition, were used. The data treatment procedure for PIT effects was the same as in previous experiments.

The devalued outcome can influence both the response it is paired with in the instrumental stage and the stimulus that it paired with in the Pavlovian stage. In this experiment, the success in observing instrumental devaluation was controlled as described in the paragraph above, and whether there was a Pavlovian devaluation was analysed.

To explore the devaluation effect in specific effects, responses were separated into R1S1 (response rates of R1 when S1 was presented), R2S1, R1S2, and R2S2. Half of the 48 participants experienced O1 devaluation, the other half experienced O2 devaluation. In instrumental devaluation, if O1 was the devalued outcome: devalued responses (r.dev) = R1S1-R1S2; non-devalued responses (r. nondev) = R2S1-R2S2. If O2 was the devalued outcome: devalued responses (r.dev) = R2S1-R2S2; non-devalued responses (r. nondev) = R1S1-R1S2. In Pavlovian devaluation, if O1 was the devalued outcome, devalued responses (cue.dev) = R1S1-R2S1; non-devalued responses (cue. nondev) = R1S2-R2S2. If O2 was the devalued outcome: devalued responses (cue.dev) = R1S2-R2S2; non-devalued responses (cue. nondev) = R1S1-R2S1.

For general effect, O3 or O4 cannot influence the stimuli (S3, S4) in the Pavlovian stage as they were not devalued, therefore, only instrumental devaluation can be analysed. To explore the devaluation effect on the general effect, responses in the CS-preCS stage were separated into R1S3 (response rates of R1 when S3 was presented), R2S3, R1S4, and R2S4. In instrumental devaluation, if O1 was the devalued outcome: devalued responses (r.dev) = R1S3-R1S4; non-devalued responses (r. nondev) = R2S3-R2S4. If O2 was the devalued outcome: devalued responses (r.dev) = R2S3-R2S4; non-devalued responses (r. nondev) = R1S3-R1S4.

PIT

Instrumental Devaluation Effect on Specific Effect

Figure 32 below shows that difference scores in congruent conditions were always higher than the scores in the incongruent conditions, and the scores in the non-devaluation conditions were always higher than the scores in the devaluation conditions. This impression was supported by results from a values (devaluation, non-devaluation) x conditions (congruent, incongruent) x blocks within ANOVA. The main effect of conditions, *F* (1,95) =57.840, *p*< .001, *MSE* = 182.170, η_P^2 = .378, and the main effect of values, *F* (1,95) =5.461, *p* = .022, *MSE* = 74.362, η_P^2 = .054, were significant. The main effect of blocks and the interactions were not significant. These results suggest that a stable specific effect and a stable devaluation effect were observed. However, the specific PIT effects showed no difference in size in devalued and non-devaluation conditions.

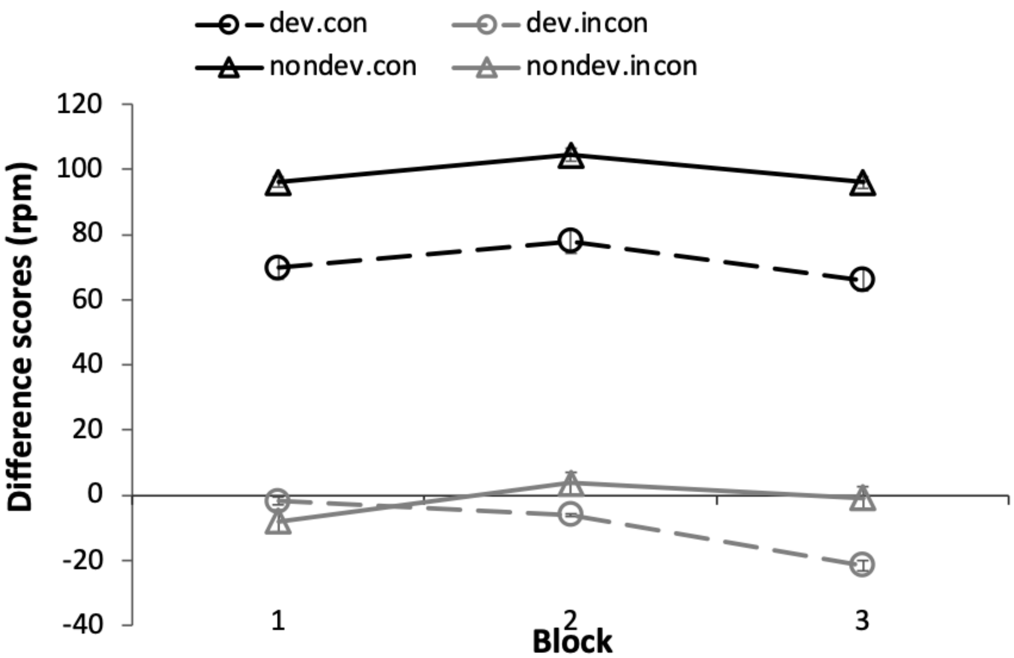

Fig.32. Mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 10. Error bars represent standard errors.

Table 39 below presented the response rates in the preCS stage is devalued.congruent (dev.con), devalued.incongruent (dev.incon), non-devalued.congruent (nondev.con) and non-devalued.incongruent (nondev.incon) conditions. A values (devaluation, non-devaluation) x conditions (congruent, incongruent) x blocks within ANOVA was conducted. The main effects and all the interactions were not significant (largest F (1,95) =3.729, p = .056, MSE = 17.477, for the main effect of conditions). These results suggest that during the preCS stage, there was no specific effect or devaluation effect.

Table 39

conditions	block1	block2	block3
dev. congruent	29.38(10.74)	31.72(11.01)	26.09(7.78)
dev.incongruent	34.38(13.01)	32.97(11.09)	32.34(10.89)
nondev.congruent	11.25(3.08)	15.31(4.40)	34.53(10.04)
nondev.incongruent	23.28(5.80)	21.09(5.03)	47.03(13.79)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 10. Standard deviations are shown in brackets.

Pavlovian Devaluation of Specific Effect

Figure 33 below shows that difference scores in congruent conditions are always higher than the scores in incongruent conditions. A values (devaluation, non-devaluation) x conditions (congruent, incongruent) x blocks within ANOVA was conducted. The main effect of conditions, F (1,95) =57.840, p< .001, MSE = 182.170, η_P^2 = .378, and the interaction between conditions and values, F (1, 95) = 5.461, p= .022, MSE = 74.362, η_P^2 = .054, were significant with small effect size. The main effect of values and other interactions was not significant (largest F = 3.422, p= .067, MSE = 35.482, for the main effect of values). Simple main effects analysis revealed that the difference scores between congruent and incongruent conditions can be observed on both non-devalued and devalued conditions, ps < .001. Post-hoc tests (Holm) showed that, in the congruent condition, rates in the non-devaluation condition were higher than rates in the devaluation condition, p= .007, while in the incongruent condition, rates in the devaluation condition showed no difference with the rates in the non-devaluation condition, p= .385. These results suggest that a stable specific effect was observed, and the devaluation effect decreased specific PIT. Specific PIT in non-devaluation conditions is larger than in the devalued conditions. Since the effect size was small, it might necessitate validation in other independent studies to test the reliability and generalizability of the results.

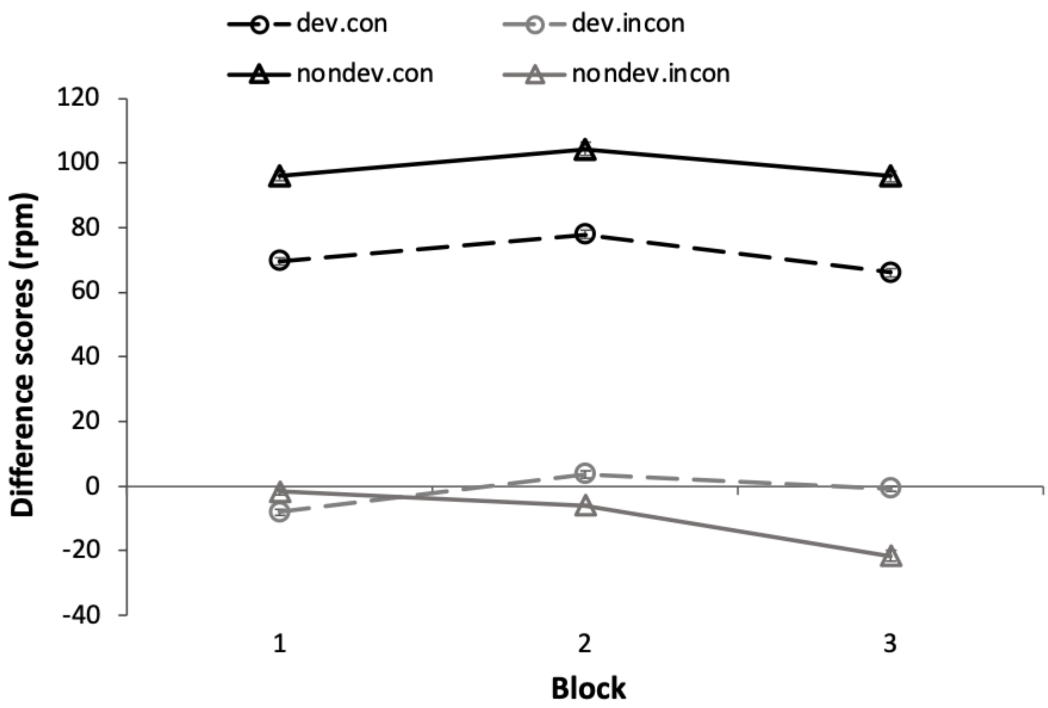

Fig.33. Mean difference scores in the congruent and incongruent conditions over the first three test blocks of Experiment 10. Error bars represent standard errors.

Table 40 shows that response rates in the congruent conditions may be lower than the rates in the preCS stage. A values (devaluation, non-devaluation) x conditions (congruent, incongruent) x blocks within ANOVA was conducted. The main effects and all the interactions were not significant (largest F = 3.729, p= .056, MSE = 17.477, for the main effect of conditions). These results suggest that during the preCS stage, there was no specific effect or devaluation effect.

Table 40

conditions	block1	block2	block3
dev.congruent	29.38(10.74)	31.72(11.01)	26.09(7.78)
dev.incongruent	23.28(5.80)	21.09(5.03)	47.03(13.79)
nondev.congruent	11.25(3.08)	15.31(4.40)	34.53(10.04)
nondev.incongruent	34.38(13.01)	32.97(11.09)	32.34(10.89)

Note. Mean preCS response rates (number of responses per minute) in the congruent and incongruent conditions over the first three test blocks of Experiment 10. Standard deviations are shown in brackets.

Devaluation of General Effect

Figure 34 below presented the difference scores in four conditions: devalued S3 (dev.S3), devalued.S4 (dev.S4), non-devalued.S3 (nondev.S3) and non-devalued.S4 (nondev.S4). The picture shows that scores in the S3 conditions were higher than the scores in the S4 conditions. A value (devaluation, non-devaluation) x conditions (S3, S4) x blocks ANOVA was conducted. The main effect of conditions, F (1,95) = 21.747, p< .001, MSE = 44.175, η_P^2 = .186, and the interaction between conditions and values, F (1, 95) = 6.282, p= .014, MSE = 70.045, η_P^2 = .062, were significant. The main effect of values was not significant, F<1. Nothing else was significant (largest F=1.294, p= .277, MSE = 75.668, η_P^2 = .013 for the interaction among conditions, values and blocks). Simple main effects analysis revealed that the difference scores between S3 and S4 conditions can be observed on non-devalued conditions, p < .001, but not on devalued conditions, p= .174. This suggests that the devaluation abolished the general PIT effect, and this can be the reason the main effect of values was not significant.

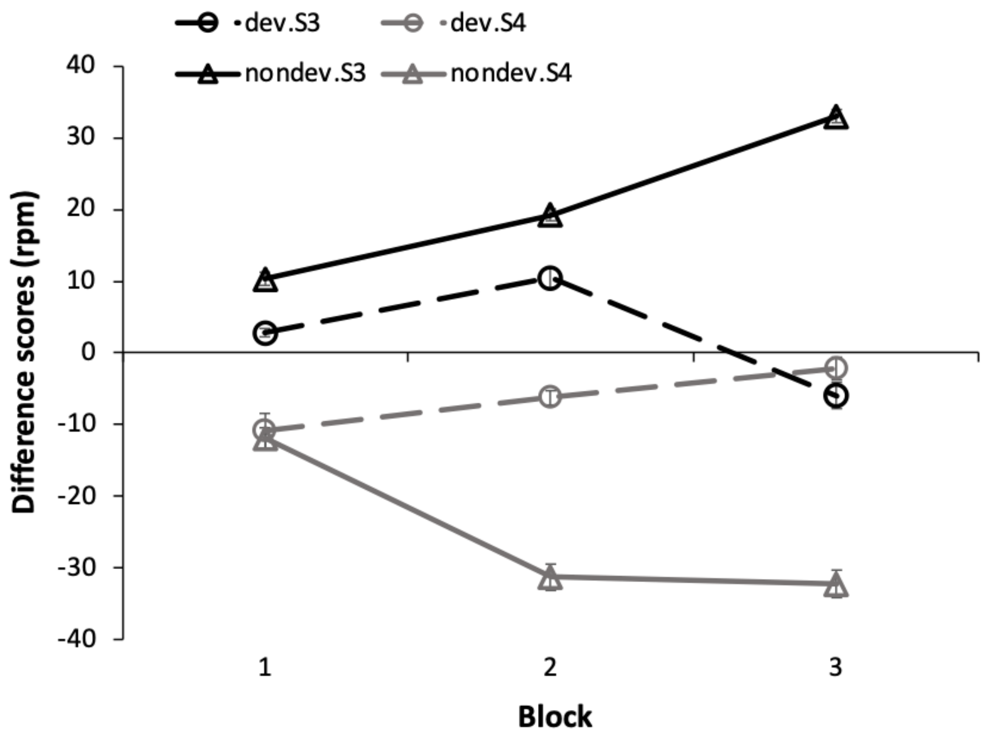

Fig.34. Mean difference scores in the S3 and S4 conditions over the first three test blocks of Experiment 10. Error bars represent standard errors.

Table 41 below showed the response rates in the preCS stage in devalued.S3 (dev.S3), devalued.S4 (dev.S4), non-devalued.S3 (nondev.S3) and non-devalued.S4 (nondev.S4) conditions. A values (devaluation, non-devaluation) x conditions (S3, S4) x blocks within ANOVA was conducted. The main effect of conditions was significant with small effect size, F (1,95) = 4.502, p= .036, MSE = 34.334, η_P^2 = .045. Nothing else was significant, largest F (1,95) = 1.139, p= .289, MSE = 79.042, for the main effect of values. These results suggest participants responded to S4 more than S3 in the preCS stage. This difference may result in the enlarged general effect by analysing difference scores, although there was no general effect observed in preCS period. Therefore, an analysis in CS stage was conducted to check if the general effect appeared.

Table 41

conditions	block1	block2	block3
dev.r.S3	32.03(12.51)	20.47(5.54)	35.94(12.82)
nondev.r.S3	33.59(11.52)	35.16(9.88)	31.72(11.55)
dev.r.S4	35.94(14.50)	30.00(10.70)	42.34(14.70)
nondev.r.S4	45.47(16.23)	54.69(16.35)	46.41(13.69)

Note. Mean preCS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 10. Standard deviations are shown in brackets.

Table 42 below showed the response rates in the CS stage in devalued.S3 (dev.S3), devalued.S4 (dev.S4), non-devalued.S3 (nondev.S3) and non-devalued.S4 (nondev.S4) conditions. A values (devaluation, non-devaluation) x conditions (S3, S4) x blocks within ANOVA was conducted. The main effect of conditions was significant, F (1,95) = 7.918, p= .006, MSE = 43.510, η_P^2 = .077, and it interacted with values, F (1,95) = 4.010, p= .048, MSE = 64.057, η_P^2 = .041. Nothing else was significant, Fs<1. Simple main effects analysis revealed that the difference scores between S3 and S4 conditions can be observed on non-devalued conditions, p = .004, but not on devalued conditions, p= .778. These results were consistent with the results by analysing difference scores, suggested that the general effect appeared in CS period, and devaluation abolished the general PIT effect.

Table 42

conditions	block1	block2	block3
dev.r.S3	34.84(8.27)	30.94(7.85)	30.00(7.58)
nondev.r.S3	43.91(11.50)	54.38(8.04)	64.69(11.09)
dev.r.S4	25.16(9.87)	23.75(8.30)	40.16(10.24)
nondev.r.S4	33.59(9.91)	23.44(10.62)	14.22(8.95)

Note. Mean CS response rates (number of responses per minute) in the S3 and S4 conditions over the first three test blocks of Experiment 10. Standard deviations are shown in brackets.

Overall, devaluation abolished general PIT (first three blocks), diminished Pavlovian-directed devaluation of specific PIT, and left instrumental-directed devaluation of specific PIT intact.

Devaluation of PIT and Impulsivity

The correlations between the effects (instrumental devaluation effect on specific effect, Pavlovian devaluation effect on specific effect, devaluation effect on general effect) in the first three blocks and impulsivity scores (S-UPPS-P: *Median* = 44.00, *IQR* = 12.00; BIS: *Median* = 64.00, *IQR* = 15.25) were analysed.

The specific effect was equal to the difference scores of response rates (number of responses per minute) in the congruent conditions minus the difference scores in the incongruent conditions. The general effect was equal to the difference scores of response rates in the S3 conditions minus the difference scores in the S4 conditions. The devaluation effect was equal to the difference scores of response rates in non-devaluation conditions minus difference scores in devaluation conditions. Therefore, the instrumental devaluation effects on specific effects (r.dev) or Pavlovian devaluation effects on specific effects (cue.dev) was equated to [(nondev. con - dev.incon) - (dev.con - nondev.incon)]. The devaluation effects on general effects (dev.general) were equated to [(nondev. S3 - dev.S4) - (dev.S3 - nondev.S4)].

A Bayesian correlation was conducted and presented in Table 43. The default prior option was used (stretched beta prior width was 1). Bayes factors (BF_{01}) ranged smaller than 0.1 between other effects and impulsivity scores, which indicated strong evidence to support H_1. Results were strongly evident that instrumental devaluation effect on specific effect was negatively correlated to negative urgency (τ_b = - .229, BF_{01} = 0.035). Some correlations among subscales appeared. The interscale correlations are in an acceptable range (< 0.6).

Table 43

Bayesian Correlations

Variable		r.specific	cue. specific	general	negative urgency	lack of premeditation	lack of perseverance	sensation seeking	positive urgency	attention	cognitive instability	motor	perseverance	self-control	cognitive complexity
1. r.specific	BF_{01}	—													
2. cue. specific	BF_{01}	2.315×10^{-4}	—												
3.general	BF_{01}	1.498	5.700	—											
4. negative urgency	BF_{01}	0.035	1.909	6.707	—										
5. lack of premeditation	BF_{01}	5.848	7.505	7.251	1.102	—									
6. lack of perseverance	BF_{01}	4.976	3.939	7.502	5.543	7.506×10^{-7}	—								
7. sensation seeking	BF_{01}	4.143	5.672	7.064	5.069	3.820	2.017	—							
8. positive urgency	BF_{01}	2.148	3.052	6.299	0.035	3.572×10^{-5}	0.146	0.003	—						
9. attention	BF_{01}	4.730	5.772	7.374	0.550	0.006	0.465	3.786	0.164	—					
10.cognitive instability	BF_{01}	4.726	4.217	7.455	4.255	0.669	5.138	0.910	0.009	0.002	—				
11.motor	BF_{01}	1.281	6.549	6.215	4.412	0.475	2.264	6.931	2.447	9.904×10^{-7}	0.074	—			
12. perseverance	BF_{01}	6.246	5.598	6.085	6.796	1.959	0.948	5.989	4.946	0.076	0.476	0.001	—		
13. self-control	BF_{01}	7.457	6.798	6.974	0.178	0.135	1.718	4.369	1.810	5.987×10^{-9}	2.288	4.268×10^{-5}	0.031	—	
14. cognitive complexity	BF_{01}	6.904	6.026	7.505	2.988	0.036	6.368×10^{-5}	7.348	2.992	2.094×10^{-6}	3.444	0.003	0.007	5.846×10^{-6}	—

Note: BF_{01}> 3: substantial evidence for H0, BF_{01}> 10: strong evidence for H0, BF_{01}> 30: very strong evidence for H0. BF_{01}<0.33: substantial evidence for H1, BF_{01}< 0.1: strong evidence for H1, BF_{01}<0.03: very strong evidence for H1. r.specific=instrumental devaluation effect on specific effect; cue. Specific=Pavlovian devaluation effect on specific effect; general=devaluation effect on general effect.

Discussion

This experiment aimed to explore how impulsivity correlated to the devaluation effect on PIT effects. Specific or general PIT effects were observed in all the non-devaluation conditions. The results of the current experiment suggested that the devaluation effect eliminated the general effect, Pavlovian-directed devaluation diminished the specific effect and instrumental-directed devaluation left the specific effect unaffected. The finding that devaluation abolished general PIT was in line with previous findings reported by Corbit et al. (2007) and Aitken et al. (2016). However, in this experiment, this phenomenon is potentially an artefact of the devaluation effect. As O1 was devalued, response rates of R1 were low. This can be the reason that the general effect in the devaluation group (equal to R1S3-R1S4) appeared to be abolished. In the meantime, the response rates of R2 were not affected by the devaluation procedure. Therefore, the general effect in the non-devaluation group (equal to R2S3-R2S4) was observed. Results also showed that Pavlovian-directed devaluation weakened specific PIT. This may be because of an artefact of response devaluation. When O1 was devalued, response rates of R1 were low while response rates of R2 were high. The specific effect in the devalued condition was equal to R1S1-R2S1. Without taking stimuli into account, R1-R2 result in a small PIT as using a low number to minus a high number. On the opposite, in the non-devalued condition, R2S2-R1S2 result in a large PIT as high R2 minus low R1 when not taking stimuli into account. Therefore, a smaller PIT effect in the devalued condition could be down to response levels. Applying instrumental-directed devaluation on specific PIT aimed to repeat the previous study (Experiment 2; Hinojosa-Aguayo & Gonzalez, 2020). However, the results in the current experiment did not show that instrumental-directed devaluation was able to affect specific PIT.

The results from correlations showed that the instrumental-directed devaluation effect on the specific effect was negatively correlated to negative urgency. It seems the same as the results reported by Hinojosa-Aguayo and Gonzalez (2020), however, in the current experiment, the instrumental-directed devaluation did not affect the specific effect. Therefore, the negative correlation between negative urgency and the effect in the current experiment may only indicate that individuals with high negative urgency traits are less sensitive to devaluation. In this experiment, correlations between impulsivity and the Pavlovian-directed devaluation of specific PIT or devaluation effect on general PIT were not significant. The results above indicated impulsivity levels may not be a factor that influenced participants' sensitivity to the values of outcomes in PIT.

General Discussion

There were three experiments in Chapter IV that explored the relationships between impulsivity and PIT. The results did not show a correlation between impulsivity and PIT effects, however, negative urgency (a subtrait in impulsivity) negatively correlated to devaluation in specific PIT. Both specific and general PIT effects were observed in the appetitive PIT task in Experiment 8, and the effects were not correlated to self-report scores from the UPPS-P scale. In Experiment 9, the same appetitive PIT task was applied with a devaluation procedure after the transfer test. The results showed that neither the PIT effects nor the devaluation effect were correlated to scores from impulsivity scales of S-UPPS-P or BIS. In Experiment 10, a devaluation procedure was applied before the transfer test in the appetitive PIT task. The results showed that instrumental-directed devaluation left specific PIT unaffected, Pavlovian-directed devaluation decreased specific PIT, and devaluation abolished general PIT. Also, instrumental-directed devaluation on specific PIT was negatively correlated to negative urgency.

The results in Experiments 8 and 9 did not repeat the results reported in Experiment 1 in previous research by Hinojosa-Aguayo and Gonzalez (2020). This may be because the observed correlation in their study appeared not strong, and difficult to be repeated with both nonparametric correlations reported in the current experiment and the same analysis used by previous researchers. The results in Experiment 10 showed that Pavlovian-directed devaluation on specific PIT was decreased, and devaluation on general PIT was abolished. This may be because of an artefact of response devaluation. The results also showed that instrumental-directed devaluation on specific PIT was negatively correlated to negative urgency, which seems to be repeated results reported in Experiment 2 by Hinojosa-Aguayo and Gonzalez (2020). However, as the instrumental-directed devaluation left specific PIT unaffected in Experiment 10, the current study came to a different conclusion — negative urgency negatively correlated to the devaluation effect.

The contribution of this study was that, with a standard PIT task that can study both specific and general effects, the correlations between impulsivity and the general effect or devaluation on general PIT were able to be explored. Overall, there was no evidence that impulsivity correlated to PIT effects, however, instrumental-directed outcome devaluation was negatively correlated to negative urgency.

Chapter V: General Discussion

5.1 Summary of Results

5.1.1 Chapter II: Avoidance-based and Appetitive PIT tasks

The aim of the two experiments in chapter II was to develop appetitive and aversive PIT tasks that can demonstrate both specific and general effects in humans. Two types of PIT tasks were conducted — an avoidance-based PIT and an appetitive PIT. Both PIT tasks followed the procedure of a standard design: instrumental training, Pavlovian conditioning, and transfer test. In the instrumental stage, participants learnt the associations of R1-O1 and R2-O2. In the Pavlovian stage, the four stimuli were paired with the four outcomes (S1-O1, S2-O2, S3-O3, S4-nothing). In the transfer stage, the stimuli were presented randomly without outcomes and the number of responses was recorded. The two PIT tasks used the same cover story (an adventure game to explore caves), the same stimuli (different coloured squares) and the same responses ('z' and 'm' keys). There were some differences between the two PIT tasks. In Pavlovian conditioning, the outcomes were aversive in the avoidance-based PIT while the outcomes were appetitive in the appetitive PIT. The instrumental conditioning in the avoidance-based PIT was avoidance learning (responding to destroy the aversive outcomes), while it was positive reinforcement in appetitive PIT (responding to get rewards).

The observed PIT effects could be either specific or general. The results of the two PIT tasks all showed that participants pressed R1 more than R2 when S1 was present and pressed more R2 than R1 when S2 was present. This indicates specific PIT effect was observed. Also, the response to S3 was more (R1+R2) than to S4. This indicates general PIT effect was observed. These effects could be observed by analysing difference scores (in the CS-preCS stage) and could not be observed when checking the preCS stage (during the period when no stimuli were present). The results indicated that stimuli presented in the previous Pavlovian stage influenced participants' instrumental behaviour.

Overall, both specific and general PIT effects were observed in the novel avoidance-based and appetitive PIT tasks. It was not easy to observe general effects in standard PIT tasks in humans. The current tasks addressed this issue and presented stable PIT effects. These two tasks were ready to be used in further experiments to explore how personality factors can influence PIT effects in humans.

5.1.2 Chapter III: Stress/Anxiety and Avoidance-based PIT

The experiments in Chapter III aimed to explore the relationship between anxiety and PIT. There were five experiments in Chapter III, which all used the avoidance-based PIT task. In Experiments 3 and 4, self-report questionnaires were used to measure anxiety or stress levels. Experiments 5, 6 and 7 used the stress mood induction procedures to change the participants' stress levels and compared their performance in PIT with the non-stressed group.

In Experiment 3, both specific and general PIT effects were observed. Classical correlations showed that the general effect was positively correlated to scores on the Generalised Anxiety Disorder Assessment (GAD-7), but not scores on the other two anxiety scales (Anxiety and stress subscales in Depression Anxiety Stress Scales; DASS and State Anxiety Scale in State-Trait Anxiety Inventory; STAI). Although the correlation was significant, the correlation coefficient was weak (r= .275). To be able to check if the significant result was reliable, the study was repeated and improved in Experiment 4. Scales in measuring both anxiety and depression were included, and Bayesian correlation was applied. The results showed that both specific and general PIT effects were observed. The results did not show that effects and scores from scales were correlated. The Bayes factor represents moderate evidence in favour of the null hypothesis.

There wasn't enough variation in anxiety in Experiments 3 and 4, which may result in correlations undiscovered. Therefore, in Experiments 5, 6, and 7, stress mood induction procedures were applied to enlarge the anxiety levels. In experiment 5, an online mood induction procedure was placed after instrumental and Pavlovian conditioning, and before the transfer test. Participants in the stress group listened to heavy metal music and watched aversive pictures, while participants in the neutral group listened to café background voice and watched pictures of objects. Participants completed a visual analogue scale immediately after the transfer test, which measured negative feelings including feeling bad, anxious, aroused, sad or annoyed at that moment. The results showed that participants in the stress group felt generally worse, more aroused, and sadder than the participants in the neutral group, but the anxiety or annoyance levels showed no differences. There were no differences in the specific and general effects between the stress and the neutral groups. These results may be because the anxiety levels between groups were not large enough. Therefore, in Experiment 6, a positive group was included — participants who listened to classical music and looked at pictures of baby animals. Also, the mood induction procedures were moved to the beginning of the experiment, as it is possible anxiety can influence performance in the transfer test by influencing learning in Pavlovian or instrumental conditioning. The self-report questionnaire in experiment 5 was novel. To improve the study, the 6-item STAI, which measured feelings at the moment, used in previous research (i.e., in Sayette et al., 2001) was applied. The STAI was presented three times: at the beginning of the experiment, immediately after mood induction, and at the end of the experiment. The results showed that stress mood induction increased the anxiety level in the stress group, but the high anxiety level did not last till the end of the experiment. Both specific and general effects appeared in the three groups, but the effects showed no difference among the groups. That mood induction did not influence anxiety levels long may because participants completed the online task in a familiar environment which helped them relax and limit the effectiveness of mood manipulations. To improve it, in experiment 7, an in-lab study was conducted, and the mood induction procedures were changed to a speech stressor task in the stress group, reading magazines in the neutral group, and relaxation techniques in the positive group. The results showed that anxiety in the stress group was higher than in the relax group, but not in the neutral group. Both specific and general effects were observed and there were no differences in the PIT effects among groups.

Overall, both specific and general effects can be studied in the novel avoidance-based PIT task. The results from experiments 3 and 4 showed that PIT effects did not correlate to anxiety scores, and the results from experiments 5-7 showed that mood-induced high anxiety did not affect specific or general effects. These results indicated that the phenomenon that anxiety influenced addictive behaviour may not be because anxiety influences PIT effects.

5.1.3 Chapter IV: Impulsivity and Appetitive PIT

The experiments in Chapter IV aimed to explore the relationship between impulsivity and PIT. There were three experiments in Chapter IV, which all used the novel appetitive PIT task. In Experiment 8, participants completed the standard PIT task and UPPS-P impulsive behaviour scale. Both specific and general effects were observed, but the effects were not correlated to scores on any subscale of the impulsivity scale. In experiment 9, a devaluation procedure was added after the PIT task and before presenting questionnaires. In the devaluation procedure, participants were encouraged to respond while no stimuli or outcomes were presented. The short version of the UPPS-P impulsivity scale and Barratt impulsiveness scale were applied. Both specific and general effects were observed, and most of the participants (36 out of 48) showed a devaluation effect (devalued R < non-devalued R). The results indicated there was no correlation between any of the effects (specific effect, general effect, and devaluation effect) and any impulsivity score (subscales of UPPS-P or BIS). In experiment 10, instead of having a devaluation procedure after the transfer test, a devaluation procedure was added after the instrumental and Pavlovian conditioning, and before the transfer task. In the devaluation procedure, participants were told one of the outcomes presented in the instrumental stage was broken (the tool cannot protect them any more). The same questionnaires were applied at the end of the experiment. Both specific and general effects were observed in the non-devalued conditions. The devaluation abolished general PIT, diminished Pavlovian-directed devaluation of specific PIT, and left instrumental-directed devaluation of specific PIT unaffected. The results from a Bayesian correlation showed that the instrumental-directed devaluation effect on the specific PIT was negatively correlated with negative urgency (a subscale in UPPS-P). The Bayes factor represents strong evidence in favour of the alternative hypothesis.

Overall, both specific and general effects can be studied in the appetitive PIT task. There was no evidence that PIT effects or devaluation effects correlated to impulsivity levels. The devaluation procedure, which was presented before the transfer test, can abolish general PIT, and decrease Pavlovian-directed outcome devaluation on specific PIT. The results showed that although instrumental-directed outcome devaluation did not influence the magnitude of specific PIT, it was negatively correlated to negative urgency.

5.2 Implications of Findings

In Chapter II, both specific and general PIT effects were observed successfully in an avoidance-based PIT task and an appetitive PIT task. The idea of the avoidance-based PIT task was inspired by tasks reported by Nadler et al. (2011) and Lewis et al. (2013). The results of the experiments add to the growing body of evidence that specific and general PIT effects could be observed in humans by applying avoidance-based PIT tasks. To my knowledge, this is the first time that an avoidance-based PIT task has been transferred to an appetitive PIT task with minimal change. This challenged the explanation of the reason that general effects could be observed in the avoidance PIT task but not the appetitive PIT tasks mentioned by Nadler et al. (2011). Nadler et al. conducted two standard appetitive PIT tasks and observed specific effects but not general effects. They then conducted a standard avoidance-based PIT task and observed both effects. Therefore, they argued that the success of observing general effects may be because aversive outcomes have stronger emotional features than appetitive ones (Nadler et al., 2011). However, the outcomes were not the only differences between the two types of their tasks in their study. The results of the current study indicate that, in human studies, cover stories may play an important role in enhancing motivation rather than outcomes. Previous research showed that the standard appetitive PIT tasks with both specific and general effects in humans have been difficult to repeat as general effects were unstable (Hinojosa-Aguayo & Gonzalez, 2020). The current appetitive PIT task showed reliable specific and general PIT effects in the series of experiments reported in this thesis. Both appetitive and avoidance-based PIT can be used as behavioural mechanisms of addiction. Based on the assumption that it is S-O-R account in PIT, the appetitive PIT demonstrated that CSs can activate reward representations, and further evoke responses to the rewards. Also, the avoidance-based PIT explains that addictive behaviour can be a result of avoiding aversive feelings that are activated by the CSs.

In Chapter III, the avoidance-based PIT task was used in the five experiments to explore the relationship between anxiety and the PIT effects. The hypothesis was that anxiety can enlarge the size of general PIT, but not specific PIT. Both anxiety scales and stress mood induction procedures were applied. The positive correlation between anxiety levels reported in GAD-7 and the general PIT effect appeared in Experiment 3 but could not be repeated in Experiment 4. The stress mood induction partially worked in the three experiments (increased negative mood was not specific to anxiety in Experiment 3; enhanced anxiety feeling did not last long in Experiment 4; anxiety level in the stress group was higher than in the relax group, but not neutral group) and the different stress levels did not affect PIT effects. Although the results in this chapter did not provide evidence that there is any relationship between anxiety and PIT effects, it is still valid in exploring this research area. Most previous research did not include both specific and general PIT effects (Pritchard et al., 2018; Vogel et al., 2018; Steins-Loeber et al., 2020) or separate the two effects clearly (Pool et al., 2015) to see how anxiety related to the PIT effect. However, anxiety levels may affect specific PIT and general PIT differently, and this may be the reason that previous results are inconsistent. The experiments in this thesis addressed this issue by applying a standard PIT task with stable specific and general effects. The results of the current experiments did not show that the size of the general effects was enlarged when anxiety increased. This may be because the range of anxiety levels was not varied enough to influence motivation. Different from animal studies, in human studies, participants usually get pictures as outcomes instead of consuming the outcomes. This may indicate the motivation generally stayed at a low level. Also, the current experiments used a non-clinical population, and the applied stress mood induction did not work at its best. It is possible that the differences in anxiety generated were small resulting in the expected phenomenon was not observed. It can be noticed that the hypothesis is based on the assumption that the mechanism of PIT is the S-O-R account, and anxiety affects the affective feature of O. However, the S-R account is also a possible explanation for PIT. It is possible that stress can improve the encoding of the information in the cover story/instruction and further enhance learning S-R association in general (Vogel & Schwabe, 2018). If this is the case, stress evokes responses without being mediated by features of O, it could be expected that the response rates differ among groups. However, the results in the current experiments did not show any differences among groups in Experiments 5-7. Overall, the results did not offer evidence that anxiety is related to PIT effects.

In Chapter IV, correlations between impulsivity and PIT effects, devaluation effects or devaluation effects on PIT effects were explored. In Experiments 8 and 9, the results did not show evidence that impulsivity correlated to PIT effects or devaluation effects. This is different from the results reported by previous research: specific PIT and the devaluation effect were negatively correlated to the negative urgency subscale in the UPPS-P impulsivity scale (Hinojosa-Aguayo & Gonzalez, 2020; Experiment 1). This may be because the method of analysis was different: instead of using a one-tailed parametric correlation in their research, a two-tailed non-parametric correlation analysis was applied as more suitable for the current experiment. In Experiment 10, by placing the devaluation procedure before the transfer test, the devaluation effect on PIT effects was able to be analysed. The results showed that devaluation abolished general PIT, diminished Pavlovian-directed devaluation on specific PIT, and left instrumental-directed devaluation on specific PIT intact. Also, instrumental-directed devaluation did not affect specific PIT, which is different from the results reported by previous research (Hinojosa-Aguayo & Gonzalez, 2020; Experiment 2). Compared with previous studies, the Pavlovian-directed devaluation on specific PIT was added. In addition, a reliable general effect was observed, and the devaluation effect on general PIT was able to be explored. The abolished general effect and the decreased specific effect by the Pavlovian-directed devaluation may be an artefact of response devaluation. The success of observing the devaluation effect was partially controlled — participants were the ones who gave more non-devalued R2 than devalued R1 in the whole transfer test procedure (preCS+CS stage). Therefore, the current study may not be the best evidence to argue if outcome devaluation can affect PIT.

Correlations between the devaluation effects on PIT effects and impulsivity were conducted. Negative urgency was negatively correlated to the effect of instrumental-directed devaluation on specific PIT although the devaluation procedure did not change the size of the specific PIT. This indicated that individuals with high negative urgency traits may be less sensitive to devaluation. However, impulsivity levels may not be a factor that influences participants' sensitivity to the values of outcomes in PIT.

Overall, the experiments have explored how anxiety and impulsivity can influence specific or general PIT. The results in the series of experiments did not offer evidence that there is any relationship between any of the personality traits and any PIT effects.

5.3 Limitations

The hypotheses in this thesis were based on the assumption that the S-O-R account explains PIT (Alarcón et al., 2018; Seabrooke et al., 2019; Hinojosa-Aguayo & González, 2020) and stimuli can be associated with different features (perceptual, motivational) of the outcomes

(Konorski 1948, 1967) in specific or general PIT effects. Therefore, the results in the current experiments could only answer the hypotheses under these assumptions.

It can be seen that the outcomes used in these two PIT tasks were symbolic. Different from animal studies, in human studies, symbolic outcomes are widely applied. Compared to traditional rewards such as food or drink, the value of the rewards used in the current appetitive PIT task depends more on the circumstance described in the cover story. Although the outcomes were not biologically significant, the tasks were able to mirror Pavlovian conditioning as PIT effects were observed successfully. Therefore, symbolic outcomes were effective enough to motivate learning in PIT. Also, using symbolic outcomes in humans is more practical compared with traditional outcomes.

In addition, the mood inductions did not manifest the most substantial impact. Although there was a significant difference in stress level scores between the stress and relax groups, it would be better if the stress levels were different from the score in the neutral group (in Experiment 7). Further research can apply other types of stress mood induction such as cold pressure tests (used by Pool et al., 2015).

5.4 Conclusion

This thesis explored the relationship between individual differences (anxiety and impulsivity levels) and PIT effects. The reason why the previous findings are not consistent may be that the PIT effects were not separated into specific or general clearly, and specific and general PIT can be affected differently by anxiety or impulsivity. Based on theoretical reasoning, anxiety enlarges general PIT, but not specific PIT. Based on previous findings, impulsivity diminished specific PIT, but not general PIT. The aim of the current study was to repeat previous studies with standard PIT tasks, which can study both specific and general PIT, applied. This exploration is important as specific and general effects depend on different features of the outcomes (specific effect: perceptual and motivational features, general effect: motivational features), and these could be affected differently by anxiety or impulsivity. The results of the current experiments did not show evidence that anxiety or impulsivity has a relationship with PIT effects. This indicated the observation that anxiety or impulsivity affects addictive behaviour may not be mediated by anxiety or impulsivity influencing PIT. However, in specific PIT, individuals with high negative urgency traits were less sensitive to instrumental-directed outcome devaluation, although the devaluation did not influence the size of specific effects.

Overall, the aim of this thesis is to explore how anxiety or impulsivity can influence specific and general PIT effects. It was important to apply an effective standard PIT task which can study both specific and general effects because specific and general effects should be influenced differently by anxiety or impulsivity. With the novel avoidance-based or appetitive PIT tasks applied, the method of observing PIT effects was improved and the literature can be supplemented. The results in this thesis did not support the argument that there was any relationship between anxiety or impulsivity and PIT effects.

Appendix

Counterbalancing in Design of Experiments 1, 2.

instrumental	**condition**	**bats**	**arrows**	**rocks**	**nothing**
R1-bats	1	S1	S2	S3	S4
R2-arrows	2	S2	S1	S3	S4
	3	S1	S2	S4	S3
	4	S2	S1	S4	S3
	5	S3	S4	S1	S2
	6	S3	S4	S2	S1
	7	S4	S3	S1	S2
	8	S4	S3	S2	S1

Note. S= stimulus, S1= red square, S2= yellow square, S3= blue square, S4= black square.

Counterbalancing in Design of Experiments 3-10.

instrumental	**condition**	**bats**	**arrows**	**rocks**	**nothing**
R1-bats	1	S1	S2	S3	S4
R2-arrows	2	S2	S1	S3	S4
	3	S1	S2	S4	S3
	4	S2	S1	S4	S3
	5	S3	S4	S1	S2
	6	S3	S4	S2	S1
	7	S4	S3	S1	S2
	8	S4	S3	S2	S1
		bats	**rocks**	**arrows**	**nothing**
R1-bats	9	S1	S3	S2	S4
R2-rocks	10	S2	S3	S1	S4
	11	S1	S4	S2	S3
	12	S2	S4	S1	S3
	13	S3	S1	S4	S2
	14	S3	S2	S4	S1
	15	S4	S1	S3	S2
	16	S4	S2	S3	S1
		rocks	**arrows**	**bats**	**nothing**
R1-rocks	17	S3	S2	S1	S4
R2-arrows	18	S3	S1	S2	S4
	19	S4	S2	S1	S3
	20	S4	S1	S2	S3
	21	S1	S4	S3	S2
	22	S2	S4	S3	S1
	23	S1	S3	S4	S2
	24	S2	S3	S4	S1
		arrows	**bats**	**rocks**	**nothing**
R1- arrows	25	S2	S1	S3	S4
R2-bats	26	S1	S2	S3	S4
	27	S2	S1	S4	S3
	28	S1	S2	S4	S3
	29	S4	S3	S1	S2
	30	S4	S3	S2	S1
	31	S3	S4	S1	S2

	32	S3	S4	S2	S1
		rocks	**bats**	**arrows**	**nothing**
R1- rocks	33	S3	S1	S2	S4
R2-bats	34	S3	S2	S1	S4
	35	S4	S1	S2	S3
	36	S4	S2	S1	S3
	37	S1	S3	S4	S2
	38	S2	S3	S4	S1
	39	S1	S4	S3	S2
	40	S2	S4	S3	S1
		arrows	**rocks**	**bats**	**nothing**
R1- arrows	41	S2	S3	S1	S4
R2-rocks	42	S1	S3	S2	S4
	43	S2	S4	S1	S3
	44	S1	S4	S2	S3
	45	S4	S1	S3	S2
	46	S4	S2	S3	S1
	47	S3	S1	S4	S2
	48	S3	S2	S4	S1

Note. S= stimulus, S1= red square, S2= yellow square, S3= blue square, S4= black square.

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