Accepted version, restricted to non-commercial and no derivative uses. Final published version available at: Quarterly Journal of Experimental Psychology DOI: 10.1177/1747021819883963

Affect-driven impulsivity impairs human action control and selection, as measured through Pavlovian instrumental transfer and outcome devaluation

Irene Hinojosa-Aguayo [a, b] and Felisa González [a,b] *

Universidad de Granada, Spain

[a] Department of Experimental Psychology, Universidad de Granada, Campus Cartuja s/n, 18071 Granada, Spain

[b] Mind, Brain, & Behavior Centre (CIMCYC), Campus Cartuja, Universidad de Granada, Spain

Running head: Impulsivity, outcome devaluation, PIT

* Corresponding author:

Email address: fgreyes@ugr.es (F. González)

Abstract

Two experiments were designed to study the role of emotional impulsiveness in action control and selection, involving healthy young women participants. In Experiment 1 the effects of both outcome devaluation and Pavlovian-to-instrumental transfer (PIT) were assessed on instrumental responding. In Experiment 2, we further explored the effect of outcome devaluation on outcome-specific PIT. The role of emotional impulsivity, specifically negative urgency (NU), was also evaluated in both experiments using a self-reported measure (UPPS-P scale, Spanish short version). Experiment 1 showed both outcome devaluation and outcome-specific PIT effects, which were positively inter-correlated and negatively correlated with scores in NU. Experiment 2 found an effect of outcome devaluation on outcome-specific PIT, which was negatively correlated with scores on NU. These results highlight the relevance of considering individual differences in affect-driven impulsivity, specifically NU, when addressing failures in action control and selection (proneness to habit). Moreover, these findings suggest that, at least with the procedure used in these experiments, outcome-specific PIT may be based on a goal-directed process that is under the participant's control.

Keywords: goal-directed action, habit, impulsivity, negative urgency, outcome devaluation, Pavlovian instrumental transfer.

Introduction

From a learning-focused perspective, adaptive reward-seeking behaviour involves the integration of two different pieces of knowledge: Learning the actions that lead to the desired outcome (instrumental conditioning), and knowing which cues signal the availability of reward (Pavlovian conditioning). From a dual-process theory of instrumental learning (Dickinson, 1985), effective reward-seeking behaviour depends on the balance between goal-directed action and habitual systems that underlie instrumental responding. In addition, successful action control involves emotion regulation processes that help us to focus on long-term interests (e.g., healthy weight) over immediate emotional needs (e.g., craving). Impaired emotion regulation may lead to the development of emotionally impulsive personality traits that would make it difficult to resist temptations and delay gratification. Among these, negative urgency, the tendency to act rashly when experiencing negative emotional states (Whiteside & Lynam, 2001), has been specifically linked to impairments in behavioural control such as those involved in eating disorders (e.g., Peterson, Collins, Davis, & Fischer, 2012).

Taking into account this general framework, in the present study we investigated whether cues associated with rewards through Pavlovian conditioning could bias action selection (i.e. the choice between instrumental responses associated with these or similar rewards) using the Pavlovian-to-instrumental transfer (PIT) paradigm (Estes, 1943). In order to estimate the degree to which instrumental behaviour was controlled by the goal-directed system, we made use of the outcome devaluation procedure (Adams & Dickinson, 1981), both for instrumental responding (Experiment 1), as well as cue-elicited responding using a PIT procedure (Experiment 2). Additionally, we investigated whether these effects were modulated by an affect-driven impulsivity trait, specifically that of self-reported negative urgency.

Pavlovian to Instrumental Transfer (PIT) and outcome devaluation

Both reward-predicting actions (instrumental learning) and cues (Pavlovian conditioning) are important in guiding behaviour, and the interaction between them may be studied through the PIT paradigm (for recent reviews, see Cartoni, Balleine, & Baldassarre, 2016; Holmes, Marchand, & Coutureau, 2010). A Pavlovian cue associated with an outcome is able to selectively promote actions linked to that outcome, referred to as *specific transfer*, as well as increase the motivation and vigour of instrumental responding linked to different outcomes of the same motivational or affective valence, known as g*eneral transfer*. Therefore, when subjects are given the opportunity to perform two alternative actions, cues will bias the choice of action in favour of the one with which they share the specific outcome, or will increase general motivation for responding when they are linked to outcomes with similar motivational properties. Behavioural, lesion, and neuroimaging evidence all suggest that these effects (on response bias and on the vigour of responding) are distinct and dissociable (e.g., Quail, Morris, & Balleine, 2017).

The PIT effect has been linked to impulse control. For instance, in relation to eating behaviour, in western and related societies we are all immersed in an *obesogenic environment* with an abundance of rewarding and highly palatable food, and are surrounded by multiple food-related cues that can elicit food-seeking and consumption in a rather automatic way, even when sated (Colagiuri & Lovibond, 2015).

Regarding action control, the dual-system theory of instrumental learning (Dickinson, 1985) proposes that flexible behaviour is determined by the balance between goal-directed and habitual systems, which exhibit varying degrees of sensitivity to changes in the motivational value of the outcome (i.e. incentive learning).

Neuroimaging studies appear to support this distinction, showing that dissociable corticostriatal circuits mediate goal-directed and cue-triggered habitual behaviour (van Steenbergen, Watson, Wiers, Hommel, & de Wit, 2017).

Effective action control requires consideration of the current motivational or incentive value of the outcome of an action, (Balleine & O'Doherty, 2010). This is not static, and it may change over time, due to, for instance, a motivational shift from satiety to hunger. Therefore, the value of the outcome needs to be regularly updated. Thus, if the outcome loses its value, behavioural flexibility (i.e. goal-directed action) would cause a decrease in the frequency or vigour of responding. Habitual responses, however, are less sensitive to changes in the incentive value of the outcome and, as a consequence, the rate or frequency of behaviour will show little change, even when the outcome is no longer rewarding. Hence, one way to estimate the relative strength of one system over the other in action control, both in animals and in humans, makes use of the outcome devaluation procedure (see e.g., Watson & de Wit, 2018) which was employed in Experiments 1 and 2 of the present study. In this procedure, the incentive value of the outcome changes (i.e., decreases) as result of an experimental manipulation such as a motivational shift (e.g., satiation), pairing food with illness produced by a toxin or with a disgusting taste, or by instructions (e.g., an otherwise previously valuable outcome no longer equates to points or even makes the participant lose them).

One issue of interest is whether specific PIT is sensitive to outcome devaluation. Unfortunately, current research on this topic has yielded mixed evidence. Whilst some studies have found, both in animals and humans, that specific PIT is observed even when the outcome is no longer desired indicating that it has an automatic component (e.g., Colagiuri & Lovibond, 2015; Colwill & Rescorla, 1990; De Tommaso, Mastropasqua, & Turatto, 2018; Hogarth & Chase, 2011; Holland, 2004; Watson, Wiers, Hommel, & de Wit, 2014), other studies with human participants have found an effect of outcome devaluation under specific circumstances (Allman, DeLeon, Cataldo, Holland, & Johnson, 2010; Eder & Dignath, 2016a; Eder & Dignath, 2016b; Seabrooke, Hogarth, Edmunds, & Mitchell, 2019; Seabrooke, Le Pelley, Hogarth, & Mitchell, 2017). Therefore, it is still unclear how and when changes in outcome value may affect specific PIT, and one of the goals of the present experiments is to increase our knowledge with regard to this issue. This topic is of theoretical importance, since it could shed light on the associative structure underlying the effect (i.e. which particular outcome properties are recovered by the Pavlovian cue — sensory or motivational), whilst also having potential clinical implications.

In humans, insensitivity to outcome devaluation in instrumental responding has been linked to altered goal-directed control in neuropsychiatric disorders and other conditions (Corbit, 2018) such as addictions (Hogarth & Chase, 2011; Hogarth, Balleine, Corbit, & Killcross, 2013), obsessive compulsive disorder (Gillan et al., 2011), obesity (Horstmann et al., 2015), stress (Quail, Morris et al., 2017; Schwabe & Wolf, 2009), schizophrenia (Morris, Quail, Griffiths, Green, & Balleine, 2015), tryptophan depletion (Worbe, Savulich, De Wit, Fernandez-Egea, & Robbins, 2015), and impulsivity (Hogarth, 2011; Hogarth & Chase, 2011; Hogarth, Chase, & Baess, 2012) measured by the Barratt’s Impulsivity Scale (BIS), which considers attentional, cognitive (non-planning), and motor dimensions of impulsiveness.

Affect-driven impulsivity: Negative urgency

Impulsivity is a broad umbrella-term comprising qualitatively different forms of impulsivity, which are often only moderately correlated (Whiteside & Lynam, 2003). Distinct forms of emotion-related impulsivity have been identified and distinguished from other forms in which emotions do not play a central role but are instead related to cognitive dimensions (e.g., the lack of premeditation or perseverance related to deficits in conscientiousness). Reflexive responses to emotions represent a core vulnerability to psychopathology, having been linked to the ‘P’ factor (Carver, Johnson, & Timpano, 2017) and both externalizing and internalizing behaviours (King, Feil, & Halvorson, 2018), such as alcohol abuse, eating disorders, anxiety, and depression (Johnson, Tharp, Peckham, Carver, & Haase, 2017).

More specifically, negative urgency — the tendency to act rashly while experiencing distress or negative mood (Whiteside & Lynam, 2001) — has been considered a predictor of stimulant and mobile phone dependence, proneness to compulsive behaviour (Cándido, Orduña, Perales, Verdejo-García, & Billieux, 2012), self-harm behaviours, alcohol consumption, and eating problems (Dir, Karyadi, & Cyders, 2013), and has been proposed as an endophenotype candidate of genetic risk for the development of eating disorders (Peterson et al., 2012).

Individuals exhibiting higher levels of self-reported negative urgency favour immediate solutions to negative emotions due to a depletion of the resources dedicated to impulse control (Cyders & Coskunpinar, 2010), and use non-adaptive cognitive strategies of emotion regulation in search of short-term emotional relief, which may lead to inefficient emotion regulation in the long-term (King et al., 2018). Negative urgency may also be related to failures in incidental (implicit-automatic) emotion regulation strategies (Braunstein, Gross, & Ochsner, 2017) such as outcome revaluation and extinction.

Goals and predictions of the present study

To our knowledge, the effects of emotion-relevant impulsivity on action control (e.g., outcome devaluation) and selection (PIT), as well as the interaction between them (i.e. the effect of outcome devaluation on outcome-specific PIT), have not been addressed to date, even though this issue is of importance for control dysregulation. To this end, we used a PIT paradigm combined with the outcome devaluation procedure; the latter occurred after (Experiment 1) or before (Experiment 2) the PIT phase (see Tables 1 and 2). This allowed us to selectively assess the effect of outcome devaluation on instrumental responding (Experiment 1) without the effect of Pavlovian cues, or on cue-elicited responding (Experiment 2). We expected to find both outcome devaluation and PIT effects in Experiment 1.

The prediction regarding the effect of outcome devaluation on specific PIT in Experiment 2 was less clear, given the mixed results reviewed above. Taking into account the paradigm we used, which involved abstract rewards or secondary reinforcers (i.e., food images), which were not properly "obtained" or consumed (and thus may be thought to be relatively weaker), and the relatively more cognitive outcome devaluation procedure (seeing a gif image in which two cockroaches run over the snack instead of a 'motivational' change, such as sensory specific satiation; see Cartoni et al., 2016), we expected to find an effect of outcome devaluation on PIT . Therefore, we implicitly considered that the specific PIT effect to be found using our procedure would be mediated by the representation of the motivational properties of the outcome, that is, mediated by a goal-directed process (see also Seabrooke et al., 2017, 2019). If this were the case, the task might be useful for assessing the incentive salience of Pavlovian cues associated with rewards, (which cannot be addressed using more conventional instrumental conditioning paradigms that involve only associations between responses and outcomes). In addition, the task might also be useful for evaluating the balance between a goal-directed process and one based on automatic responding (by way of the outcome devaluation procedure).

A noteworthy feature of our study is that it was carried out with young women who were not selected for their impulsiveness scores or any other condition. We were interested in looking for vulnerability or risk factors related to behavioural inflexibility in otherwise healthy people, such as habit propensity (Robbins, Gillan, Smith, de Wit, & Ersche, 2012). Given the fact that insensitivity to outcome devaluation — as well as negative urgency — has been linked to several externalizing behaviours associated with psychological disorders and other conditions, we reasoned that both of these might also be related in healthy people. If this is the case, a negative correlation between performance on the experimental tasks and self-reported negative urgency should be expected. Thus, in the case of Experiment 1 we hypothesized that negative urgency would be associated with poorer reward-value updating; that is, we expected to find that the weaker the effect of outcome devaluation on responding, the higher the score on this impulsivity trait. Additionally, if the PIT task is indeed goal-directed, we expected to find a reduction in specific PIT in participants with higher levels of negative urgency; that is, for these participants there would be a smaller difference between performance in the presence of the cue that shares the outcome with that particular response and performance in the presence of the alternative cue. For Experiment 2, we hypothesised that the putative effect of outcome devaluation on PIT (if found) will be inversely related to negative urgency, due to a failure in outcome-value updating after the devaluation phase.

Experiment 1

One additional goal of Experiment 1 was to validate in our sample the adapted version of an instrumental computerized task (see the Procedure section for a detailed description of the modifications). The aim of this task was to study both the PIT and outcome devaluation effects, in that order (see Table 1). Participants first had to learn which one of two responses led to which of two different outcomes during the instrumental training phase and, afterwards, which cues (colours) signalled the availability of four different outcomes during Pavlovian training, before freely performing both responses in an extinction test in which the four cues were presented occasionally (PIT test). Three outcomes were images of several snacks that could hypothetically be gained (i.e. never delivered in reality) whereas the fourth outcome was an image with the message "empty". Two of the three outcomes had previously been used to reinforce the instrumental responses during the instrumental training phase. Finally, one of the two instrumental outcomes was devalued by presenting its picture in a gif image displaying two cockroaches running over it, before carrying out a second test in extinction, this time without cues (outcome devaluation test). Prior to the experimental session, participants completed several online questionnaires at home, one of which measured negative urgency (the Spanish adaptation of the short version of the UPPS-P, the details of which can be found in the Materials section).

Methods

Participants

Forty-eight young female undergraduate students from the University of Granada participated in the study in exchange for academic credit. The students' ages ranged from 18 to 30 years (*M* = 20.08, *SD* = 2.22), and their body mass index (BMI) ranged from 16.65 to 30.12 (*M* = 21.63, *SD* = 3.01). They provided written consent before the study, and had normal or corrected vision. The study received ethical approval from the Human Research Ethics Committee of the University of Granada (#71/CEIH/2015), and all procedures were conducted in accordance with the 1964 Helsinki Declaration and its later amendments.

Materials

Initial level of hunger and outcome rating. Before starting the experimental task, participants rated their level of hunger and the pleasantness of the three outcomes to be used during the experiment using a 7-point Likert scale with responses ranging from 0 (“not at all”) to 7 (“extremely”).

Behavioural task. The computerized task was an adaptation of that used by Quail, Morris et al. (2017) and Morris, Quail, Griffiths, Green, and Balleine (2015), kindly provided by the authors. The task was programmed using PsychoPy Software (Peirce, 2007) and presented on two available PC desktops, one with a HD 21.5” screen with a resolution of 1920 x 1080 pixels, and the other with a LCD, 19” screen with a resolution of 1440 x 990 pixels. Raw data from the task were extracted and organized using R scripts. The adaptation of the original task involved introducing the following slight modifications to the procedure: some of the outcomes were substituted to make them more familiar to Spanish participants; the specific instructions given to the participants were changed in order to describe the goal of the task (i.e. imagining collecting snacks for the birthday parties of impoverished children); an outcome devaluation phase was added at the end of the experiment, which made use of a gif picture instead of a video clip; and the items were translated into Spanish. All other details of the task were broadly similar to those of the original version.

Spanish adaptation of the short version of the UPPS-P questionnaire. In order to obtain a measure of emotional impulsivity, we administered the Spanish short version of the UPPS-P questionnaire (Cándido et al., 2012), following the French short version of Billieux et al. (2012). The short version of the UPPS-P contains 20 items, four for each of the traits considered in the five-factor model of impulsive behaviour (Whiteside & Lynam, 2001): positive and negative urgency, sensation seeking, (lack of) premeditation, and (lack of) perseverance, all of which have been found to be only moderately correlated (Fisher, Smith, & Cyders, 2008). The first two are considered to be affect-driven dimensions, whilst the latter two are regarded as indicators of poor executive functioning or conscientiousness. This version of the questionnaire shows a factorial structure of five specific but related factors that fit with the five traits proposed by the original model, and shows appropriate internal consistency. Its use shortens the time needed to complete the scales (the original version contains 59 items) without altering the psychometric properties of the original scales (Cándido et al., 2012). In addition, the Spanish short version of the UPPS-P shows adequate equivalence to the original 59-item Spanish version (Lozano, Díaz-Batanero, Rojas, Pilatti, & Fernández-Calderón, 2018). In the present study, the Cronbach's α of the different dimensions ranged from .56 to .84 (negative urgency, .83) in Experiment 1, and from .62 to .83 (negative urgency, .78), in Experiment 2.

Procedure

Because we are currently undertaking a wider unrelated research project, participants completed the Spanish short version of the UPPS-P in combination with other questionnaires (see Appendix A for more details) and responded to questions asking for demographic data. A link to the battery of questionnaires to be completed at home was sent by email to participants who had previously agreed to take part in our study. Once the battery had been completed, they were invited to take part in the experimental study in the laboratory. Upon arrival, participants read and signed the consent form. As part of the wider research project mentioned previously, they performed an unrelated task (Implicit Association Test, IAT) in the same experimental session (this only happened in Experiment 1). The order in which participants performed the IAT task, before or after the target tasks, was counterbalanced across participants. The target tasks (Pavlovian-to-instrumental transfer and outcome devaluation in an appetitive instrumental task) involved a total of four phases (see Table 1). All instructions were presented on the screen and paraphrased by the experimenter if necessary (the specific instructions can be found in Appendix B, translated into English). Spanish instructions are available upon request.

(Insert Table 1 about here)

Instrumental training phase. The outcomes (Os) used during the task were images of three snacks (counterbalanced) acting as O1, O2, and O3. The three Os were images of: M&Ms chocolates, a popular chocolate cookie (Príncipe), and crisps; the latter two were substitutes for two others used in the studies by by Quail, Morris et al., in order to make them more familiar to Spanish participants. After rating their level of hunger and the pleasantness of the three snacks, participants were given the instructions that explained their goal. They were told that their task was to obtain as many snacks as they could in order to support birthday parties for disadvantaged children with no resources (see Appendix B for more details). Therefore, an important difference between Quail, Morris, et al.'s task and ours is that participants did not receive any snack; the reward was symbolic (conditioned) in that they never obtained it or consumed it. An image of a schematic vending machine appeared on the screen. Participants were told that they had to press keys B and N of the QWERTY keyboard with the index finger of their dominant hand in order to tilt the machine left or right (responses R1 and R2) to obtain two different outcomes (O1 and O2). Therefore, in this phase participants concurrently learnt two different associations (R1 → O1; R2 → O2). Initially, there were six blocks of trials. In each block, participants freely performed R1 and R2, which were reinforced according to a random ratio reinforcement schedule so that the number of consecutive responses required for reinforcement varied randomly in an interval between 5 and 10 responses. This reinforcement consisted of the appearance of an image of the corresponding outcome for 1-sec. After three outcomes had been obtained, the participants were instructed to withhold responding for 1-sec and asked which key they should press in order to get the outcome whose image appeared on the screen (O1 or O2); this outcome was always the last one the participant had won. Participants were given feedback on their responses; the word "Correct" or "Incorrect" appeared on the screen for 1-sec. In total, they were asked six times about their outcome-action (O-R) knowledge. The procedure finished when the participant answered the six questions correctly. In the event that the participants failed to answer one question in any block, they were given a further six blocks, with a maximum of 25 blocks [1].

Pavlovian phase. In this stage of the experiment participants did not perform any action. Instead, they had to observe the relationship between several stimuli (colours — see below) and the accidental delivery of one of the three outcomes or no outcome at all. They were told that the vending machine was full of one of the snacks that freely fell from the machine from time to time, and that the colours gave predictive information about which outcomes would be delivered each time. On some occasions, the front

[1] However, this only occurred for one participant in Experiment 1 and another in Experiment 2; in both cases, they failed just one question in the first block, so they completed seven blocks in total.

panel of the machine was lit with one of four colours (red, green, blue, and yellow), which acted as Pavlovian cues or stimuli (S1, S2, S3, and S4). The assignment of stimuli to outcomes was as follows: S1:O1; S2:O2; S3:O3; S4: “no outcome” delivered, that is, the machine was empty. Thus, S1 and S2 shared the outcomes with R1 and R2, S3 (CS+) was predictive of a similarly pleasant snack not previously experienced (O3), and S4 (CS-) predicted no reward. There were 12 blocks of trials. In each one, the image of the vending machine remained on the screen in its original colour (black) for 3-sec. The machine was then lit with one of the four colours (randomly selected) for 1-sec upon which the image of the corresponding outcome immediately appeared under the machine icon for 2-sec during which the machine remained illuminated with the colour. After four trials, the vending machine was lit in one of the four colours while participants were given a multiple-choice question asking about which of the four outcomes would follow (random order). Feedback was given in a similar way to the previous phase. In total, the participants were questioned 12 times about their knowledge of the cue-outcome (S-O), three times for each outcome.

Pavlovian-to-Instrumental Transfer. In this phase participants had to tilt the vending machine again (freely performing R1 and R2), but in extinction, i.e. no outcomes appeared on the screen. Participants were told that although no snacks would be delivered, they had to use the knowledge they had acquired during the previous phases in order to get as many snacks as they could. There were six blocks of trials with four trials each, one for each Pavlovian cue (colours). Each trial began with the appearance of the vending machine in its original colour (black) whose duration varied in an interval between 8 and 16-sec according to a fixed sequence that varied from block to block. The final 6-sec of this period was considered to be the pre-CS period. After this, the machine appeared in one of the four colours for 6-sec (again in a fixed sequence that varied from block to block); this period was considered to be the CS period. R1 and R2 responses were recorded for both intervals. The whole procedure lasted for 442 s. To evaluate the influence of specific PIT, we considered only the trials on which S1 and S2 had been presented. R1 and R2 responses were categorized as 'Same' or 'Different' according to the outcome (O1 or O2) they had been associated with during instrumental training. Therefore, R1 was the response "Same" when S1 was presented, but was considered to be the response "Different" when S2 was presented; the opposite was true for R2 (this was response "Same" when S2 was presented during the CS period, but "Different" if S1 was presented during that period). To determine the degree of general PIT, we considered R1 and R2 jointly as "responses" on trials in which S3 and S4 were presented. This was always true for the pre-CS period (no distinction between R1 and R2 was made).

Outcome devaluation. In this phase, one of the two outcomes used during instrumental training, O1 or O2 (counterbalanced across participants), was devalued. We modified the devaluation procedure used by Morris et al. (2015) for convenience. Instead of watching a video clip showing the outcome infected with cockroaches, participants observed a gif image in which two cockroaches run over the snack. The image lasted for approximately 10-sec. After this, participants were given the outcome devaluation test, lasting 120-sec, in which they could freely perform the two actions (R1 or R2) in extinction (no outcomes were delivered). Finally, they rated again the level of pleasantness of the three snacks and the level of hunger.

Results and discussion

Statistics. In this and the following experiment, repeated-measures analyses of variance (ANOVAs) were used to determine the locus of significant main effects and interactions. Greenhouse-Geisser correction for the violation of the sphericity assumption was applied when appropriate. Student's paired t-test (one-tailed in the case of directional a priori hypotheses) was used for testing pairwise mean differences, whereas Holm's correction was used for multiple comparisons. Estimated effect sizes were generated using Cohen's *d*, for *t*-tests, and η^2_p, for the ANOVAs. Pearson's correlation coefficients, with 95% confidence intervals, were computed to estimate the degree of relationship between the behavioural measures and the negative urgency scores.

To provide evidence in favour of the null hypothesis in the case of non-significant differences, we computed Bayes factor (BF), estimated by using Jeffreys-Zellner-Siow (JZS) prior (Rouder, Speckman, Sun, Morey, & Iverson, 2009) and JASP (JASP & JASP Team, 2019) software. We followed the conventional interpretation of JZS-values proposed by Wagenmakers, Wetzels, Borsboom, and van der Maas (2011) and the recommendations made by Schönbrodt, Wagenmakers, Zehetleitner, and Perugini (2017) according to Rouder et al. (2009), to incorporate prior knowledge, if available, by tuning the width of the Cauchy prior. Therefore, in Experiment 1, without prior evidence for the estimation of the effect size using our modified task, we selected the value of the Cauchy prior width corresponding to a small effect size ($r = \sqrt{2}/2$); in Experiment 2, taking into account the large effect sizes found in Experiment 1 for both outcome devaluation and outcome-specific PIT, we set the Cauchy prior width to $r = \sqrt{2}$. In the case of Bayesian correlations, we selected the value of the stretched beta prior width to 0.5, following the suggestions of Quintana and Williams (2018).

Preliminary analyses:

Initial hunger level and pleasantness outcomes ratings. Before starting the experiment, participants rated their hunger level (range 1-7, *M* = 3.13, *SEM* = 0.26). The pleasantness ratings of the three outcomes used throughout the experiment (M&Ms, *M*

= 4.73, *SEM* = 0.26; Chips, *M* = 5.33, *SEM* = 0.20; Cookies, *M* = 5.31, *SEM* = 0.16) were submitted to a repeated measures (RM) one-way ANOVA that yielded a significant effect of outcome, $F(1.81, 85.03) = 3.88$, $p = .028$, $\eta^2_p = .076$. Holm's post hoc tests did not reveal any significant difference between the three means, although the difference between M&Ms and Cookies fell short of conventional levels of significance, $p =.051$, $BF_{s\ 10} \leq 2.41$.

Instrumental training. As expected, the RM-ANOVA did not reveal differences between the total number of R1 and R2 responses made (R1: *M* = 119.85, *SEM* = 10.09; R2: *M* = 119.81, *SEM* = 9.26), or the number of O1 or O2 outcomes gained (O1: *M* = 9.06, *SEM* = 0.42; O2: *M* = 9.00, *SEM* = 0.43), both $F_s < 1$, $BF_{s\ 10} = 0.16$. All participants correctly answered the questions about explicit O-R knowledge (i.e., which response lead to which outcome); therefore, the average accuracy was 100%.

Pavlovian training. During this phase, participants observed the relationships between the four Pavlovian cues (CSs) and the four possible outcomes. Out of the 12 questions, two participants failed two of these, and eight participants failed one question. The remaining 38 participants answered each question correctly. The average number of correctly answered questions on explicit S-O knowledge was *M* =11.75 (*SEM* = 0.08), that is, average accuracy was 98%.

Pavlovian-to-instrumental transfer (PIT):

Specific transfer. To evaluate the effect of the different Pavlovian cues on instrumental responding, we first determined a baseline rate by averaging for each participant the number of R1 and R2 responses made during the pre-CSs periods. Likewise, for each participant the total number of responses *Same* and *Different* was averaged over trials. The average preCS responses were then subtracted from these values in order to obtain a differential [CS-preCS] score for each condition, *Same* and *Different*, per participant. These scores were then submitted to a RM-ANOVA (see Figure 1, left-hand panel). There was a significant effect of PIT, $F(1, 47) = 13.68$, $p < .001$, $\eta^2_p = .226$; the cue produced an increase in responding for the action associated with the same outcome during instrumental training (Same); correspondingly, this produced a decrease for the alternative action (Different). We therefore found an outcome specific PIT effect.

(Figure 1 about here)

General transfer. To assess the influence of cues S3 (CS+) and S4 (CS-) on the vigour of responding, we calculated a differential preCS-CS score by subtracting the average number of preCS responses computed previously from the number of responses made during each of these CSs averaged by trial (see Figure 1, right-hand panel). The RM-ANOVA conducted on the differential scores yielded a significant effect of CS, $F(1, 47) = 52.85$, $p < .001$, $\eta^2_p = .529$, thus finding a general transfer effect, at least when defined as a higher level of responding in the presence of CS+ in comparison with CS-.

Transfer on baseline responding. In order to obtain a more direct index of the influence of the four cues on baseline responding, we compared the differential scores with the value of zero through several one-sample *t-tests*. We found significant differences for conditions *Same* ($p = .002$), *Different* ($p = .003$), and *CS-* ($p < .001$), but not in the case of *CS+* ($p = .553$; $BF_{10} = 0.19$). Therefore, although the cues predicting the instrumental outcomes (O1 and O2) were able to produce a specific increase or decrease in the corresponding instrumental actions, R1 and R2 (i.e., specific transfer), above or below baseline, a cue (CS+) predicting a (motivationally) similar but different (in terms of sensory aspects) outcome (O3) did not produce any noticeable change in baseline responding. However, a cue predicting no outcome (CS-) induced response suppression. Therefore, we detected just a partial general transfer effect by which a cue predicting no reward decreased motivation for responding and, accordingly, lowered it below baseline.

Effect of outcome devaluation on instrumental responding

The total number of responses for the non-devalued (M = 352.42, SEM = 23.05) and the devalued (M = 217.98, SEM = 21.21) responses were submitted to a RM-ANOVA, which yielded a significant effect of devaluation, $F(1, 47) = 10.85$, $p = .002$, $\eta^2_p = .188$, confirming that the devaluation treatment decreased responses for the action whose associated outcome during instrumental training was devalued before the test.

Effect of outcome devaluation on outcome pleasantness rating scores:

We then analysed the differences in participants' reported pleasantness ratings before and after outcome devaluation in search for a decrement in the outcome that was devalued, which should be absent for the rest of the outcomes. The RM-ANOVA with outcome (devalued, nondevalued1, nondevalued2) and time (pre, post) yielded a significant Outcome x Time interaction $F(1.43, 67.37) = 4.77$, $p = .021$, $\eta^2_p = .092$; the two main effects were not significant, largest $F(1, 47) = 3.17$, $p = .082$, for time. We explore the interaction through one-tailed t-test, finding a significant decrease in the case of the devalued outcome, t(47) = 3.19, $p = .001$, $d = 0.46$, (M = 5.27, SEM = 0.19, and M = 4.71, SEM = 0.23; before and after devaluation, respectively). None of the two non-devalued outcomes showed a significant decrease in pleasantness, when comparing the scores pre and post the devaluation phase, $t(47) = - 1.11$, $p = .863$, $d = - 0.16$, $BF_{+0} = 0.08$ ($M_{pre} = 4.77$, SEM = 0.24; $M_{post} = 4.98$, SEM = 0.24) ; $t(47) = 1.43$, $p = .080$, d =

0.26, BF_{+0} = 0.74 (M_{pre} = 5.33, *SEM* = 0.184; M_{post} = 5.04, *SEM* = 0.19). Therefore, the devaluation treatment procedure we used in the present experiment (i.e., exposure to a gif image showing cockroaches running over the snack) was effective in reducing the incentive value of the outcome, and this reduction lead to a decrease in response rate for the action whose associated outcome was devalued, as well as a reduction in the reported pleasantness of the devalued outcome.

In summary, during instrumental training responding rates for R1 and R2 or the number of O1 and O2 gained did not differ, with the causal R-O knowledge of the participants being 100% accurate. Participants also learned the S-O relationships with an average accuracy of 98% during Pavlovian training. The outcome devaluation procedure was effective in reducing the pleasantness ratings of the outcome (liking), and, more importantly, the response rate for the action whose outcome had been previously devalued (wanting); that is, we found the outcome devaluation effect on instrumental responding, suggesting an underlying goal-directed process.

On the PIT test, S1 and S2 cues selectively enhanced the response rate above baseline for the action with which they shared the outcome (Same condition), compared with the alternative action (Different condition), leading to a reliable specific PIT effect (see the left-hand panel of Figure 1). However, the CS+ (S3) did not increase responding above baseline, while S4 (CS-) had an impact on general performance, reducing responding below baseline (see the right-hand panel of Figure 1). Therefore, it appears that the adapted task employed in these experiments generated broadly similar effects to those found previously in the literature, at least with regard to outcome-specific PIT, although general PIT results were somewhat less conclusive.

It is not clear why the CS+ did not increase the response rate above baseline. One possibility is that baseline responding might have been high, reducing the likelihood of detecting a positive transfer effect. Although we did find a specific transfer effect for stimulus Same, general transfer could simply be weaker and more difficult to detect in the case of CS+. It is also possible that the use of two reinforcers that shared motivational properties but differed primarily in terms of sensory attributes during instrumental training encouraged learning of an association between the two responses and the sensory attributes of their outcomes, with attention being focused on these properties rather than the motivational attributes (Holland, 2004). This could explain why the CS+ did not elevate performance above baseline. However, the general transfer effect was not completely absent, since the cue predicting no outcome (CS-) readily depressed responding below baseline. Inhibitory effects on PIT, specifically when using inhibitory training procedures (feature- negative conditioned inhibition) have previously been reported in humans (e.g., Alarcón & Bonardi, 2016; Laurent & Balleine, 2015; Quail, Laurent, & Balleine, 2017). However, whilst no specific inhibitory procedures were used in the present experiment, the absence of an outcome in a context in which outcomes were expected may have provided the required conditions for inhibitory learning to take place (for similar results, see, for example, Colagiuri & Lovibond, 2015; Quail, Morris, et al., 2017).

The role of negative urgency

Following this overall analysis, we analyzed the effect of negative urgency on action control and selection. As a reminder, we anticipated that participants with higher negative urgency scores would show insensitivity to outcome devaluation, making relatively more devalued responses than participants with lower scores. The implications for the PIT effect were less clear. If we consider that specific PIT is mediated by the outcome value (i.e. the effect depends on the updating of the motivational value of the outcome and is a goal-directed process), we might expect that participants with higher levels of negative urgency should show poorer action selection, responding relatively less in the presence of the stimulus ‘Same’ than participants with lower scores on negative urgency.

We conducted two one-tailed correlational analyses in accord with our hypotheses in which we expected to find negative correlations between negative urgency scoring and measures of outcome devaluation and PIT. First, we calculated the correlation between the score on negative urgency and the differential responding during the outcome-devaluation test (Diff_Dev), number of responses associated with the non-devalued outcome minus number of responses associated with the devalued outcome, Figure 2A), which was negative and significant, as predicted, r = - .29, p = .022, 95% CI: [-1.000, - 0.057], one-tailed. This result indicated that responding was less sensitive to the current value of the outcome (an index of habitual responding), the higher the score on negative urgency. No other impulsivity traits were significantly correlated, lowest r = - .18, p = .109, 95% CI: [-1.000, 0.062], BF_{-0} = 0.94, for positive urgency.

(Figure 2 about here)

Second, we computed the correlation between negative urgency and specific PIT. To this end, we calculated the difference between the number of ‘Same’ and 'Different’ responses made during the PIT test (Same_Diff). This correlation turned out to be negative and significant, r = - .26, p = .039, 95% CI: [-1.000, - 0.018], one-tailed (Figure 2B), as was also the case for positive urgency, r = - .30, p = .017, 95% CI: [-1.000, - 0.070]. Both emotional impulsiveness traits were linked to less specific PIT.

Lack of perseverance, lack of premeditation, and sensation seeking showed no significant correlations with any of the measures, lowest r = - .22, p = .062, 95% CI: [-1.000, 0.017], BF_{-0} = 1.48, for lack of perseverance.

This pattern of results highlights the relevance of emotional impulsivity, as opposed to other forms of impulsiveness, in cued responding (specific PIT), and the uniqueness of negative urgency in predicting failures in action control, measured by sensitivity to outcome devaluation. Given that both effects appear to be negatively correlated with emotional impulsiveness, the question arises as to whether the two effects could be related to each other. A two-tailed correlation analysis computed between Diff_Dev (sensitivity to outcome devaluation) and Same_Diff (outcome-specific PIT) scores found a significant positive correlation, r = .52, p < .001, 95% CI: [0.283, 0.704], a result that is compatible with the notion that both effects could be underpinned by a common process. The correlation between Diff_Dev and CS+/CS- (general transfer index), however, turned out to be non-significant, r = .20, p = .174, 95% CI: [- 0.090, 0.458], BF_{10} = .63, along with the correlation between specific and general PIT, r = .15, p = .318, 95% CI: [- 0.143, 0.414], BF_{10} = .42.

These results suggest that in our task, and for participants with lower negative urgency scores, the specific PIT effect might be mediated by the representation of the current motivational value of the outcome and therefore the underlying process could be goal-directed. This possibility makes testable predictions, one of which is that the PIT effect observed using our procedure should be sensitive to outcome devaluation, a prediction tested in Experiment 2.

Experiment 2

Experiment 1 showed that both outcome devaluation and specific PIT effects were impaired in young women with higher scores on negative urgency in comparison with those who showed lower scores on this trait. In Experiment 2 we examined the interaction between these effects with a two-fold aim. Our first goal was to add evidence to the current debate as to whether outcome devaluation has an effect on specific PIT, and secondly, if this indeed were the case, we aimed to investigate the role of negative urgency in generating this effect. Regarding the first goal, the outcome devaluation procedure took place before the PIT test on this occasion (see Table 2). Taking into account the results of Experiment 1 (which indicate that the specific PIT effect found using our task was, unlike general PIT, linked to the current motivational value of the outcome, i.e. goal directed) we predicted that outcome devaluation would decrease or eliminate this effect whilst having no impact on general PIT. In relation to the second goal, we aimed to replicate the findings of Experiment 1 with respect to negative urgency. Given that we found a negative correlation between negative urgency and specific PIT, we expected to observe an effect of outcome devaluation on specific PIT in participants with a lower score on negative urgency, but not in those with higher scores on this trait; that is, we predicted a negative correlation between PIT devaluation and negative urgency.

Methods

Participants

Forty-eight young female university students participated in the study in exchange for academic credit. The ages of the students ranged between 18 and 24 years (*M* = 19.69, *SD* = 1.56), and their body mass index (BMI) ranged between 16.81 and 28.40 (*M* = 21.76, *SD* = 2.78).

Materials

Measures, tasks, and questionnaires were the same as those used in Experiment 1, with the exception of minor details that are described in the Procedure section.

(Insert Table 2 about here)

Procedure

Table 2 summarizes the design of Experiment 2. The instrumental and Pavlovian training phases were broadly similar to those described in Experiment 1. However, the outcome devaluation procedure took place before the PIT test, which was, as in Experiment 1, a test in extinction during which participants freely performed R1 and R2 while the four Pavlovian cues (colours) were presented from time to time. For half of the participants, the devalued response was R1, and for the remainder this was R2.

Outcome-specific PIT. In order to evaluate the influence of devaluation on specific PIT, we selected those trials on which S1 and S2 were presented. R1 and R2 responses were then categorized as 'Same' or 'Different', according to the outcome (O1 or O2) with which they were associated during instrumental training. Because on this occasion the test was conducted after the devaluation procedure, one of the responses was associated with the now-devalued outcome and we thus added further labelling using the terms Devalued (Dev) or Non-Devalued (NonDev). For instance, consider those participants for whom O1 was devalued, and a particular trial in which S1 was presented. In this case, R1 would be labelled 'Same', because it shared the outcome with S1, and 'Devalued', because the shared outcome was devalued; thus, it would be labelled 'SameDev'. Now consider a trial in which S2, instead of S1, is presented. Now R2 would be a 'Same' response, but its associated outcome has not been devalued, and it would therefore be labelled as a 'SameNonDev' response.

General PIT. To estimate the magnitude of the general PIT effect, we followed Experiment 1 considering both R1 and R2 as "responses" on those trials in which either S3 (CS+) or S4 (CS-) were present.

In this case, however, the calculation of the number of preCS responses as an estimation of baseline responding was complicated by the fact that one of the responses was already "devalued". For this reason, and because our hypotheses were more specifically linked to the specific PIT effect, we decided to analyse the PIT effect in two ways: one of these involved using the differential CS-preCS score, taking into account separately the preCS value for the devalued and the non-devalued response, whilst the other used the average number of responses made in the presence of the stimuli.

Finally, participants were again required to rate the level of pleasantness of the three outcomes. It is important to note that, unlike Experiment 1, and in order to perform the PIT test immediately after the devaluation phase, this evaluation was conducted at the end of the experiment, and not after the devaluation procedure.

Results and discussion

Preliminary analyses:

Initial hunger level and pleasantness outcomes ratings. Before starting the experiment, participants rated their hunger level (range 1-7, M = 3.06, SEM = 0.24). The pleasantness ratings of the three outcomes used throughout the experiment (M&Ms, M = 4.69, SEM = 0.26; Cookies, M = 4.75, SEM = 0.25; and Chips, M = 4.73, SEM = 0.24) were submitted to a one-way ANOVA that did not yield a significant effect, $F < 1$ (paired samples t-test $BF_{s\ 10} < 0.10$).

Instrumental training. The number of responses made, both R1 and R2, did not differ[2], (*M* = 111.60, *SEM* = 6.97, and *M* = 115.96, *SEM* = 6.62, respectively), along with the number of outcomes gained, O1 and O2 (*M* = 8.96, *SEM* = 0.30, and *M* = 9.10, *SEM* = 0.30, respectively), both $F_s < 1$, $BF_{s\ 10} < 0.10$. All participants correctly answered the questions about explicit O-R knowledge (i.e., which response lead to which outcome); therefore average accuracy was 100%.

Pavlovian training. During this phase, participants observed the relationships between the four Pavlovian cues (CSs) and the four possible outcomes. Out of the 12 questions, fourteen participants failed one question, and one of the participants failed three questions. The remaining 33 participants answered each question correctly. The average number of correctly answered questions on explicit S-O knowledge was *M* =11.69 (*SEM* = 0.07), thus indicating 97% accuracy.

Effect of outcome devaluation on baseline responding:

Because the PIT task was performed after outcome devaluation, one of the two responses, R1 or R2, could be considered “devalued” (i.e., the one that was associated with the now-devalued outcome during instrumental learning). Indeed, the average number of instrumental responses performed in the presence of the stimulus whose associated outcome was devalued (the stimulus that was relevant to either the condition Same or Different) was significantly lower (*M* = 16.73, *SEM* = 1.54) than that of the alternative response (i.e., the one performed in the presence of the stimulus whose outcome was not devalued, *M* = 23.48, *SEM* = 1.63), $t(47) = 3.54$, $p < .001$, $d = 0.51$. Similar results were found when analyzing the responses performed during the preCS period, where the average number of responses was lower for the response whose

[2] We excluded the data of one participant from the analysis due to an error in recording the data during the instrumental phase (responses performed and outcomes obtained). However, data for this participant were included in the remaining analyses.

outcome had been devalued (*M* = 9.77, *SEM* = 0.88) than for the one whose outcome had not, (*M* = 13.77, *SEM* = 1.45), $t(47) = 2.70$, $p = .010$, $d = 0.40$. These results suggest that our outcome devaluation manipulation was, once again, effective.

However, these differences made it difficult to average responses in order to calculate a single ‘baseline’ level of responding for the transfer test analyses. For this reason, as previously mentioned, separate preCS periods, for responses linked either to the devalued or the non-devalued outcomes, were taken into account. Note that this is a rather conservative test for our hypothesis, since responding was clearly biased toward the response associated with the still valued outcome. This may likely reduce the opportunity to observe an increase above baseline in the case of the SameNonDev condition (see e.g., Colagiuri & Lovibond, 2015; Seabrooke et al., 2019). However, it would still allow for comparing the effect of devaluation on the Same vs Diff contrasts depending on whether the relevant outcome was previously devalued or not. Specifically, if devaluation indeed has an impact on PIT, we anticipated that such a difference would emerge only in the non-devalued condition.

Effect of outcome devaluation on Pavlovian-to-instrumental transfer:

Specific transfer. To evaluate the effect of outcome devaluation on specific transfer, we first computed the average R1 and R2 number of responses for each participant in the presence of both S1 and S2. As in Experiment 1, the number of R1 responses performed in the presence of S1 was referred to as *Same* and referred to as *Different* when performed during S2. Accordingly, R2 performed in the presence of S2 was referred to as *Same* and referred to as *Different* when performed during S1. Furthermore, as explained previously, R1 and R2 responses were also denoted as Devalued (Dev) or Non-devalued (NonDev), according to whether O1 or O2 was devalued (or not) during the outcome devaluation phase. In order to calculate the CS-preCS difference scores, the average number of responses performed during the preCS period for either the devalued response (preCS Dev) or the non-devalued response (preCS_NonDev), were subtracted from the number of responses performed during the presence of the stimulus. In total, four difference scores were estimated for each participant: SameDev and DiffDev, using the preCS Dev, and SameNonDev and DiffNonDev, using the preCS NonDev. These difference scores were submitted to a RM-ANOVA with stimulus (Same, Different) and devaluation (Dev, NonDev) as factors, yielding a significant main effect of stimulus, $F(1, 47) = 12.26$, $p = .001$, $\eta^2_p = .207$, as well as an interaction between these variables, $F(1, 47) = 4.48$, $p = .040$, $\eta^2_p = .087$, whilst no significant effect of devaluation was found, $F < 1$. The simple main effects analysis showed that outcome-specific PIT was significant in the NonDev condition, $p < .001$, but there was no evidence of this in the Dev condition, $p = .141$, $BF_{10} = 0.24$ [means, SameNonDev, 0.72 (*SEM* = 0.90); DiffNonDev, - 4.80 (*SEM* = 1.70); SameDev, - 0.56 (*SEM* = 1.14); DiffDev, - 2.45 (*SEM* = 0.98)]. As mentioned previously, although the Same vs Diff contrast was significant only in the case of the NonDev condition, providing that the outcome-specific PIT effect did occur, it was difficult to detect an increase above baseline in the case of the SameNonDev condition, possibly due to the bias in responding toward the non-devalued instrumental response (see Seabrooke et al., 2019).

(Figure 3 about here)

The pattern of results was, however, similar (and much clearer) when using the raw number of responses performed in the presence of the stimulus (Figure 3). The RM-ANOVA yielded main effects of both stimulus, $F(1, 47) = 12.27$, $p = .001$, $\eta^2_p = .207$, and devaluation, $F(1, 47) = 12.54$, $p < .001$, $\eta^2_p = .211$. Moreover, the interaction was also significant, $F(1, 47) = 4.48$, $p = .040$, $\eta^2_p = .087$. Inspection of Figure 3 (left-hand panel) suggests that there was an effect of specific transfer; that is, participants made a greater number of responses, on average, in the Same condition (in comparison with the Different condition), but only when the associated outcome had not previously been devalued. This impression was confirmed by statistical analyses. The simple main effects analysis showed that outcome-specific PIT was significant in the NonDev condition, $p < .001$, but there was no evidence of this effect in the Dev condition, $p = .141$, $BF_{10} = 0.24$. Moreover, the number of responses was significantly higher for SameNonDev compared with SameDev, $t(47) = 3.38$, $p < .001$, $d = 0.49$, whilst no such difference was found when comparing the two Diff conditions, $t(47) = 1.46$, $p = .152$, $BF_{10} = 0.23$. Therefore, the outcome devaluation procedure eliminated the effect of specific transfer, suggesting that this was mediated by a goal-directed process.

General transfer. To assess the influence of outcome devaluation on the ability of S3 (CS+) and S4 (CS-) to affect R1 and R2 responding, we considered the number of responses in the presence of each stimulus for the non-devalued and the devalued response (S3NonDev, S3Dev; S4NonDev, S4Dev). As in the previous specific PIT analyses, we subtracted the corresponding average, preCS_Dev or preCS_NonDev, in order to obtain difference scores (CS+NonDev, $M = -1.90$, $SEM = 0.95$; CS+Dev $M = 0.66$, $SEM = 1.26$; CS-NonDev, $M = -6.93$, $SEM = 1.27$; CS-Dev, $M = -2.55$, $SEM = 0.83$). A RM-ANOVA with devaluation (non-devalued, devalued) and general transfer (CS+ vs. CS-) as factors revealed significant main effects of general transfer (i.e., CS+ > CS-), $F(1, 47) = 22.70$, $p < .001$, $\eta^2_p = .326$, and devaluation, $F(1, 47) = 9.74$, $p = .003$, $\eta^2_p = .172$. The interaction was, however, not significant, $F(1, 47) = 1.25$, $p = .268$. Accordingly, and irrespective of devaluation, comparisons between CS+ and CS- scores, either in the non-devalued, $t(47) = 4.43$, $p < .001$, $d = .64$, or the devalued conditions, $t(47) = 2.59$, $p = .013$, $d = .37$, remained significant. The pattern of results obtained using the number of responses performed in the presence of the stimuli was similar, since the analyses yielded a main effect of stimulus, $F(1, 47) = 22.69$, $p < .001$, $\eta^2_p = .326$, but no effect of devaluation, $F < 1$, or an interaction, $F(1, 47) = 1.25$, $p = .268$, $\eta^2_p = .026$ (CS+ NonDev $M = 11.88$, $SEM = 1.14$; CS+Dev $M = 10.43$, $SEM = 1.00$; CS-NonDev $M = 6.84$, $SEM = 0.69$; CS-Dev $M = 7.21$, $SEM = 1.00$). Differences between CS+ and CS- were significant both in the non-devalued condition, $t(47) = 4.43$, $p < .001$, $d = 0.64$, as well as in the devalued condition, $t(47) = 2.59$, $p = .013$, $d = 0.37$. These results suggest that general transfer is not mediated by a goal-directed process, and behaviour seems instead to be insensitive to changes in the current motivational value of the outcome with which it shares similar motivational properties (but from which it differs in terms of sensory properties).

Effect of outcome devaluation on outcome pleasantness rating scores:

After the PIT task, participants were asked again to rate the three outcomes. For the outcome that was devalued, we expected a decrease in outcome rating after devaluation, as was found in Experiment 1. The RM-ANOVA with outcome (devalued, nondevalued1, nondevalued2) and time (pre, post) yielded a marginally significant interaction $F(1.47, 68.00) = 3.25$, $p = .060$, $\eta^2_p = .065$; the main effects were not significant, largest $F(1.94, 91.46) = 2.28$, $p = .110$, for outcomes. A one-tailed t-test, $t(47) = 1.85$, $p = .036$, $d = 0.27$, confirmed the expectation ($M_{pre} = 4.50$, $SEM = 0.23$; $M_{post} = 4.14$, $SEM = 0.29$). None of the non-devalued outcomes showed a decrease in pleasantness when comparing the pre and post devaluation scores, $t_s < 1$ ($M_{s\ pre} = 4.75$ and 4.92, $SEM_s = 0.26$ and 0.25, respectively; $M_{s\ post} = 4.83$ and 5.00, $SEM_s = 0.28$ and 0.26, respectively; $BF_{s\ +0} < 0.10$). The effect of outcome devaluation on this explicit measure seems to be weaker than the one found in Experiment 1. This could be due to the delay introduced between the outcome devaluation procedure and its explicit assessment: in this case, it took place after the behavioural devaluation test (and not immediately after the devaluation procedure). The data of the devaluation test, however, showed that baseline responding for the response that was linked to the devalued outcome was lower than that linked to the still valued one, whilst it was also shown to have an impact on specific PIT, at least in participants with lower negative urgency scores. Although it could possible that this might have negatively affected general PIT, in the present study we were not able to specify how this might have occurred.

In summary, during instrumental training, there was no difference between R1 and R2 in terms of the number of responses made, or between gained outcomes, O1 and O2. Causal knowledge of the R-O relationships was 100% accurate, whereas it was again slightly lower (97%) in the case of the knowledge regarding the S-O relationship acquired during Pavlovian training. Regarding the PIT test conducted after outcome devaluation (see Figure 3), S1 and S2 cues selectively enhanced response rates for the action with which they shared the outcomes (Same condition), but only if they had not been previously devalued (NonDev condition, see Figure 3). Otherwise, the specific PIT effect was absent.

Therefore, on the basis of this preliminary analysis it appears that the specific PIT effect found using our experimental procedure was sensitive to outcome devaluation, and thus goal-directed. However, no differential effect of outcome devaluation was detected in general PIT. This latter result is consistent with the notion that the general PIT transfer found with our procedure is insensitive to changes in the motivational value of the outcome, although this conclusion might be premature, given that we did not observe a significant increase in responding at baseline in the case of S3 (CS+), only a decrease in the case of S4 (CS-). Whatever the precise mechanism underlying this pattern of results, its insensitivity to outcome devaluation is consistent with data from Experiment 1 showing that the difference in performance between CS+ and CS – was not significantly related to the effect of outcome devaluation found on instrumental responding.

The role of Negative urgency

Following these general analyses, we looked at the effect of negative urgency on devaluation of the specific PIT. In order to estimate the effect of outcome devaluation on specific PIT, we considered the number of responses performed in the presence of the stimuli and two pairwise comparisons: SameNonDev vs. Diff Dev, and SameDev vs. DiffNonDev. The extent to which they differed was determined using the following formula: PIT_Diff = [(SameNonDev – Diff Dev) – (SameDev – DiffNonDev)], where the higher the devaluation effect, the higher the PIT_Diff value. The underlying rationale was that, if outcome devaluation affected PIT, an increase in responding would be observed only for the SameNonDev condition, but not for the SameDev condition, and, theoretically, the Diffs conditions would be much less affected, if at all, by the devaluation procedure. To recap, we did expect to find a lower specific PIT effect in those participants with higher negative urgency scores, that is, we expected to find a significant negative correlation between both measures. To test this possibility, we calculated the correlation (one-tailed test) between the PIT_Diff score and the score on negative urgency (Figure 4), which turned out to be negative and significant, as expected, $r = -.38$, $p = .004$, 95% CI: [-1.000, - 0.152]; that is, the higher the score on negative urgency, the lower the effect of outcome devaluation on the specific PIT. The correlation with positive urgency was also found to be significant, $r = -.29$, $p = .024$, 95% CI: [-1.000, - 0.051], whilst no other significant correlations were found for the remaining impulsiveness traits, $BF_{s\text{-}0} < 0.10$, lowest $r = .01$, $p = .532$, 95% CI: [-1.000, 0.252], for lack of premeditation.

(Figure 4 about here)

General Discussion

One aim of the present research was to validate, in our sample, a modified appetitive instrumental task based on those used by Quail, Morris et al. (2017) and Morris et al. (2015) using abstract or conditioned rewards (images) instead of real rewards, to study the effects of outcome devaluation and Pavlovian to instrumental transfer (PIT) on action control and selection. In Experiment 1 we found the expected effect of outcome devaluation in which, during an extinction test, there was a decline in the response whose outcome had previously been devalued (in comparison with an alternative response), suggesting that instrumental behaviour was indeed goal-directed, since the instrumental response was mediated by the updated outcome value and modified accordingly (Dickinson, 1985). We also found a specific PIT effect by which the stimuli associated with the instrumental outcomes (S1 and S2) selectively biased action selection toward the one with which it shared the outcome (Same) in preference to the alternative action (Different) in a choice test in extinction.

A second goal of our study was to evaluate in healthy people (i.e. participants not selected for their scores on impulsiveness or other conditions) the impact of an affect-driven impulsivity trait, specifically negative urgency, on these effects. In Experiment 1 we found negative correlations between self-reported negative urgency scores, measured by the UPPS-P, and indexes of both outcome devaluation and specific PIT. As reviewed in the Introduction, negative urgency has been linked to the ‘P’ factor (Carver et al., 2017) and to both externalizing and internalizing behaviours (King et al., 2018; Johnson, et al., 2017). These results therefore add to previous findings in the literature showing how PIT may be a reliable procedure that is useful for characterizing pathologies such as schizophrenia, addiction, and major depressive disorders (Cartoni et al., 2016).

To the best of our knowledge, this is the first report linking affect-driven impulsiveness, specifically negative urgency, to failures in updating the motivational value of the outcome (i.e., incentive learning), as well as in the adaptive ability to extract predictive information from environmental stimuli to make optimal choices, both of which form the basis of the PIT effect (Quail, Morris et al., 2017). Therefore, a novel contribution of our study is that negative relations with measures of incentive learning and cue-driven behaviour (action control and selection) can be observed in a non-clinical group varying in a single affect-driven impulsivity trait dimension such as negative urgency.

Another important aim of our study was to shed light on the ongoing debate over whether outcome devaluation affects specific PIT, and thus whether the latter could be based on a goal-directed process. To this end, we scheduled the outcome devaluation phase before the PIT test in Experiment 2. Unlike what has often been found in both animal and human studies (see below), we observed an effect of outcome devaluation on specific PIT, the implications of which will be discussed later. Additionally, we further studied the mediating effect of emotional impulsivity, finding a significant negative correlation between negative urgency and the effect of outcome devaluation on specific PIT.

Taken together, these results have some important implications. First, we will consider the general effects, after which we will focus on the impairment in action control that seems to be induced by emotional impulsivity.

Effect of outcome devaluation on specific and general PIT

The specific PIT effect was shown to be sensitive to outcome devaluation (Experiment 2), suggesting that the underlying mechanism is goal-directed. This is an interesting result in itself given that previous literature with animal or human subjects has reported insensitivity to outcome devaluation (or extinction) in specific PIT (e.g., Colagiuri & Lovibond, 2015; Colwill & Rescorla, 1990; De Tommaso et al., 2018; Delamater, 1996; Hogarth & Chase, 2011; Watson et al., 2014; see also Seabrooke et al., 2017, Exp. 1).

Indeed, PIT has been mostly considered as an instance of stimulus-bound (cue-triggered) outcome-insensitive behaviour that may be of relevance for research into habit formation (Watson & de Wit, 2018). This view suggests that the motivational or incentive value of the outcome is not encoded in the S-O-R associative chain by which the stimulus activates a representation of the associated outcome, inducing its anticipation, which in turns triggers the performance of the motor response with which it shares the outcome (for a recent description of the associative structures underlying PIT see, for example, Alarcón, Bonardi, & Delamater, 2017). The view that PIT is governed by a rather automatic system assumes that the cue activates a representation of the sensory —but not motivational — attributes of the outcome; thus, devaluation is ineffective in reducing the response rate. This possibility appears to be particularly likely when two, instead of one, different instrumental response-outcome relationships are trained concurrently (Holland, 2004). However, there is some disagreement about the underlying associative mechanisms involved in specific PIT, with this issue currently being a matter of ongoing debate (e.g., Alarcón et al., 2017; Cartoni et al., 2016; Holmes et al., 2010; Watson, Wiers, Hommel, & de Wit, 2018).

It has recently been suggested that the specific PIT effect could, at least in humans, have both implicit and explicit components, with the former ascribed to subcortical structures and the latter to more cortical frontal areas (Garofalo & di Pellegrino, 2017). Support for a goal-directed (explicit-like) component was provided by the results of Experiment 1, in which we found a moderately high correlation between outcome devaluation (i.e., difference between non-devalued and devalued responses) and the specific PIT (i.e. difference between Same and Different responses). Specific PIT could be mediated by an association between the representation of the instrumental response and a detailed representation of the outcome. In the case of general PIT, an increase in responding could instead be driven by a more general facilitatory process, being greater when the response is controlled to a lesser extent by its specific consequences. In fact, both PIT effects have been dissociated at a neuroanatomical level in lesion studies with animals, and neuroimaging studies with humans (Quail, Morris, et al., 2017). Consistent with this view, which emphasizes the difference between both PIT effects, no significant correlations were found between outcome devaluation and general PIT or between specific and general PIT effects. The effect of individual differences in emotional impulsiveness on outcome devaluation and specific (but not general) PIT found here contributes further evidence towards the investigation of the mechanisms underlying goal-directed action and habitual behaviour.

Evidence is also available showing sensitivity to outcome devaluation in specific PIT in humans (e.g., Allman et al., 2010; Eder & Dignath, 2016a; Eder & Dignath, 2016b; see also Seabrooke et al., 2017, Exps. 2 & 3; Seabrooke et al., 2019). It has been claimed that some of these studies have used designs with “cognitive” devaluation strategies (Cartoni et al., 2016) that might encourage participants to use a more explicit strategy leading to reasoned outcome expectations rather than performance that is reliant on learned associations (see also Watson et al., 2018). Cue-elicited behaviour could in this way be overridden by explicit strategies. In these specific circumstances, PIT might be sensitive to changes in goal-incentive value. However, the accuracy of explicit knowledge of the instrumental O-R contingency was 100% in both studies, and the degree of knowledge of the Pavlovian S-O contingency exhibited by participants in the present study did not correlate with scores on negative urgency, either in Experiment 1, $r = -.12$, $p = .424$, 95% CI [- 0.389, 0.172], $BF_{10} = 0.35$, or Experiment 2, $r = -.16$, $p = .291$, 95% CI [- 0.421, 0.135], $BF_{10} = 0.44$. Therefore, differences in performance may be attributable to other factors.

The results obtained in Experiment 1 suggest that emotional impulsivity is a key factor leading to failures in updating incentive learning, even if the incentive was effectively devalued. This result points to an impairment in the goal-directed process (see e.g., Corbit, 2018; Watson & de Wit, 2018). Specific PIT was also negatively correlated with negative urgency. In spite of the fact that participants with higher negative urgency were equally aware of the O-R and S-O contingencies, they appeared to show a failure to integrate these two pieces of knowledge. This prompts the suggestion that failures in both outcome devaluation and specific PIT could reflect the action of the habit system in these participants. Therefore, individual differences need to be taken into account when considering the mechanisms underlying PIT (see also Garofalo & di Pellegrino, 2015).

Affect-driven effects on action control and emotion regulation

Our results involving emotional impulsiveness may be relevant to the concept of *habit propensity* (Robbins et al., 2012), which proposes that individuals differ in the degree of balance between goal-directed actions and habit systems, being more prone to act out of habit by relatively faster habit formation or stronger habit expression. Linnebank, Kindt, and de Wit (2018) have recently explored this possibility, finding evidence for the hypothesis that habit propensity may be a stable personal characteristic, underlying both performance in experimental studies and real-life measures of habit propensity. However, they did not find complete correspondence between these two aspects. In this regard, the data from Experiments 1 and 2 suggest that subclinical impulsive participants with higher levels of emotional impulsivity — specifically negative urgency — appear to be more prone to habitual responding (if we interpret the absence of a devaluation effect in this sense) than those with lower levels of this trait. This habit propensity in people exhibiting emotional impulsivity could be taken to reflect a “temperamental pre-existing vulnerability” or disposition towards habits (Linnebank et al., 2018), which might be linked to failures in automatic emotion regulation.

Normal performance following outcome devaluation requires updating the current value of the outcome, adjusting behaviour according to its most recently experienced consequences. Indeed, within a multi-level framework of emotion regulation, outcome revaluation has been characterized as a relatively automatic process of implicit emotion regulation (Braunstein et al., 2017) that does not involve a conscious desire to change emotions (i.e., there is no explicit goal to regulate emotions), as might be the case in situations involving chronically active goals that are important for survival, such as the goal to respond to, and accurately represent, the current value of a relevant outcome (Braunstein et al., 2017). Regarding the nature of the emotion change process itself, the devaluation of outcome, as well as extinction, may be considered as instances of affective (or incentive) learning by which an organism experiences shifts in the contingent outcome and learns to update its prior affective value, involving few or no top-down control processes.

Thus, failure to update the current incentive or affective value of the outcome (i.e., outcome revaluation) points to impairments in implicit-automatic emotion regulation. This may have important implications when tailoring interventions for people exhibiting clinical conditions, and suggests the convenience of including emotion regulation training that incorporates metacognitive techniques in order to increase awareness and reconfiguration of responses to emotional states.

Limitations

One possible limitation of the present study is that participants were young undergraduate women, and this could limit the generalizability of our conclusions to the male gender or other age groups. Measurement and structural invariance of the UPPS-P (original 59-item version) in healthy (non-clinical) undergraduate students have proved to be comparable between men and women, although men generally score higher on positive urgency and sensation seeking (but not on negative urgency). In addition, the relationship between the five traits and risk outcomes has been found to be invariant across gender (Cyders, 2013). The impulsivity subscales of the short Spanish version of the USSP-P used in this study, validated in undergraduate students of the University of Granada, have also not been found to show gender differences (Cándido et al., 2012), whereas age was found to correlate negatively with all facets of impulsivity, except for negative urgency. However, additional research will be needed to determine whether the results observed in these studies can also be confirmed in young males as well as for older adults of both genders.

Additionally, our procedure had some characteristics that may have affected the observed pattern of results. As explained in more detail in the Introduction, we decided to maximize the likelihood of observing an outcome-devaluation effect on PIT by using abstract instead of real natural rewards. Our outcome devaluation procedure consisted of pairing the images of the outcome with some insects running over it, a procedure that can be considered more of a cognitive than a motivational change. Although both manipulations proved to be successful, we acknowledge that the pattern of results found in Experiment 2 (i.e., effect of outcome-devaluation on specific PIT) could be different in the case of using different kinds of outcomes and/or devaluation procedures, as previously found in the literature. Regarding general PIT, the CS+ failed to increase responding above baseline in both experiments, and a similar pattern was found for the SameNonDev condition in Experiment 2. Perhaps interposing an instrumental extinction session before the PIT test could have been of some help in reducing the baseline rate, thereby favoring the detection of an increment in responding (e.g., Dickinson, Smith, & Mirenowicz, 2000).

Finally, although we followed previous designs aimed at studying both outcome-specific and general PIT, in our specific procedure S4 (CS-) seems to signal the absence of reward rather than not being associated with any of the outcomes, possibly acting as an inhibitor and thus decreasing responding below baseline. In future experiments it might be worth considering the possibility of adding a novel, briefly preexposed, stimulus in the PIT test as a further control condition Dickinson et al., 2000).

Conclusions

Adaptive action control and selection involve the integration of knowledge about contingencies between actions and outcomes, as well as between cues and outcomes, in order to make optimal choices among various courses of action. In addition, updating the incentive value of the outcome is critically important for action flexibility and control. People exhibiting higher levels of affect-driven impulsivity — specifically negative urgency — may fail in the integration of knowledge about the current value of the outcome, which they do indeed acquire along with action-outcome knowledge, showing performance that is insensitive to changes in incentive value. They also show an apparent failure to use predictive cue-outcome knowledge to guide action selection (outcome specific PIT). This pattern of results suggests that negative urgency causes automatic processes to control instrumental responding, impairing the goal-directed processes that are normally involved in both action control and selection in healthy people, and this impairment appears to be linked to failures in implicit emotion regulation (i.e., outcome revaluation).

Acknowledgments:

This research was supported by the Spanish Ministerio de Economía y Competitividad (MINECO), Ministerio de Ciencia, Innovación y Universidades, and FEDER funds (grants PSI2015-64345-R; PGC2018-096438-I00). We would like to thank S. Quail for kindly providing access to the task files and scripts, J. C. Perales for assistance with R programming, G. Hall for helpful discussion on a previous version of the manuscript, and M. Symonds for proofreading the manuscript.

Conflicts of interest.

Declarations of interest: none.

Table 1

Experiment 1. Experimental design for the PIT task and Outcome Devaluation Test (adapted from Quail, Morris & Balleine, 2016).

Instrumental Training	Pavlovian Training	Transfer Test	Devaluation Test
R1 - O1 R2 - O2	S1 - O1	S1: R1 (Same), R2 (Diff)?	Outcome Devaluation
	S2 - O2	S2: R1 (Diff), R2 (Same)?	R1, R2?
	S3 - O3	S3: R1, R2? (CS+)	
	S4 - NO OUTCOME	S4: R1, R2? (CS-)	

Note: PIT = Pavlovian-to-instrumental transfer. R = response: O = outcome; S = stimulus CS+ = excitor CS; CS - = inhibitor CS.

Table 2

Experiment 2. Experimental design for the PIT task and Outcome Devaluation Test (adapted from Quail, Morris & Balleine, 2016).

Instrumental Training	Pavlovian Training	Devaluation	Transfer Test
R1 - O1 R2 - O2	S1 - O1	Outcome Devaluation (either O1 or O2)	S1: R1 (SameDev), R2 (DiffNonDev)? S2: R1 (DiffDev), R2 (SameNonDev)?
	S2 - O2		S1: R1 (SameNonDev), R2 (DiffDev)? S2: R1 (DiffDev), R2 (SameDev)?
	S3 - O3		S3: R1, R2? (CS+)
	S4 - NO OUTCOME		S4: R1, R2? (CS-)

Note: PIT = Pavlovian-to-instrumental transfer. R = response: O = outcome; S = stimulus CS+ = excitor CS; CS - = inhibitor CS.

References

Adams, C. D., & Dickinson, A. (1981). Instrumental responding following reinforcer devaluation. *The Quarterly Journal of Experimental Psychology Section B*, *33*, 109-122. https://doi.org/10.1080/14640748108400816

Alarcón, D., & Bonardi, C. (2016). The effect of conditioned inhibition on the specific pavlovian-instrumental transfer effect. *Journal of Experimental Psychology: Animal Learning and Cognition*, *42*(1), 82–94. https://doi.org/10.1037/xan0000087

Alarcón, D. E., Bonardi, C., & Delamater, A. R. (2017). Associative mechanisms involved in specific Pavlovian-to-instrumental transfer (PIT) in human learning tasks. *The Quarterly Journal of Experimental Psychology*, *71*, 1607–1625. https://doi.org/10.1080/17470218.2017.1342671

Allman, M. J., DeLeon, I. G., Cataldo, M. F., Holland, P. C., & Johnson, A. W. (2010). Learning processes affecting human decision making: An assessment of reinforcer-selective pavlovian-to-instrumental transfer following reinforcer devaluation. *Journal of Experimental Psychology: Animal Behavior Processes*, *36*(3), 402–408. https://doi.org/10.1037/a0017876

Balleine, B. W., & O'Doherty, J. P. (2010). Human and rodent homologies in action control: Corticostriatal determinants of goal-directed and habitual action. *Neuropsychopharmacology*, *35*(1), 48–69. https://doi.org/10.1038/npp.2009.131

Billieux, J., Rochat, L., Ceschi, G., Carré, A., Offerlin-Meyer, I., Defeldre, A. C., … Van Der Linden, M. (2012). Validation of a short French version of the UPPS-P Impulsive Behavior Scale. *Comprehensive Psychiatry*, *53*(5), 609–615. https://doi.org/10.1016/j.comppsych.2011.09.001

Braunstein, L. M., Gross, J. J., & Ochsner, K. N. (2017). Explicit and implicit emotion regulation: a multi-level framework. *Social Cognitive and Affective Neuroscience*, *12*(10), 1545–1557. https://doi.org/10.1093/scan/nsx096

Cándido, A., Orduña, E., Perales, J. C., Verdejo-García, A., & Billieux, J. (2012). Validation of a short Spanish version of the UPPS-P impulsive behaviour scale. *Trastornos Adictivos*, *14*(3), 73–78. https://doi.org/10.1016/S1575-0973(12)70048-X

Cartoni, E., Balleine, B. W., & Baldassarre, G. (2016). Appetitive Pavlovian-instrumental transfer: A review. *Neuroscience and Biobehavioral Reviews*, *71*, 829-848. https://doi.org/10.1016/j.neubiorev.2016.09.020

Carver, C. S., Johnson, S. L., & Timpano, K. R. (2017). Toward a functional view of the p factor in psychopathology. *Clinical Psychological Science*, *5*, 880-889. https://doi.org/10.1177/2167702617710037

Colagiuri, B., & Lovibond, P. F. (2015). How food cues can enhance and inhibit motivation to obtain and consume food. *Appetite*, *84*, 79–87. https://doi.org/10.1016/j.appet.2014.09.023

Colwill, R. M., & Rescorla, R. A. (1990). Effect of reinforcer devaluation on discriminative control of instrumental behavior. *Journal of Experimental Psychology: Animal Behavior Processes*, *16*(1), 40–47. https://doi.org/10.1037/0097-7403.16.1.40

Corbit, L. H. (2018). Understanding the balance between goal-directed and habitual behavioral control. *Current Opinion in Behavioral Sciences*, *20*, 161-168. https://doi.org/10.1016/j.cobeha.2018.01.010

Cyders, M. A. (2013). Impulsivity and the sexes: Measurement and structural invariance of the UPPS-P impulsive behavior scale. *Assessment*, *20*(1), 86–97. https://doi.org/10.1177/1073191111428762

Cyders, M. A., & Coskunpinar, A. (2010). Is urgency emotionality? Separating urgent behaviors from effects of emotional experiences. *Personality and Individual Differences*, *48*(7), 839–844. https://doi.org/10.1016/j.paid.2010.02.009

De Tommaso, M., Mastropasqua, T., & Turatto, M. (2018). Working for beverages without being thirsty: Human Pavlovian-instrumental transfer despite outcome devaluation. *Learning and Motivation*, *63*, 37–48. https://doi.org/10.1016/j.lmot.2018.01.001

Delamater, A. R. (1996). Effects of several extinction treatments upon the integrity of Pavlovian stimulus-outcome associations. *Animal Learning and Behavior*, *24*(4), 437–449. https://doi.org/10.3758/BF03199015

Dickinson, A. (1985). Actions and habits: the development of behavioural autonomy. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences Animal Intelligence (Feb. Phil. Trans. R. Soc. Lond. B, 308*(1135), 67–78. https://doi.org/10.1098/rstb.1985.0010

Dickinson, A., Smith, J., & Mirenowicz, J. (2000). Dissociation of Pavlovian and instrumental incentive learning under dopamine antagonists. *Behavioral Neuroscience*, *114*, 468-483. https://doi.org/10.1037/0735-7044.114.3.468

Dir, A. L., Karyadi, K., & Cyders, M. A. (2013). The uniqueness of negative urgency as a common risk factor for self-harm behaviors, alcohol consumption, and eating problems. *Addictive Behaviors*, *38*(5), 2158–2162. https://doi.org/10.1016/j.addbeh.2013.01.025

Eder, A. B., & Dignath, D. (2016a). Asymmetrical effects of posttraining outcome revaluation on outcome-selective Pavlovian-to-instrumental transfer of control in human adults. *Learning and Motivation*, *54*, 12–21. https://doi.org/10.1016/j.lmot.2016.05.002

Eder, A. B., & Dignath, D. (2016b). Cue-elicited food seeking is eliminated with aversive outcomes following outcome devaluation. *Quarterly Journal of Experimental Psychology*, *69*(3), 574–588. https://doi.org/10.1080/17470218.2015.1062527

Estes, W. K. (1943). Discriminative conditioning. I. A discriminative property of conditioned anticipation. *Journal of Experimental Psychology*, *32*(2), 150–155. https://doi.org/10.1037/h0058316

Fisher, S., Smith, G., & Cyders, M. A. (2008). Another look at impulsivity: A meta-analytic review comparing specific dispositions to rash action in their relationship to bulimic symptoms. *Clinical Psychology Review*, *28*(8), 1413–1425. https://doi.org/10.1016/j.cpr.2008.09.001

Garofalo, S., & di Pellegrino, G. (2015). Individual differences in the influence of task-irrelevant Pavlovian cues on human behavior. *Frontiers in Behavioral Neuroscience*, *9*, 1-14. https://doi.org/10.3389/fnbeh.2015.00163

Garofalo, S., & di Pellegrino, G. (2017). Commentary: Monetary, food, and social rewards induce similar Pavlovian-to-instrumental transfer effects. *Frontiers in Behavioral Neuroscience*, *11*(136), 1-3. https://doi.org/10.3389/fnbeh.2017.00136

Gillan, C. M., Papmeyer, M., Morein-Zamir, S., Sahakian, B. J., Fineberg, N. A., Robbins, T. W., & de Wit, S. (2011). Disruption in the balance between goal-directed behavior and habit learning in obsessive-compulsive disorder. *American Journal of Psychiatry*, *168*(7), 718–726. https://doi.org/10.1176/appi.ajp.2011.10071062

Hogarth, L. (2011). The role of impulsivity in the aetiology of drug dependence: Reward sensitivity versus automaticity. *Psychopharmacology*, *215*(3), 567–580. https://doi.org/10.1007/s00213-011-2172-0

Hogarth, L., Balleine, B. W., Corbit, L. H., & Killcross, S. (2013). Associative learning mechanisms underpinning the transition from recreational drug use to addiction. *Annals of the New York Academy of Sciences*, *1282*(1), 12–24. https://doi.org/10.1111/j.1749-6632.2012.06768.x

Hogarth, L., & Chase, H. W. (2011). Parallel goal-directed and habitual control of human drug-seeking: Implications for dependence vulnerability. *Journal of Experimental Psychology: Animal Behavior Processes*, *37*(3), 261–276. https://doi.org/10.1037/a0022913

Hogarth, L., Chase, H. W., & Baess, K. (2012). Impaired goal-directed behavioural control in human impulsivity. *Quarterly Journal of Experimental Psychology*, *65*(2), 305–316. https://doi.org/10.1080/17470218.2010.518242

Holland, P. C. (2004). Relations between Pavlovian-instrumental transfer and reinforcer devaluation. *Journal of Experimental Psychology: Animal Behavior Processes*, *30*(2), 104–117. https://doi.org/10.1037/0097-7403.30.2.104

Holmes, N. M., Marchand, A. R., & Coutureau, E. (2010). Pavlovian to instrumental transfer: A neurobehavioural perspective. *Neuroscience and Biobehavioral Reviews*, *38*(4), 1277-1295. https://doi.org/10.1016/j.neubiorev.2010.03.007

Horstmann, A., Dietrich, A., Mathar, D., Pössel, M., Villringer, A., & Neumann, J. (2015). Slave to habit? Obesity is associated with decreased behavioural sensitivity to reward devaluation. *Appetite, 87*, 175–183. https://doi.org/10.1016/j.appet.2014.12.212

JASP, & JASP Team. (2019). JASP. *[Computer Software]*.

Johnson, S. L., Tharp, J. A., Peckham, A. D., Carver, C. S., & Haase, C. M. (2017). A path model of different forms of impulsivity with externalizing and internalizing psychopathology: Towards greater specificity. *British Journal of Clinical*

Psychology, *56*(3), 235–252. https://doi.org/10.1111/bjc.12135

King, K. M., Feil, M. C., & Halvorson, M. A. (2018). Negative rrgency is correlated with the use of reflexive and disengagement emotion regulation strategies. *Clinical Psychological Science*, *6*(6), 822-834. https://doi.org/10.1177/2167702618785619

Laurent, V., & Balleine, B. W. (2015). Factual and counterfactual action-outcome mappings control choice between goal-directed actions in rats. *Current Biology*, *25*(8), 1074–1079. https://doi.org/10.1016/j.cub.2015.02.044

Linnebank, F. E., Kindt, M., & de Wit, S. (2018). Investigating the balance between goal-directed and habitual control in experimental and real-life settings. *Learning and Behavior*, *46*(3), 306-319. https://doi.org/10.3758/s13420-018-0313-6

Lozano, Ó. M., Díaz-Batanero, C., Rojas, A. J., Pilatti, A., & Fernández-Calderón, F. (2018). Concordance between the original and short version of the impulsive behaviour scale UPPS-P using an IRT model. *PLoS ONE, 13*(3), 1-15. https://doi.org/10.1371/journal.pone.0194390

Morris, R. W., Quail, S., Griffiths, K. R., Green, M. J., & Balleine, B. W. (2015). Corticostriatal control of goal-directed action is impaired in schizophrenia. *Biological Psychiatry*, *77*(2), 187–195. https://doi.org/10.1016/j.biopsych.2014.06.005

Peirce, J. W. (2007). PsychoPy-Psychophysics software in Python. *Journal of Neuroscience Methods*, *162*(1–2), 8–13. https://doi.org/10.1016/j.jneumeth.2006.11.017

Peterson, C. M., Collins, B., Davis, K., & Fischer, S. (2012). The role of negative urgency in the etiology of bulimia nervosa in adolescents. In *Psychology of impulsivity* (pp. 209–232, xi, 282).

Quail, S. L., Laurent, V., & Balleine, B. W. (2017). Inhibitory Pavlovian-instrumental transfer in humans. *Journal of Experimental Psychology: Animal Learning and Cognition*, *43*(4), 315–324. https://doi.org/10.1037/xan0000148

Quail, S. L., Morris, R. W., & Balleine, B. W. (2017). Stress associated changes in Pavlovian-instrumental transfer in humans. *Quarterly Journal of Experimental Psychology*, *70*(4), 675–685. https://doi.org/10.1080/17470218.2016.1149198

Quintana, D. S., & Williams, D. R. (2018). Bayesian alternatives for common null-hypothesis significance tests in psychiatry: A non-technical guide using JASP. *BMC Psychiatry*, *18*(1), 1-8. https://doi.org/10.1186/s12888-018-1761-4

Robbins, T. W., Gillan, C. M., Smith, D. G., de Wit, S., & Ersche, K. D. (2012). Neurocognitive endophenotypes of impulsivity and compulsivity: towards dimensional psychiatry. *Trends in Cognitive Sciences*, *16*(1), 81–91. https://doi.org/10.1016/j.tics.2011.11.009

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & Iverson, G. (2009). Bayesian t tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin and Review*, *16*(2), 225-237. https://doi.org/10.3758/PBR.16.2.225

Schwabe, L., & Wolf, O. T. (2009). Stress prompts habit behavior in humans. *Journal of Neuroscience*, *29*(22), 7191–7198. https://doi.org/10.1523/JNEUROSCI.0979-09.2009

Schönbrodt, F. D., Wagenmakers, E.-J., Zehetleitner, M., & Perugini, M. (2017). Sequential hypothesis testing with Bayes factors: Efficiently testing mean differences. *Psychological Methods*, *22*(2), 322-339. https://doi.org/10.1037/met0000061

Seabrooke, T., Hogarth, L., Edmunds, C. E. R., & Mitchell, C. J. (2019). Goal-directed control in Pavlovian-instrumental transfer. *Journal of Experimental Psychology: Animal Learning and Cognition*, *45*(1), 95-101.

https://doi.org/10.1037/xan0000191

Seabrooke, T., Le Pelley, M. E., Hogarth, L., & Mitchell, C. J. (2017). Evidence of a goal-directed process in human pavlovian-instrumental transfer. *Journal of Experimental Psychology: Animal Learning and Cognition*, *43*(4), 377–387. https://doi.org/10.1037/xan0000147

van Steenbergen, H., Watson, P., Wiers, R. W., Hommel, B., & de Wit, S. (2017). Dissociable corticostriatal circuits underlie goal-directed vs. cue-elicited habitual food seeking after satiation: evidence from a multimodal MRI study. *European Journal of Neuroscience*, *46*(2), 1815–1827. https://doi.org/10.1111/ejn.13586

Wagenmakers, E. J., Wetzels, R., Borsboom, D., & van der Maas, H. L. J. (2011). Why Psychologists Must Change the Way They Analyze Their Data: The Case of Psi: Comment on Bem (2011). *Journal of Personality and Social Psychology, 100*(3), 426-433. https://doi.org/10.1037/a0022790

Watson, P., & de Wit, S. (2018). Current limits of experimental research into habits and future directions. *Current Opinion in Behavioral Sciences*, *20*, 33-39. https://doi.org/10.1016/j.cobeha.2017.09.012

Watson, P., Wiers, R. W., Hommel, B., & de Wit, S. (2018). Motivational sensitivity of outcome-response priming: Experimental research and theoretical models. *Psychonomic Bulletin and Review*, *25*(6), 2069-2082. https://doi.org/10.3758/s13423-018-1449-2

Watson, P., Wiers, R. W., Hommel, B., & de Wit, S. (2014). Working for food you don’t desire. Cues interfere with goal-directed food-seeking. *Appetite*, *79*, 139–148. https://doi.org/10.1016/j.appet.2014.04.005

Whiteside, S. P., & Lynam, D. R. (2001). The five factor model and impulsivity: Using a structural model of personality to understand impulsivity. *Personality and*

Individual Differences, *30*(4), 669–689. https://doi.org/10.1016/S0191-8869(00)00064-7

Whiteside, S. P., & Lynam, D. R. (2003). Understanding the role of impulsivity and externalizing psychopathology in alcohol abuse: Application of the UPPS impulsive behavior scale. *Experimental and Clinical Psychopharmacology*, *11*(3), 210–217. https://doi.org/10.1037/1064-1297.11.3.210

Worbe, Y., Savulich, G., de Wit, S., Fernandez-Egea, E., & Robbins, T. W. (2015). Tryptophan depletion promotes habitual over goal-directed control of appetitive responding inhumans. *International Journal of Neuropsychopharmacology*, *18*(10). https://doi.org/10.1093/ijnp/pyv013

Figure captions

Figure 1. Experiment 1. Specific and general Pavlovian-to-instrumental transfer (PIT). Mean CS-preCS difference score (compared with baseline) by condition during the PIT test (whole sample). Same = response that shared the outcome with the Pavlovian stimulus presented during the test; Diff = alternative response; CS + = stimulus (S3), which during Pavlovian training, signalled a third outcome, not presented during instrumental training (O3); CS - = stimulus (S4) which signalled no outcome during Pavlovian training (O4). Bars represent ± SEM.

Figure 2. Experiment 1. (A) Negative relationship between difference in the number of non-devalued responses and devalued responses (Diff_Dev) and score on negative urgency (Neg Urg). The negative relationship illustrates that the devaluation effect decreases with increases in Negative urgency score. (B) Negative relationship between difference in responding to the Same condition compared to the Diff condition (specific PIT, Same_Diff) and score on negative urgency (Neg Urg). The negative correlation illustrates that the effect of specific PIT decreases with increases in Negative urgency score. (A) and (B): Scatterplots; one-tailed Pearson's coefficient, 95% confidence interval.

Figure 3. Experiment 2. Effect of outcome devaluation on specific Pavlovian-to-instrumental transfer (PIT) during the devaluation-PIT test. Average number of responses by condition. Same = response that shares the outcome with the Pavlovian stimulus presented during the test; Diff = alternative response. NonDev = response whose associated outcome had not been previously devalued; Dev =

response whose associated outcome had been previously devalued. Bars represent ± SEM.

Figure 4. Experiment 2. Negative relationship between PIT_Diff score [differential number of responses: (SameNonDev – DiffDev) – (SameDev – DiffNonDev)] and score on negative urgency (Neg Urg). The negative relationship illustrates that the devaluation effect on outcome-specific PIT decreases with increases in Negative urgency score. (Same = response that shares the outcome with the Pavlovian stimulus presented during the test; Diff = alternative response; NonDev = response whose associated outcome had not been previously devalued; Dev = response whose associated outcome had been previously devalued). Scatterplot; one-tailed Pearson's coefficient, 95% confidence interval.

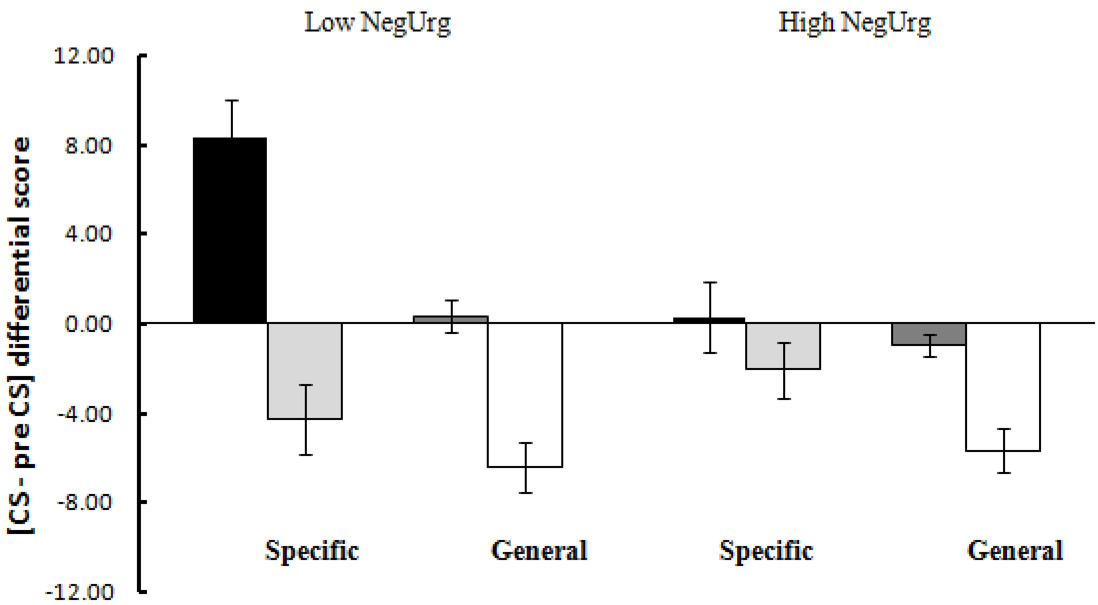

Low NegUrg
High NegUrg
12.00
8.00
4.00
0.00
-4.00
-8.00
-12.00
[CS - pre CS] differential score
Specific
General
Specific
General

Figure 1

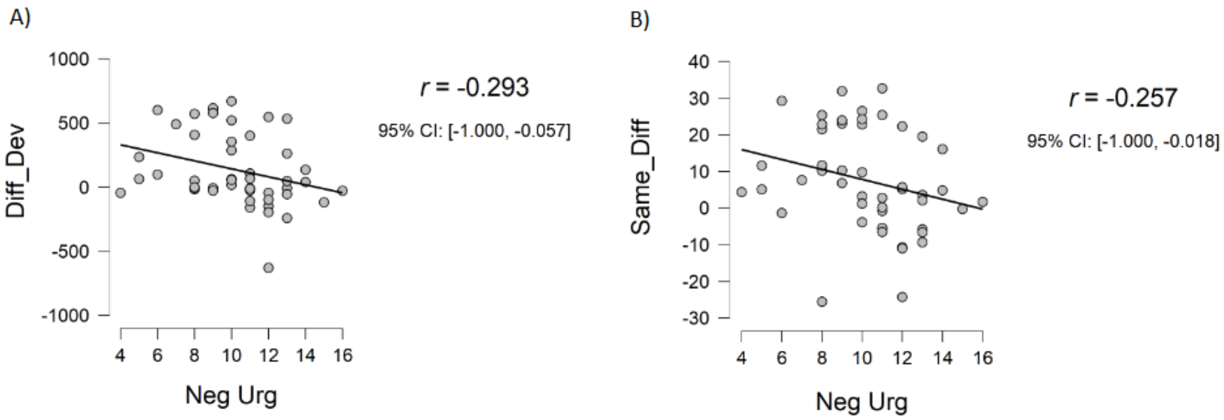
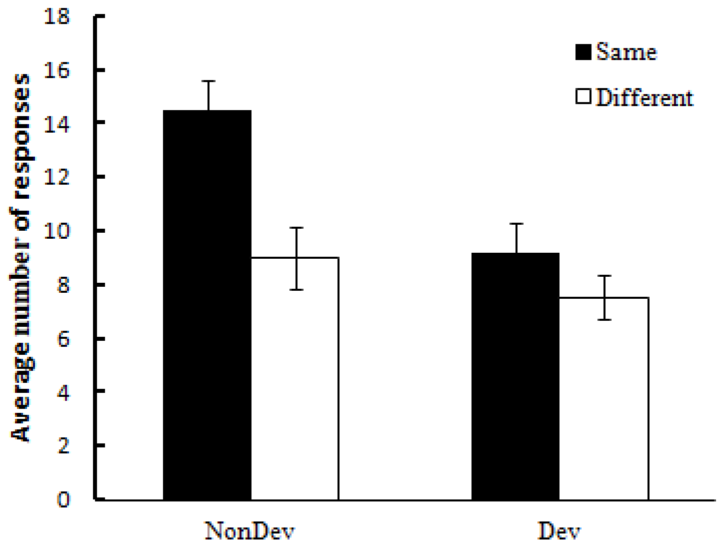

A)
1000
500
0
-500
-1000
Diff_Dev
4 6 8 10 12 14 16
Neg Urg
r = -0.293
95% CI: [-1.000, -0.057]
B)
40
30
20
10
0
-10
-20
-30
Same_Diff
4 6 8 10 12 14 16
Neg Urg
r = -0.257
95% CI: [-1.000, -0.018]

Figure 2



Average number of responses
18
16
14
12
10
8
6
4
2
0
Same
Different
NonDev
Dev

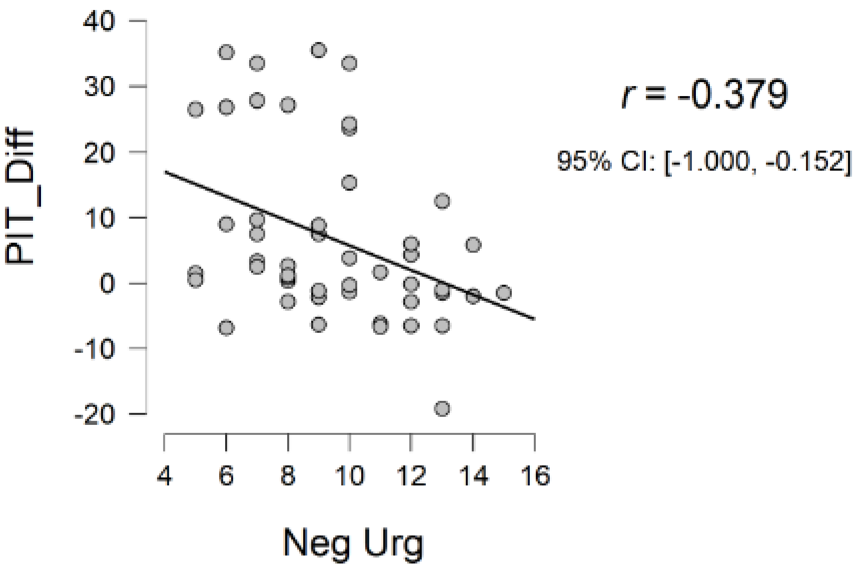

r = -0.379
95% CI: [-1.000, -0.152]
PIT_Diff
40
30
20
10
0
-10
-20
4
6
8
10
12
14
16
Neg Urg

Figure 4

Appendix A

Composition of the battery of questionnaires answered online by participants in Experiments 1 and 2.

As part of a wider unrelated research project aimed at studying several variables related to eating styles and personality traits, participants responded to a battery that was composed of, in addition to the UPPS-P, the following questionnaires or items: Spanish Revised Restraint Scale; Power of Food Scale, PFS, translated to Spanish by one of the authors and one English (American) native speaker; Spanish Version of the Shortened Sensitivity to Punishment and Sensitivity to Reward Questionnaire SPSRQ-20; Spanish Version of the Three-Factor Eating Questionnaire-R18; Item 26 of the Spanish Version of the Yale Food Addiction Inventory Scale, YFAS-S, and the three items of the Perceived Self-Regulatory Success measure applied to dieting, translated to Spanish by one of the authors and one English (American) native speaker. Participants responded online before being invited to participate in the experimental task of the present study.

Appendix B

Instructions of Experiments 1 and 2 (Translated from Spanish; original instructions are available upon request)

Experiments 1 and 2 (Instrumental and Pavlovian training were identical)

Instrumental training:

'You form part of a group whose aim is to obtain goodies to help impoverished children to celebrate their birthday parties. Each piece of food obtained will be of great utility. There is a rumour saying that it is possible to get free snacks from a vending machine. Press Key B in order to tilt the machine to the left, and Key N to tilt the machine to the right. Use only the pointing finger of your dominant hand. Tilt the machine until a product falls. You have to learn which snack falls when you tilt the machine to the right and which one falls when you tilt it to the left. Occasionally a question about this relationship will appear in order to check your knowledge about it. Press the space bar to continue'.

Pavlovian training:

'Your group has discovered that, when the machines are completely full of products, it is easier for products to fall freely. The lights on the front panel of the machine will signal when the machine is too full. You should just observe and pay attention in order to learn how the colours of the lights are related to each product. Again, you will occasionally be asked about these relationships. Use the keyboard [keys a, b, c, d] in order to select the correct answer. Press the space bar to continue'.

Experiment 1 (PIT first, devaluation afterwards)

Pavlovian-to-instrumental transfer

‘Now you and your group are going to be tested about the knowledge you have acquired so far. The aim of this phase is to optimize the process before going to the street to obtain products. Remember that you will be able to get them by tilting the machine to the left (Key B) or the right (Key N) in the way that you learnt in the first phase. Again, use only your dominant hand. Depending on the key you press, you will get one product or the other. However, in this phase you will not see images on the screen, although your task is still to obtain as many snacks as you can in the most efficient way. Additionally, consider the colour that the machine occasionally shows because this will give you a clue about which product is more likely to fall in a given time, as you learnt during the second phase. In summary, press keys ‘B’ and ‘N’ during the task in order to get products, as you did during the first phase. Likewise, take into account the colours that will occasionally light up in the machine in order to know which product is more likely to fall, according to what you have learned during the second phase. Finally, note that the task will last for approximately 7 minutes. Use this time to gain as many products as you can so the impoverished children can have the best birthday party of their lives. Press the space bar to continue’.

Outcome Devaluation

‘Congratulations, you have successfully passed the test and are now on the street with your group trying to get goodies for the impoverished children. You and your group are in an area with plenty of vending machines, thus it looks like a good place to start. However, one of you has discovered that the machines are infested! Disgusting insects have invaded some of the snack packages. When you tilt the machine, one of the products will be shared with these new inhabitants. Not all the snack packages, but half of them. Next you can see an image showing an instance of the state of half of the packages of that specific product. Pay close attention during the time the image is presented.

(After watching the image)

This is really a problem because, on the one hand, you need to get as many products as you can and, on the other, half of the packages of one of the products are infested with the insects. Remember that you will keep getting snacks by tilting the machine to the left (Key B) or to the right (Key N), as you learnt during the first phase. Again, use only the pointing finger of your dominant hand. Depending on which key you press, you will get one product or the other. However, in this phase you will not see the images of the products on the screen, although your task is still to obtain as many products as you can in the most efficient way. Go ahead, press the space bar to continue and get goodies for the impoverished children'.

Experiment 2 (Devaluation first, PIT afterwards)

'Congratulations, you have successfully passed the test and are now on the street with your group trying to get goodies for the impoverished children. You and your group are in an area with plenty of vending machines, thus it looks like a good place to start. However, one of you has discovered that the machines are infested! Disgusting insects have invaded some of the snack packages. When you tilt the machine, one of the products will be shared with these new inhabitants. No all the snack packages, but half of them. Next you can see one image showing an instance of the state of half of the packages of that specific product. Pay close attention during the time the image is presented.

(After watching the image)

This is really a problem because, on the one hand, you need to get as many products as you can and, on the other, half of the packages of one of the products are infested with the insects.

Now you get snacks by tilting the machine to the left (Key B) or to the right (Key N), as you learnt during the first phase. Again, use only the pointing finger of your dominant hand. Depending on which key you press, you will get one product or the other. However, in this phase you will not see the images of the products on the screen, although your task is still to obtain as many products as you can in the most efficient way. Depending on the key you press, you will get one product or another. Additionally, consider the colour that the machine occasionally shows because this will give you a clue about which product is more likely to fall in a given time, as you learnt during the second phase.

In summary, press the keys 'B' and 'N' during the task in order to get products, as you did during the first phase. Likewise, take into account the colours that will occasionally light up in the machine in order to know which product is more likely to fall, according to what you learned during the second phase.

Finally, note that the task will last for approximately 7 minutes. Use this time to gain as many products as you can so the impoverished children may have the best birthday party of their lives. Press the space bar to continue'.