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Value-based decision-making in daily tobacco smokers following experimental manipulation of mood

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Abstract

Background: Induction of negative mood increases tobacco choice in dependent smokers; however, less is known about the mechanisms behind this. This study addressed this gap by applying a computational model of value-based decision-making to tobacco and tobacco-unrelated choices following mood manipulation. **Method:** Using a pre-registered, within-subject design, 49 daily tobacco smokers (>10 daily cigarettes) watched two different videos which primed them to experience negative and positive mood (tobacco valuation and devaluation, respectively). Participants completed self-report measures of mood and craving to smoke before and after priming, followed by a two-alternative forced-choice task with (separate) blocks of tobacco-related and unrelated (animal) images. On each block, participants selected the image that they previously rated higher. A drift-diffusion model was fitted to the reaction time and error data to estimate evidence accumulation (EA) processes and response thresholds during the different blocks. **Results:** After watching videos intended to induce negative mood, happiness scores were lower ($p < .001$, $d = 1.16$), while sadness and craving to smoke scores were higher (both ps $< .001$, $ds > .60$), compared to after watching videos intended to induce positive mood. However, contrary to hypotheses, the experimental manipulation did not robustly affect EA rates ($F = 1.15$, $p = .29$, $\eta_p^2 = .02$) or response thresholds ($F = .07$, $p = .79$, $\eta_p^2 = .00$) for either tobacco or tobacco-unrelated decisions. **Conclusions:** Manipulation of mood in daily smokers did not lead to alterations in the internal processes that precede value-based decisions made about tobacco and tobacco-unrelated cues.

Keywords: Computational; Experimental; Mood; Tobacco; Valuation

Public Significance Statement

Contrary to theory, this pre-registered study found that being in a negative—relative to a positive—mood state does not correspond to changes in how people value tobacco or tobacco-unrelated alternatives. This result is important because it suggests that negative reinforcement models might not fully explain behaviour, or that the way mood affects how we value drugs might be more complex than we currently understand.

Introduction

Tobacco smoking is a leading global cause of preventable disease and death (Forouzanfar et al., 2016). In England, there are around 5.3 million current tobacco smokers (representing 12.7% of the population aged 18 and over; Office for National Statistics, 2023), leading to substantial health and socioeconomic consequences. Behavioural economic *reinforcer pathology* models posit that addiction (tobacco use disorder) develops and is maintained via distortions in valuation processes, such that tobacco is overvalued relative to other available reinforcers (Acuff et al., 2023; Bickel et al., 2011, 2014; Bickel & Athamneh, 2020; García-Pérez et al., 2022). Consistent with behavioural economic models, experimental research has shown that people ascribe higher value to tobacco relative to tobacco-unrelated alternative reward following the induction of negative mood (for a review, see Hogarth & Field, 2020). However, less is known about the underlying cognitive mechanisms through which this effect occurs. The present study applied computational advances in the measurement of value-based choice to decisions made about tobacco and tobacco-unrelated cues after experimental manipulation of mood.

Hypothetical purchase tasks are often used to experimentally measure "demand"—a behavioural economic construct that represents the reinforcing value of a commodity (MacKillop, 2016). During the cigarette purchase task (CPT; MacKillop et al., 2008), a person (hypothetically) estimates the number of cigarettes they would purchase to consume across steadily increasing prices. From this, a tobacco demand curve (i.e., a plot of the level of consumption and tobacco-related expenditure as function of cigarette price) can be generated that enables indices of tobacco value to be extracted (Aston & Cassidy, 2019). An alternative, but also commonly used method of quantifying drug value is with concurrent choice tasks (e.g., Hogarth et al., 2015) where a person chooses between tobacco and tobacco-unrelated images for a reward (e.g., image enlargement) over repeated trials. On

these tasks, the percentage choice of tobacco (relative to tobacco-unrelated) reward is taken to index the value ascribed to tobacco.

A robust body of evidence using these tools has demonstrated positive associations between nicotine dependence and tobacco value (González-Roz et al., 2019; Hardy et al., 2018; Miele et al., 2018; Zvorsky et al., 2019). Experimentally, studies have also uncovered important state-like fluctuations in drug value (Acuff et al., 2020; Amlung et al., 2015; Aston et al., 2021; Hogarth & Field, 2020). For example, Hogarth et al. (2015) found that when nicotine deprived smokers smoked to satiety (tobacco devaluation), tobacco choice on the concurrent choice task decreased in participants where positive mood was induced, but this was not observed in participants assigned to negative mood induction. This demonstrates the induction of negative mood augmented tobacco value to the extent that it outweighed the previous devaluation effect. Similar mood induction procedures have been used in alcohol-related studies, findings from which support the notion that negative mood is a powerful driver of elevated drug value (Hardy & Hogarth, 2017; Hogarth et al., 2018). This aligns with *negative reinforcement* models (Baker et al., 2004; Blevins et al., 2016; Cooper et al., 1995): substances may increase in value because they assist with the avoidance or regulation of negative internal states (Hogarth, 2022). However, existing studies are methodologically limited by concurrent choice tasks which do not provide insight into cognitive processes underlying decisions, and which focus solely on drug value. This may be a key oversight considering the emphasis on drug-free reinforcement in contemporary behavioural economic models of addiction (Acuff et al., 2023).

Value-based decision-making (VBDM) provides a framework that can be used to model the internal cognitive processes that determine momentary decisions (Berkman et al., 2017). According to VBDM, choice options (e.g., whether to smoke a cigarette, or to go for a run) are identified and assigned an overall value. The value of each option is determined via

an integration of context sensitive choice-relevant attributes (Berkman, 2018), and the response option with the highest value is acted upon. This process can be understood with the drift-diffusion model (DDM; Ratcliff & McKoon, 2008), which assumes people accumulate noisy evidence in favour of a response option until a response threshold is reached, at which point the decision is made (for a review, see Ratcliff et al., 2016). By fitting the DDM to behavioural data from VBDM tasks (Polanía et al., 2014), parameters with well-established psychological interpretation can be estimated. Two important parameters are rate of evidence accumulation (EA; the average rate at which value evidence is accumulated) and response threshold (decision conservativeness represented by speed-accuracy trade-offs).

Guided by conceptual accounts (Copeland et al., 2021; Field et al., 2020), several studies have extended VBDM to addiction research (Copeland, Stafford, Acuff, et al., 2023; Copeland, Stafford, & Field, 2023; Copeland et al., 2024; Dora, Copeland, et al., 2023). One online experimental study (Dora, Copeland et al., 2023) found that in heavy drinkers, inducing a negative mood altered the cognitive processes underlying value-based food decisions, but had no effect on alcohol valuation. However, to date VBDM has not been directly explored in tobacco smokers following the experimental manipulation of mood. It is important to note that in these studies (and the present study), participants make decisions about substance-related and substance-free stimuli separately. Although this methodology deviates from concurrent choice tasks because reinforcer value is not quantified *relatively*, it is essential for obtaining interpretable decision parameters and is common practice within the broader VBDM field (e.g., Polanía et al., 2014).

The present study is inspired by conceptual accounts of VBDM (Copeland et al., 2021; Field et al., 2020) and prior findings indicating that negative mood increases choice for tobacco over non-tobacco rewards (Hogarth et al., 2015). We predict that mood manipulation

will alter computational parameters of value-based choice (EA rates and response thresholds) in decisions involving tobacco and non-tobacco cues. Our hypotheses are that:

1. When participants are primed to experience negative mood, they will have increased EA rates and lower response thresholds when choosing between tobacco images compared to when choosing between tobacco-unrelated (animal) images.
2. When participants are primed to experience positive mood, they will have increased EA rates and lower response thresholds when choosing between tobacco-unrelated (animal) images compared to when choosing between tobacco images.
3. When choosing between tobacco images, participants will have increased EA rates and lower response thresholds when primed to experience negative mood compared to when primed to experience positive mood.
4. When choosing between tobacco-unrelated (animal) images, participants will have increased EA rates and lower response thresholds when primed to experience positive mood compared to when primed to experience negative mood.

Method

We report how we determined our sample size, all data exclusions, all manipulations, and all measures used throughout this section. Design, hypothesis, and analysis strategy were pre-registered before data collection commenced (https://aspredicted.org/XR7_6CY). Data preparation and statistical analyses were conducted in RStudio version 4.0.2 (R Core Team, 2023), and all anonymised data and analysis scripts are available: https://researchbox.org/3481&PEER_REVIEW_passcode=NXOCQR.

Participants

An *a priori* power analysis conducted on G*power (Faul et al., 2007) revealed that to detect a difference between two dependent groups with a medium effect size (d = .50 (or ηp^2

= .06); Cohen, 1988) at 90% power with an alpha of .05, 36 participants were required. We recruited 50 daily tobacco smokers through Prolific (https://www.prolific.co/)—an online platform designed for recruiting participants for research studies, however data from one participant was removed prior to analysis[1]. The remaining sample (n = 49; 30 females, 19 males) were aged between 26 and 69 years old (mean age = 46.96, SD = 12.33). Inclusion criteria were age ≥18 years old, current residence in the United Kingdom, identification as a current smoker who has smoked for >1 year, smoking >10 cigarettes per day, and only smoking tobacco. Participants were required to have taken part >10 previous studies with >95% approval on Prolific to maximise retention and data quality. The study was approved by the University of Sheffield research ethics committee, and all participants gave informed consent. Recruitment took place between July and August 2021. Participants were reimbursed with 0.38p for completing the pre-screen, and £12.50 for completing the study (in Prolific credit).

Materials

Pictorial stimuli for the VBDM task

The 30 smoking images were selected from the Geneva smoking pictures data set (Khazaal et al., 2012) and the 30 smoking-unrelated (animal) images were selected from the international affective picture system (IAPS; Lang et al., 2008). Standardised valence ratings that accompany the picture sets were used to guide selection of images that were likely to be rated as highly positive, highly negative, or intermediate (for more detail, see supplementary file).

[1]This is because it was not possible to recover DDM parameters for this participant in one of the conditions due to an accuracy score of 0.

Video stimuli (experimental manipulation)

Previously validated videos (Marcusson-Clavertz et al., 2019) were used in attempt to indirectly manipulate tobacco value via mood. The videos (described below) contained film clips and self-referential statements accompanied by music[2] and were selected because they have been found to successfully alter participant mood in an online sample recruited from Prolific (Marcusson-Clavertz et al., 2019). Participants were informed that after watching, they would answer two questions about each video, all of which they answered correctly.

We aimed to induce positive mood (tobacco devaluation) by instructing participants to watch a 4-minute video of Timon & Pumbaa's "Hakuna Matata" scene from the Lion King, followed by another 4-minute video which presented 15 positive Velten statements (e.g., "*Most people like me*") accompanied by upbeat music (Coppelia, Act I: 1. Prelude et Mazurka by Léo Delibes). Existing positivity ratings (Marcusson-Clavertz et al., 2019) determined the Velten statements' order, ending with the most positive.

We aimed to induce negative mood (tobacco valuation) by instructing participants to watch a 4-minute video of Mufasa's death scene from the Lion King, followed by another 4-minute video which presented 15 negative Velten statements (e.g., "*When I talk no one really listens*") accompanied by downbeat music (Adagio for Strings, Op. 11 by Samuel Barber). Existing negativity ratings (Marcusson-Clavertz et al., 2019) determined the Velten statements' order, ending with most negative. This experimental condition contained a 'mood repair' so that participants would not end their participation in a heightened negative mood[3].

Questionnaires

[2]The videos are maintained in a library that is owned by Marcusson-Clavertz et al. (2019). Please contact the author(s) for permission to access or use these materials.
[3]This included eight highly rated amusing video clips (Samson et al., 2016), each lasting ~30 seconds, distinct from the mood manipulation, which is important for the counterbalanced order of conditions.

We administered: The 6-item Fagerström Test for Cigarette Dependence (Fagerström, 2012, McDonald's ω = .60 (McDonald, 1970, 1999)) to measure cigarette dependence, the 13-item Brief Self-Control Scale (BSCS; Tangney et al., 2004, ω = .80) to measure self-control, the 22-item Cigarette Purchase Task (CPT; Aston et al., 2021; MacKillop et al., 2008) to estimate indices of cigarette demand (intensity, O_{max}, P_{max}, breakpoint, elasticity)[4], the Contemplation Ladder (Biener & Abrams, 1991) to capture motivation to quit smoking (ladder ranging from 0 (no thought about quitting) to 10 (taking action to quit)), the Positive and Negative Affect Schedule-Expanded (PANAS-X; Watson & Clark, 1999, all ω's > .77) to measure participant joviality (8-items) and sadness (5-items) pre and post manipulation, a single item of craving (West & Ussher, 2010) to measure craving to smoke (visual analogue scale ranging from 0 (no urge to smoke) to 100 (extreme urge to smoke)) pre and post manipulation. Finally, we measured participant demographics (age, gender, smoking quit attempts (if any), typical cigarette consumption per day, years smoked, and age of initiation of smoking).

Procedure

Participants completed the study online. In line with Marcusson-Clavertz et al. (2019), a short (3-minute) pre-screen including the PHQ-2 (Kroenke et al., 2003) was administered to safeguard participants who might be vulnerable to distress induced by the negative mood induction. Participants were not eligible if they scored >1 on both questions of the PHQ-2.

Eligible participants were invited to two testing sessions, with counterbalanced mood induction order (positive first for half, negative first for the other half; see supplementary file for analyses of order effects). After session 1, participants completed session 2 within 10 days (M = 2.65, SD = 1.69). In each condition, participants rated images, completed questionnaires (only in session 1), reported mood and craving before and after mood manipulation, and then

[4] See supplementary file for the exact scenario wording and price points.

completed the VBDM task. The study lasted 88.30 minutes on average (SD = 19.07). The VBDM task was programmed in PsychoPy and hosted on Pavlovia (Peirce et al., 2019).

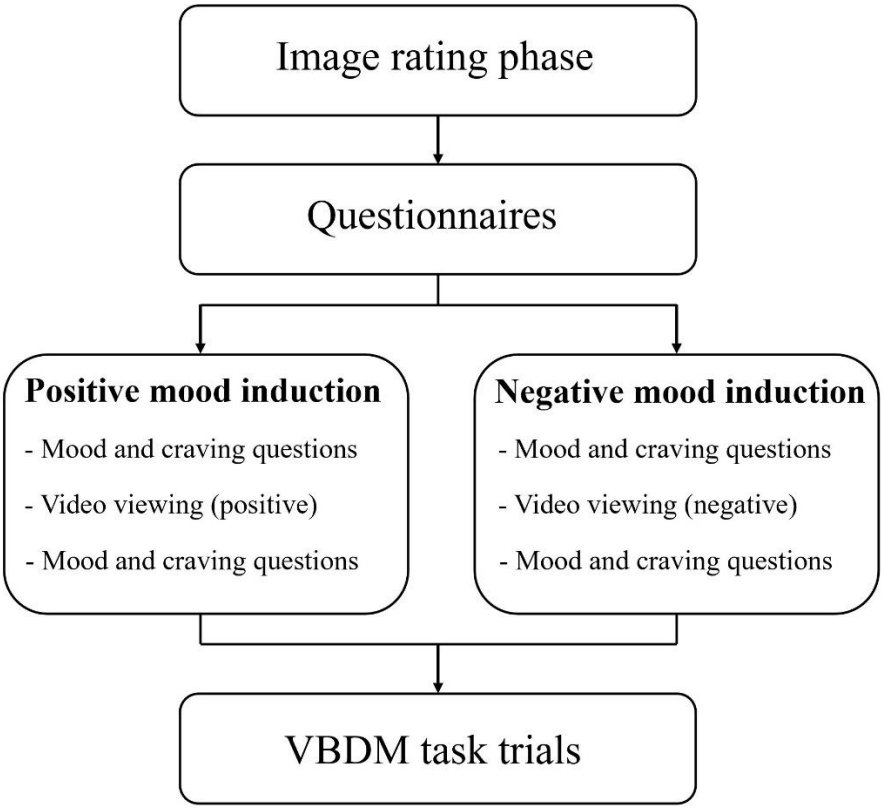
Image-rating phase

Participants viewed two sets of 30 images (a tobacco-related set, and a tobacco-unrelated (animal) set) and made preferential judgements about them using a computer mouse to indicate how positive they rate the image: 'Most positive', 'Somewhat positive', 'Somewhat negative', and 'Most negative'. For each picture set, participants were instructed to rate all 30 images, whilst assigning at least five images to each category.

Value-based decision-making (VBDM) task

In the VBDM task, five images were randomly selected from each category ('Most positive', 'Somewhat positive', 'Somewhat negative', and 'Most negative'). Each image was displayed in the centre of the screen for 3 seconds, followed by a 500ms fixation cross, to familiarise participants with the selected images and their evaluations. Following this, participants completed the task. On each trial, two images appeared in the centre of the screen and participants were instructed to use one of two keys to choose the image that they rated higher by pressing one of two keys ('Z' for left and 'M' for right) as quickly as possible. They started with some practice trials followed by the main task of 300 trials divided into two 150-trial blocks (tobacco-unrelated and tobacco-related; order randomized) with breaks every 50 trials. Difficulty levels varied: the rating difference between images could be 1 (hard), 2 (medium), or 3 (easy). The higher-rated image's position (left or right) was randomised. Participants had up to four seconds to respond, responses outside of this response window were classed as "miss trials" (Polanía et al., 2014).

Figure 1. *Schematic overview of the study procedure*



Note. Questionnaires include demographic questions (age and gender), questions about cigarette use such as quit attempts (if any), typical cigarette consumption per day, years smoked, and age of initiation of smoking, the Fagerström Test for Cigarette Dependence, the Brief self-control scale (BSCS), the Cigarette Purchase Task (CPT), and a Contemplation Ladder. The order of mood induction was counterbalanced, and participants only completed the self-report questionnaires in the first experimental condition that they completed.

Data preparation and analysis

On the VBDM task, "miss trials" (responses exceeding 4 seconds) were removed (0.15%) and trials that were under 300ms (0.21%) as these are likely to be fast guesses (Ratcliff et al., 2006) resulting in the removal of 0.36% of trials. We then fitted the DDM (Ratcliff & McKoon, 2008) using the EZ method (Wagenmakers et al., 2007) which takes response accuracy, mean correct RT, and variance of correct RT as input to estimate three key parameters which are: EA rate (also referred to as 'drift rate' (v)), response threshold

(also referred to as 'boundary separation' (*a*)), and non-decision time (T_{er}). Parameters were estimated for each of the experimental conditions, difficulty level, and image type (see supplementary file for analyses on difficulty levels in isolation).

For the CPT, the consistency of the demand data was checked using a standardised three-point algorithm (Stein et al., 2015) as cases that violate any of the following criteria: *trend* (detection limit for $\Delta Q < 0.025$); *bounce* (detection limit for $B = 0.10$); and *reversals from zero* (detection limit number for reversals = 2 or more). Data from all participants passed these criteria. Four observed (intensity, breakpoint, O_{max}, P_{max}) indices were generated from raw consumption and expenditure data, while elasticity was derived using the exponentiated demand equation (Koffarnus et al., 2015) in the R package "beezdemand" (Kaplan et al., 2019)[5]. Outliers greater than 3.29 standard deviations from the mean (index level) were winsorized to one unit above the greatest non-outlying value (Tabachnick & Fidell, 2013). The exponentiated equation provided an excellent fit for both participant-level and aggregated data ($R^2 = 0.92$ and $R^2 = 0.98$ respectively).

Paired samples (one-tailed) *t*-tests were used to analyse the data for the primary pre-registered hypotheses, supplemented by exploratory repeated-measure ANOVAs to interpret any group differences in VBDM parameters. Non-parametric tests were used for data that were not approximately normally distributed. All participants passed >75% of the attention checks which was our pre-registered criterion.

Results

See Table 1 for descriptive statistics.

Table 1

[5]The *k* value was approximately 2.48 and was calculated using the *GetK* function in "beezdemand" (Kaplan et al., 2019).

Descriptive statistics of the sample (values represent the mean, standard deviation, and range)

Variable	Mean (SD, range)
BSCS	37.61 (7.75, 23-52)
FTCD	5.10 (1.79, 1-10)
Contemplation ladder	5.45 (2.56, 0-10)
Cigarettes smoked per day	17.94 (8.13, 5-60)
Years smoked	30.84 (12.09, 12-53)
Age (years) of smoking initiation	15.49 (2.76, 10-22)
Number of previous quit attempts	1.76 (1.52, 0-6)
CPT indices of demand	
Intensity	22.37 (8.02, 10-41)
O_{max}	14.13 (11.68; 2-49)
BP1	2.89 (2.72, .40-10)
P_{max}	1.79 (1.89, .20-7)
Elasticity	.01 (.01, .00-.04)

Note. BSCS = brief self-control scale. FTCD = Fagerström test for cigarette dependence.

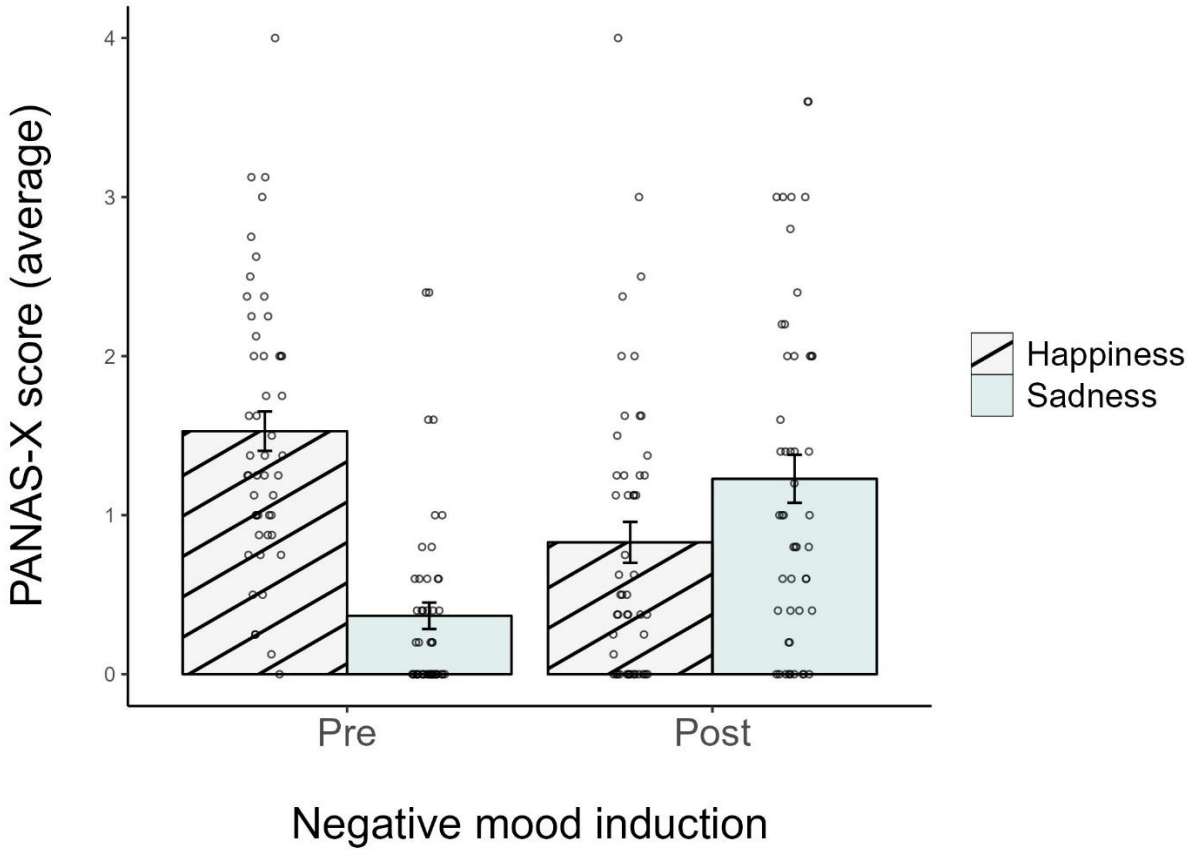
Effects of experimental manipulation on mood scores (Figures 2 and 3)

Self-report mood ratings were analysed using a three-way repeated measures ANOVA with mood (2: happy; sad), time (2: before video; after video), and experimental condition (2: positive; negative) as within-subject variables. There was a significant three-way interaction between mood, time, and condition, $F(1, 48) = 66.96$, $p < .001$, $\eta_p^2 = .58$. To examine this interaction further, subsequent two-way ANOVAs were conducted on each mood separately, followed by post-hoc tests (applying the Holm-Bonferroni correction to *p*-values for multiple comparison). These analyses revealed a significant interaction between time and

experimental condition for both moods (happy mood, $F(1, 48) = 67.32$, $p < .001$, $\eta_p^2 = .58$; sad mood, $F(1, 48) = 43.01$, $p < .001$, $\eta_p^2 = .47$). Post-hoc tests revealed that after watching the videos intended to induce negative mood, happiness scores decreased ($p < .001$, $d = .78$) whilst sadness scores increased compared to before viewing the videos ($p < .001$, $d = 1.76$). A different pattern was seen after participants watched the videos intended to induce positive mood: happiness scores increased compared to before viewing the videos ($p < .001$, $d = .44$), but sadness scores did not significantly differ as a result of viewing the videos ($p = .07$, $d = .36$).

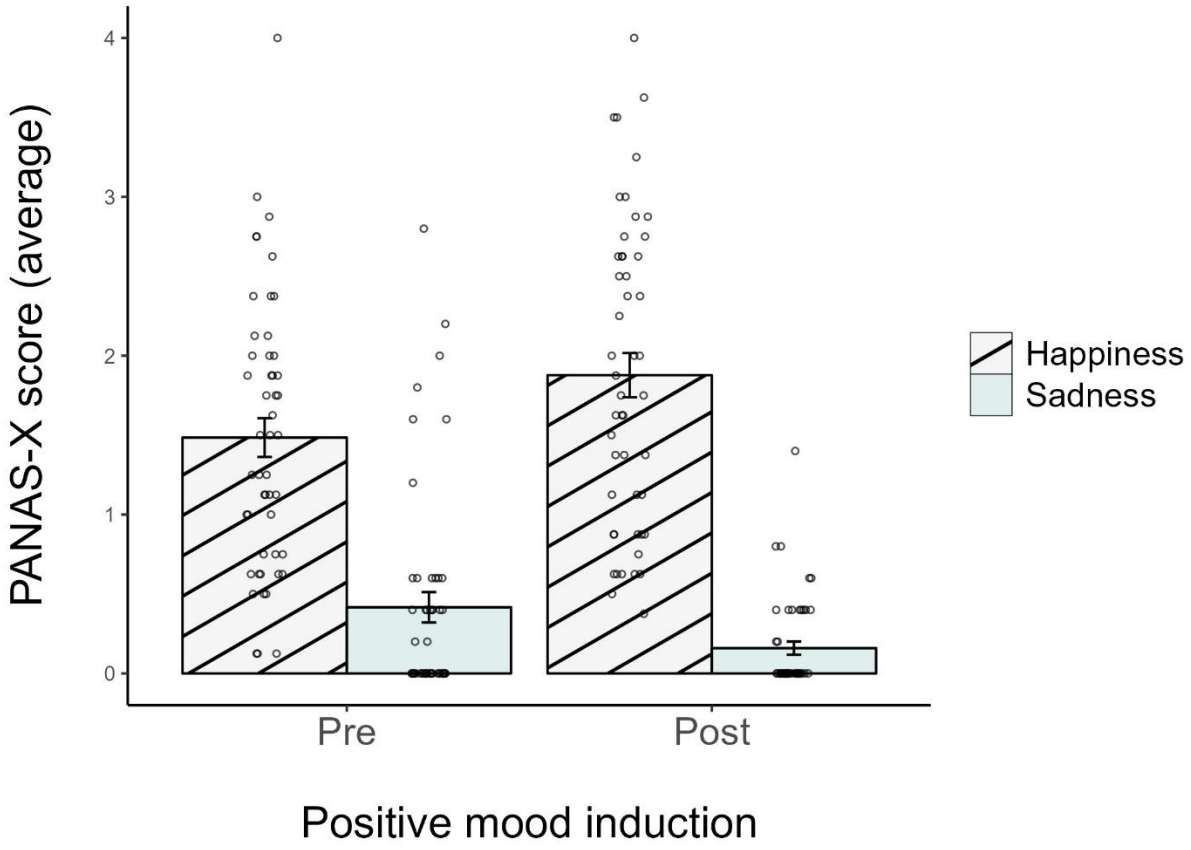
Looking at contrasts for scores after watching the videos only, sadness scores were significantly higher after the negative videos compared to after the positive videos ($p < .001$, $d = 1.52$), while happiness scores were significantly higher after the positive videos compared to after the negative videos ($p < .001$, $d = 1.16$). Looking at contrasts for before watching the videos only, there were no significant differences in sadness ($p = .70$, $d = .07$) or happiness ($p = .73$, $d = .05$) scores.

Figure 2. *Average PANAS-X scores (happiness and sadness subscales) pre (before) and post (after) watching the negative videos in the negative mood experimental condition*



Note. Error bars represent the standard error (SE) of the mean.

Figure 3. *Average PANAS-X scores (happiness and sadness subscales) pre (before) and post (after) watching the positive videos in the positive mood experimental condition*



Note. Error bars represent the standard error (SE) of the mean.

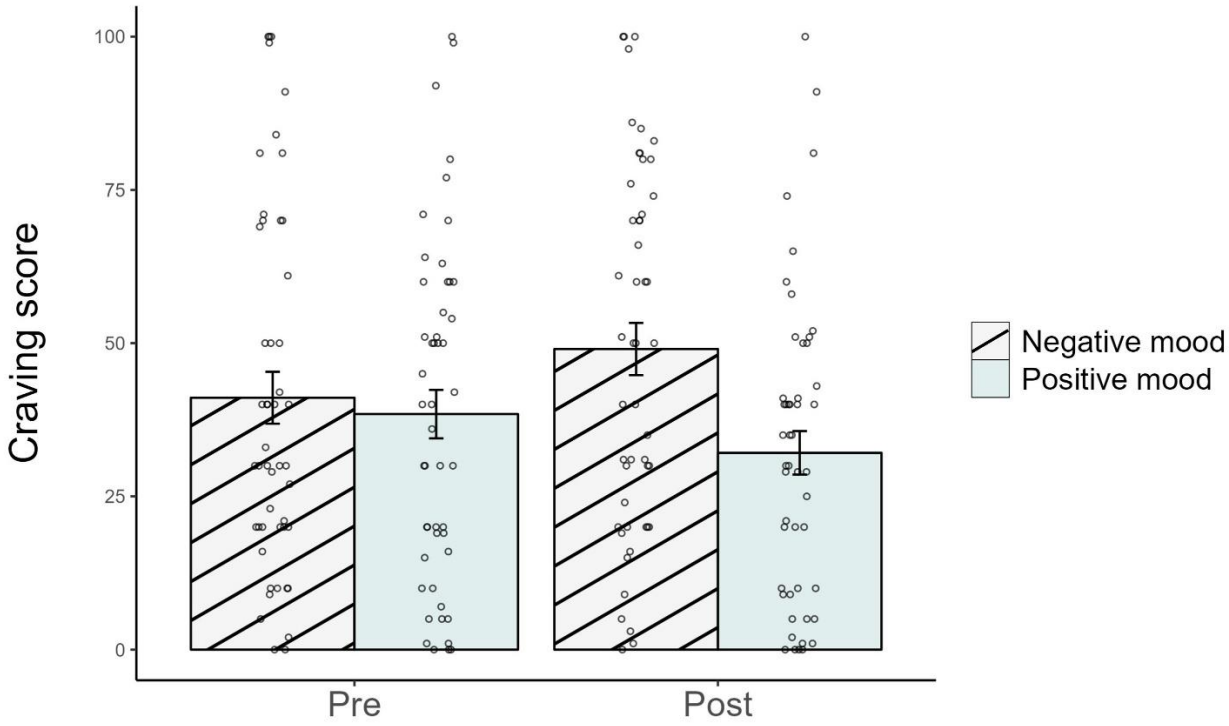
Effects of experimental manipulation on craving to smoke (Figure 4)

Craving scores were analysed using a two-way repeated measures ANOVA with time (2: before video; after video), and experimental condition (2: positive; negative) as within-subject variables. There was a significant interaction between time and condition ($F(1, 48) = 17.90$, $p < .001$, $\eta_p^2 = .27$). Post-hoc tests revealed that in the negative mood condition, craving was higher after watching the videos compared to before watching, but this was not statistically significant ($p = .05$, $d = .28$). Similarly, in the positive mood condition, there were no significant differences in craving before versus after watching the videos ($p = .08$, $d = .23$).

Looking only at craving after viewing the videos, craving scores were significantly higher after the negative videos compared to after positive videos ($p < .001$, $d = .60$).

Looking at contrasts only before watching the videos, there were no significant differences in craving scores (p = .39, d = .10).

Figure 4. *Craving to smoke scores split by experimental condition pre and post the experimental induction of negative and positive mood*



Note. Error bars represent the standard error (SE) of the mean.

Pre-registered analyses

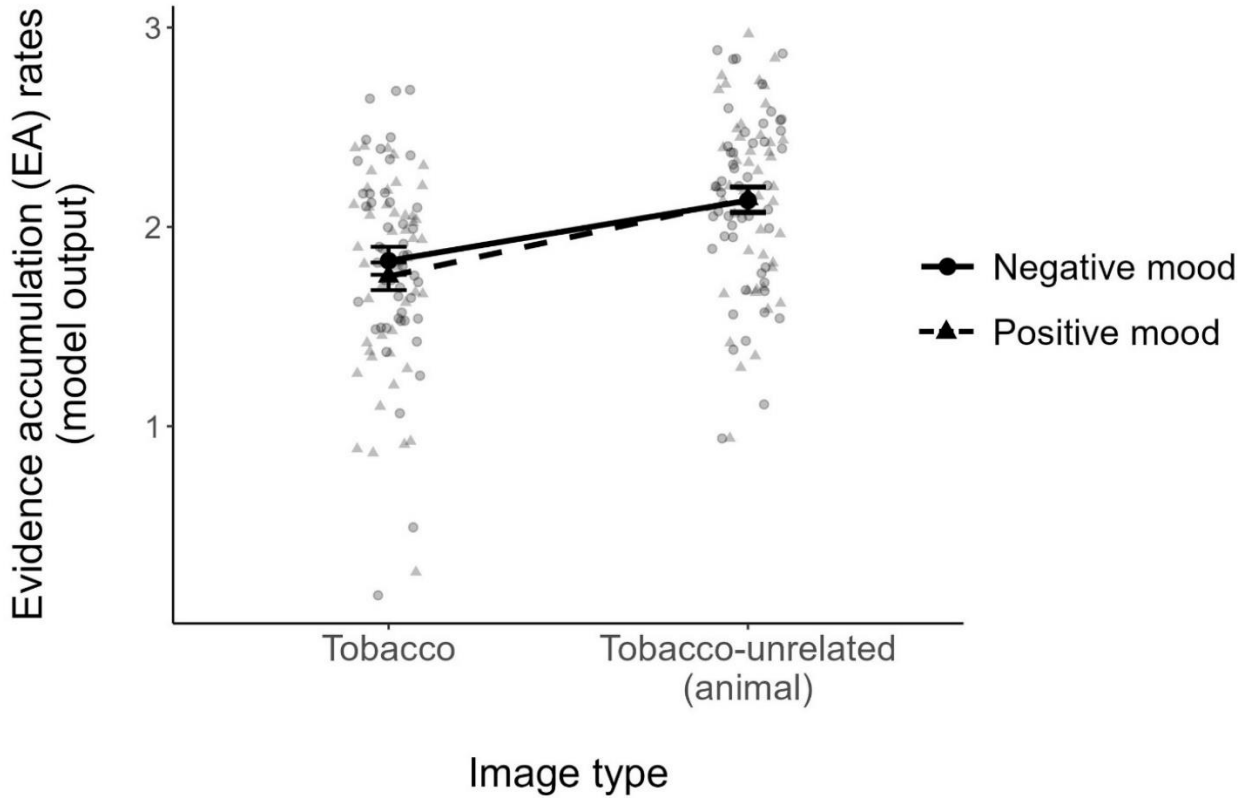
Hypothesis 1: When primed to experience a negative mood, participants did not have significantly higher tobacco EA rates (M = 1.83 SD = .49) compared to tobacco-unrelated (animal) EA rates (M = 2.13, SD = .45), $t(48) = 4.50$, $p = 1.00$, $d = .64$. Furthermore, participants did not have significantly lower tobacco response thresholds (M = 1.57, SD = .31) compared to tobacco-unrelated (animal) thresholds (M = 1.57, SD = .31), $t(48) = .09$, $p = .46$, $d = .01$. Therefore, this hypothesis was not supported.

Hypothesis 2: When primed to experience a positive mood, participants had significantly higher tobacco-unrelated (animal) EA rates (M = 2.14, SD = .44) compared to tobacco EA rates (M = 1.75, SD = .48), $t(48) = 6.02$, $p < .001$, $d = .86$. However, they did not have significantly lower tobacco-unrelated (animal) response thresholds (M = 1.54, SD = .29) compared to tobacco response thresholds (M = 1.52, SD = .29); $t(48) = .53$, $p = .70$, $d = .08$. Therefore, this hypothesis was partially supported.

Hypothesis 3: When choosing between tobacco images, EA rates in the negative mood condition (M = 1.83, SD = .49) were not significantly higher compared to in the positive mood condition (M = 1.75, SD = .48); $t(48) = 1.15$, $p = .13$, $d = .16$. Furthermore, response thresholds were not significantly lower in the negative mood condition (M = 1.57, SD = .31) compared to in the positive mood condition (M = 1.52, SD = .29), $t(48) = 1.24$, $p = .89$, $d = .18$. Therefore, this hypothesis was not supported.

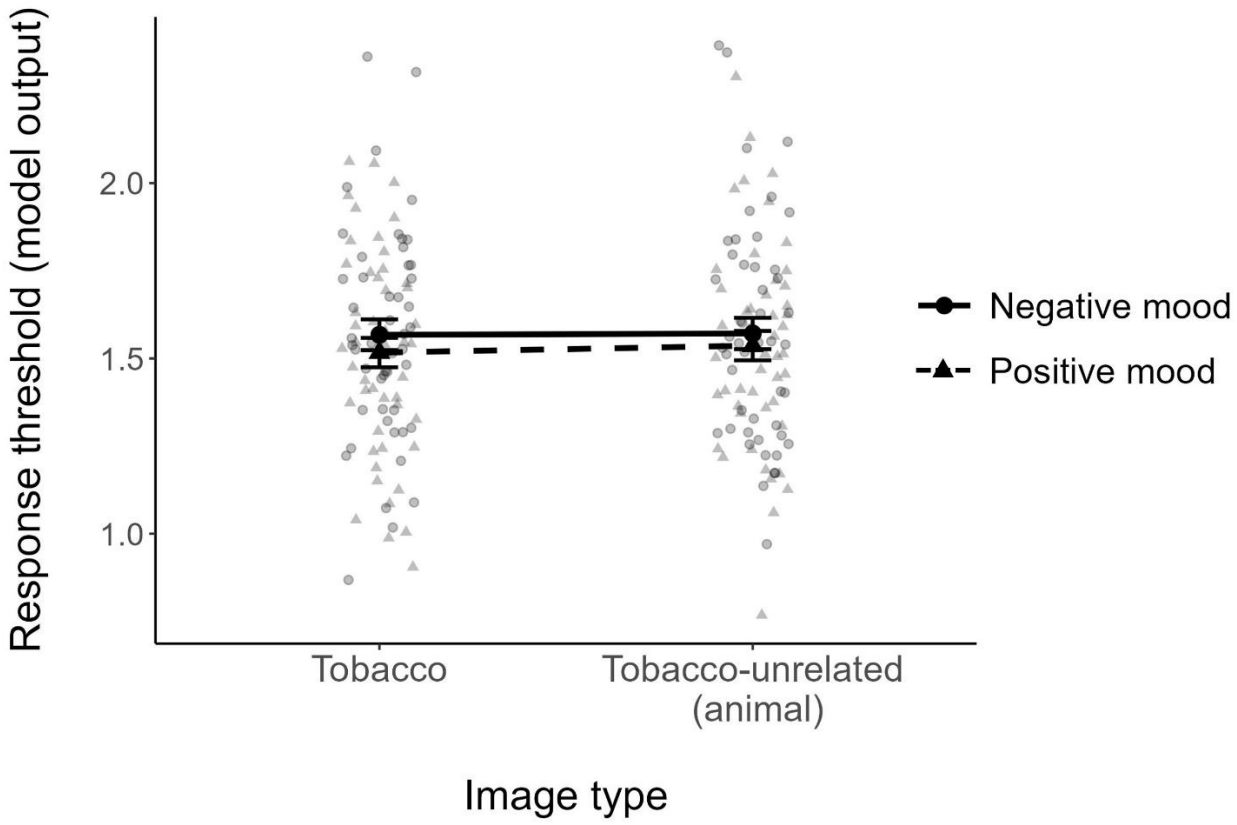
Hypothesis 4: When choosing between tobacco-unrelated (animal) images, EA rates were not significantly higher in the positive mood condition (M = 2.14, SD = .44) compared to the negative mood condition (M = 2.13, SD = .45), $t(48) = .10$, $p = .46$, $d = .01$. Furthermore, response thresholds were not significantly lower in the positive mood condition (M = 1.54, SD = .29) compared to the negative mood condition (M = 1.57, SD = .31), $t(48) = .89$, $p = .19$, $d = .13$. Therefore, this hypothesis was not supported.

Figure 5. *Evidence accumulation (EA) rates for tobacco and tobacco-unrelated (animal) choices split by negative (solid black line; circle) and positive (dashed black line; triangle) mood conditions*



Note. Error bars represent the standard error (SE) of the mean.

Figure 6. *Response thresholds for tobacco and tobacco-unrelated (animal) choices split by negative (solid black line; circle) and positive (dashed black line; triangle) mood conditions*



Note. Error bars represent the standard error (SE) of the mean.

Exploratory analyses

To supplement the VBDM analyses presented above, we conducted exploratory repeated-measure ANOVAs on EA rates and response thresholds using within-subject factors of image type (2: tobacco-unrelated (animal); tobacco) and experimental condition (2: positive; negative)[6]. When looking at EA rates, there was a significant main effect of image type ($F(1, 48) = 43.37$, $p < .001$, $\eta_p^2 = .47$), but no significant main effect of experimental condition ($F(1, 48) = .33$, $p = .57$, $\eta_p^2 = .01$), and no interaction ($F(1, 48) = 1.15$, $p = .29$, $\eta_p^2 = .02$). Post-hoc tests for the significant main effect of image type revealed that, collapsed across experimental condition, EA rates were higher for tobacco-unrelated (animal) choices (M = 2.14, SD = .35) compared to tobacco choices (M = 1.79, SD = .43; $p < .001$). When

[6]We note our study was powered to detect mean differences between dependent groups, not interaction effects.

looking at response thresholds, there was no significant main effect of image type ($F(1, 48) = .20$, $p = .66$, $\eta_p^2 = .00$) or experimental condition ($F(1, 48) = 2.47$, $p = .12$, $\eta_p^2 = .05$), and no interaction between the two ($F(1,48) = .07$, $p = .79$, $\eta_p^2 = .00$).

Discussion

The present study applied computational advances in the measurement of value-based choice to daily smokers' tobacco and tobacco-unrelated decisions following experimental manipulation of mood.

Inspired by conceptual accounts of VBDM (Copeland et al., 2021; Field et al., 2020) and prior findings (Hogarth et al., 2015; Hogarth & Field, 2020), we hypothesised that negative (relative to positive) mood would increase tobacco value, reflected in EA rates and/or response thresholds. Unexpectedly, we did not observe any robust between or within-condition differences in VBDM parameters following the experimental manipulation of mood, and therefore our findings did not support pre-registered hypotheses. Although tobacco-unrelated (animal) EA rates were significantly higher compared to tobacco EA rates when participants were primed to experience positive mood, additional analyses demonstrated that tobacco-unrelated EA rates were consistently higher regardless of the experimental manipulation.

The finding that mood manipulation did not robustly alter VBDM parameters does not align with conclusions derived from existing experimental studies that captured overt choice (Hardy & Hogarth, 2017; Hogarth et al., 2015, 2018). Our findings highlight the need to reassess the robustness of existing assumptions about the relationships between mood and drug value. While we can be reasonably confident that post-manipulation there were statistically significant differences in self-reported mood across groups, the anticipated effects on VBDM parameters were not empirically observed. This null result warrants careful

consideration, as it suggests either that negative reinforcement models may be inaccurate or that nuanced effects of mood on drug value remain uncaptured.

However, it is important to acknowledge methodological differences which impede direct comparison between the present study and previous work, including the task used to capture value-based choice. In line with existing VBDM research (e.g., Polanía et al., 2014) we instructed participants to choose between two tobacco or tobacco-unrelated images in separate blocks because this generates the behavioural data required to recover interpretable parameters that represent the internal processes underpinning value-based choice (Field et al., 2020). In addition, Hogarth et al. (2015) used a similar, but briefer manipulation of mood, and administered a singular-scale to explore the effect of the mood manipulation. Other differences are that the present study used a within-subjects, rather than between-subjects, design, and that it was conducted online rather than in a laboratory setting. Overall, these methodological differences may in part account for why it is difficult to reconcile our findings with previous research.

Another potential explanation for the non-significant findings in the present study stems from research uncovering complexity in relationships between mood and drug use. An individual-level meta-analysis (Dora, Piccirillo, et al., 2023) containing daily survey data from >12,000 participants found that people are more likely to drink heavily on days they experience high positive affect, not when they experience high negative affect. These observational findings challenge the general assumption that people consume more alcohol in response to negative mood. Although the aforementioned findings are specific to alcohol, the direct contrast between negative and positive mood in the present study may have obscured any clear distinction in VBDM parameters. Meta-analytic findings (Acuff et al., 2020) have also quantified small and non-significant effect sizes for the influence of negative affect on tobacco value as captured by hypothetical purchase tasks; therefore, it may be that our

manipulation of tobacco value was relatively weak in comparison to other techniques such as deprivation (Lawn et al., 2015), satiation (Hogarth, 2012; Hogarth & Chase, 2011), and stress induction (Aston et al., 2021). While negative mood induction strongly heightened feelings of sadness, and moderately heightened craving to smoke, it did not lead to alterations in tobacco value.

This study has limitations; unlike previous research (Dahne et al., 2017), we did not measure the time since participants last smoked or the number of cigarettes consumed before participating, meaning baseline differences in nicotine satiety may have added noise to the mood manipulation effect. Future studies of this type should use biochemical verification of smoking status and recent smoking, where possible. Secondly, participants took part from home, limiting environmental control. However, Prolific is known for generating high quality data (Peer et al., 2021), likely due to its ID verification requirements which other crowdsourcing platforms do not have, and participants were instructed to complete the study in a quiet, distraction-free setting. Thirdly, depression is associated with mood-induced tobacco-seeking (Hogarth et al., 2017), and our pre-screening process (in which we prioritised participant wellbeing) may have unintentionally excluded participants most susceptible to a mood-driven increase in tobacco craving.

Future VBDM research may recruit larger samples, and use different techniques to manipulate tobacco value such as deprivation (Lawn et al., 2015) and satiety (Hogarth, 2012; Hogarth & Chase, 2011) which can be objectively verified by expired carbon monoxide. This would also enable quantification of time since participants last smoked, meaning this can be controlled for. Another interesting avenue would be to recruit a sample with a broader range of depressive symptom scores, alongside inclusion of self-report measures that may also be important predictors of negative mood-induced tobacco seeking, such as coping motives (Hogarth, 2022). Finally, previous studies have used food/chocolate (Chase et al., 2013;

Hogarth et al., 2015) or face (Hardy et al., 2018) images as the tobacco-unrelated category. We used animal stimuli to align with our previous VBDM research on tobacco choice (Copeland, Stafford, & Field, 2023), but future studies could explore tobacco-unrelated stimuli that are perceived as equally rewarding as tobacco cues. Additionally, although our experimental comparison aligns with Hogarth et al. (2015), future research should compare mood-induced effects on VBDM parameters with a neutral manipulation.

To conclude, the experimental manipulation of mood in daily tobacco smokers did not alter EA rates or response thresholds for tobacco and tobacco-unrelated decisions. These findings suggest that in contrast to existing experimental evidence and negative reinforcement models, the induction of negative mood may not consistently lead to elevations in drug value, although future research is this area is warranted.

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Supplementary files for "Value-based decision-making in daily tobacco smokers following experimental manipulation of mood".

Contents:

1. Images used in the VBDM task and their valence ratings

The 30 smoking images are taken from the Geneva Smoking Images (Khazaal et al., 2012). These tobacco-related images comprise the product itself (e.g., a burning cigarette), smoking-related behaviours (e.g., a person smoking), and tobacco-related cues (e.g., an ashtray, a lighter). Images which depicted tobacco brands were not included to reflect the plain packaging legislation in the UK. Below are the filenames of the images and their valence ratings. All images can be found in the supplementary material of the original paper here: https://www.karger.com/Article/Fulltext/335083

Table S1

Image filenames and valence ratings of the Geneva Smoking Images

Image (file) name	Valence rating
GSP1.jpg	3.50
GSP29.jpg	3.96
GSP25.jpg	4.22
GSP30.jpg	4.30
GSP20.jpg	4.30
GSP28.jpg	4.41
GSP39.jpg	4.70
GSP37.jpg	4.76
GSP40.jpg	5.09
GSP32.jpg	5.13
GSP6.jpg	5.15
GSP50.jpg	5.15
GSP31.jpg	5.26
GSP26.jpg	5.33
GSP54.jpg	5.37
GSP23.jpg	5.87
GSP58.jpg	5.98

GSP8.jpg	6.07
GSP17.jpg	6.09
GSP22.jpg	6.13
GSP15.jpg	6.24
GSP13.jpg	6.33
GSP10.jpg	6.62
GSP43.jpg	6.63
GSP47.jpg	7.17
GSP24.jpg	7.26
GSP11.jpg	7.59
GSP56.jpg	7.83
GSP9.jpg	7.83
GSP51.jpg	7.96

The 30 animal images are taken from the International Affective Picture System (IAPS; Lang et al., 2008). These images comprise a number of different animals (e.g., parrots, dogs, insects, snakes). Below are the filenames of these images and their valence ratings. This link has information on how to request access to the images: https://csea.phhp.ufl.edu/media/iapsmessage.html.

Table S2

Image filenames and valence ratings of the International Affective Picture System images

Image (file) name	**Valence rating**
1710.jpg	8.34
1750.jpg	8.28
1460.jpg	8.21
1400.jpg	8.19
1620.jpg	7.37
1600.jpg	7.37
1721.jpg	7.30
1500.jpg	7.24

1740.jpg	6.91
1603.jpg	6.90
1812.jpg	6.83
1720.jpg	6.79
1650.jpg	6.65
1419.jpg	6.54
1333.jpg	6.11
1560.jpg	5.97
1670.jpg	5.82
1121.jpg	5.79
1903.jpg	5.50
1350.jpg	5.25
1726.jpg	4.79
1945.jpg	4.59
1390.jpg	4.50
1321.jpg	4.32
1930.jpg	3.79
1280.jpg	3.66
1300.jpg	3.55
1050.jpg	3.46
1202.jpg	3.35
1274.jpg	3.17

2. Further detail on the experimental manipulation of mood

The experimental manipulation of mood in this study used materials from a previous study which found they were effective in inducing happy and sad moods via online methods (Marcusson-Clavertz et al., 2019; please contact these author(s) for permission if you wish to access or use these materials).

Positive mood induction (8 minutes in total)

Video 1: Lion King: Timon & Pumbaa - "Hakuna Matata" (4 minutes)

Video 2: Music: Coppelia, Act I: 1. Prelude et Mazurka (4 minutes) + 15 positive Velten statements (each presented for 16s)

Positive Velten statements:

1. "*If I set my mind to it, I can make things turn out fine*"
2. "*Most people like me*"
3. "*When I have the right attitude, nothing can depress me*"
4. "*The world is full of opportunities and I'm trying to take advantage of them*"
5. "*I feel creative*"
6. "*I can make things happen*"
7. "*I'm in charge of my life and I like it that way*"
8. "*I'm energized*"
9. "*I'm pleased that most people are so friendly to me*"
10. "*I know I can do it; I'm going to seize the day!*"
11. "*The relationships I have now are the best I've ever had*"
12. "*I've got some good friends*"
13. "*Life's a blast: I can't remember when I felt so good*"
14. "*Things look totally awesome*"

15. "*It's great to be alive*"

Negative mood induction (8 minutes in total)

Video 1: Lion King: Death of Mufasa (4 minutes)

Video 2: Music: Barber's Adagio for Strings (4 minutes) + 15 negative Velten statements (each presented for 16s)

Negative Velten statements:

1. "*Sometimes I feel really guilty about the way I've treated my parents*"
2. "*I feel like my life's in a rut that I'm never going to get out of*"
3. "*Nobody understands me or even tries to*"
4. "*Life is such a heavy burden*"
5. "*I wish I could be myself, but nobody likes me when I am*"
6. "*Every time I turn around, something else has gone wrong*"
7. "*When I talk no one really listens*"
8. "*I don't think things are ever going to get better*"
9. "*I feel cheated by life*"
10. "*My mistakes haunt me; I've made too many*"
11. "*I'm unhappy with myself*"
12. "*I feel I am being suffocated by the weight of my past mistakes*"
13. "*Sometimes I feel so guilty that I can't sleep*"
14. "*I'm completely alone*"
15. "*I feel worthless*"

3. CPT questionnaire details

Below are the exact price points that were used in the Cigarette Purchase Task (CPT) which are similar to those employed in recent research (Aston et al., 2021), however we modified the prices so that they are presented in pounds (£) rather than dollars ($) because our sample comprised people residing in the United Kingdom.

1. Free [£0/pack]
2. 1p each [20p/pack]
3. 5p each [£1/pack]
4. 10p each [£2/pack]
5. 20p each [£4/pack]
6. 30p each [£6/pack]
7. 40p each [£8/pack]
8. 50p each [£10/pack]
9. 60p each [£12/pack]
10. 70p each [£14/pack]
11. 80p each [£16/pack]
12. 90p each [£18/pack]
13. £1 each [£20/pack]
14. £2 each [£40/pack]
15. £3 each [£60/pack]
16. £4 each [£80/pack]
17. £5 each [£100/pack]
18. £6 each [£120/pack]
19. £7 each [£140/pack]

20. £8 each [£160/pack]

21. £9 each [£180/pack]

22. £10 each [£200/pack]

4. Primary analyses split by difficulty level

Table S3

A table displaying the p-value and effect size for each of the hypotheses split by difficulty level

Contrast	Easy trials	Medium trials	Difficult trials
Drift / EA rate			
Positive condition: tobacco vs. animal	***p* = .01, *d* =.34**	***p* < .001 *d* = .81**	***p* < .001, *d* = .71**
Negative condition: tobacco vs. animal	$p = .81$, $d = .13$	$p = 1.00$, $d = .76$	$p = 1.00$, $d = .74$
Tobacco: positive vs. negative condition	$p = .35$, $d = .05$	$p = .23$, $d = .11$	***p* = .03, *d* = .28**
Animal: positive vs. negative condition	$p = .18$, $d = .13$	$p = .46$, $d = .02$	$p = .91$, $d = .19$
Response threshold			
Positive condition: tobacco vs. animal	$p = .30$, $d = .08$	$p = .75$, $d = .10$	$p = .90$, $d = .19$
Negative condition: tobacco vs. animal	$p = .54$, $d = .02$	$p = .55$, $d = .02$	$p = .25$, $d = .10$
Tobacco: positive vs. negative condition	$p = .50$, $d = .00$	$p = .95$, $d = .24$	$p = .83$, $d = .14$
Animal: positive vs. negative condition	$p = .32$, $d = .07$	$p = .12$, $d = .17$	$p = .40$, $d = .04$

Note. Significant findings are in bold. Positive condition refers to the induction of positive mood intended to lower tobacco value. Negative condition refers to the induction of negative mood intended to elevate tobacco value.

Brief summary: In the positive mood condition the data strongly support hypothesis 2 (although this is likely because animal EA rates are always higher than tobacco which makes this difficult to interpret). Although there were no significant differences in tobacco EA rates in the negative versus positive mood induction conditions, we can see here that in trials that are difficult, the hypothesised effect is observed. In other words, tobacco EA rates increased (M = 1.09, SD = .41) when negative mood was induced compared to when positive mood was induced (M = .97, SD = .41).

5. Core analyses repeated using only data from the first session participants completed

The core analyses presented here are slightly different because given that they are only looking at data from session 1, this necessitates the use of between-subject (rather than within-subject) analyses to explore mood contrasts (hypotheses 3 and 4). Overall, the pattern of results reported here do not differ from what is reported in the main manuscript, although it is interesting to note that only here are the results pertaining to hypothesis 4 descriptively in the hypothesised direction (but not statistically significant).

Hypothesis 1: When primed to experience a negative mood, participants did not have significantly higher tobacco EA rates (M = 1.66 SD = .50) compared to tobacco-unrelated (animal) EA rates (M = 1.89, SD = .41), $t(24) = 2.63$, $p = .99$, $d = .54$. Furthermore, participants did not have significantly lower tobacco response thresholds (M = 1.64, SD = .30) compared to tobacco-unrelated (animal) thresholds (M = 1.66, SD = .30), $t(24) = .47$, $p = .32$, $d = .09$.

Hypothesis 2: When primed to experience a positive mood, participants had significantly higher tobacco-unrelated (animal) EA rates (M = 2.05, SD = .42) compared to tobacco EA rates (M = 1.65, SD = .39), $t(23) = 4.52$, $p < .001$, $d = .92$. However, they did not have significantly lower tobacco-unrelated (animal) response thresholds (M = 1.56, SD = .32) compared to tobacco response thresholds (M = 1.52, SD = .29); $t(23) = .89$, $p = .81$, $d = .18$.

Hypothesis 3: When choosing between tobacco images, EA rates in the negative mood condition (M = 1.66, SD = .50) were not significantly higher compared to in the positive mood condition (M = 1.65, SD = .39); $t(47) = .04$, $p = .48$, $d = .01$. Furthermore, response thresholds were not significantly lower in the negative mood condition (M = 1.64, SD = .30)

compared to in the positive mood condition (M = 1.52, SD = .29), $t(47) = 1.36$, $p = .91$, $d = .39$.

Hypothesis 4: When choosing between tobacco-unrelated (animal) images, EA rates were not significantly higher in the positive mood condition (M = 2.05, SD = .42) compared to the negative mood condition (M = 1.89, SD = .41), $t(47) = 1.31$, $p = .10$, $d = .37$. Furthermore, response thresholds were not significantly lower in the positive mood condition (M = 1.56, SD = .32) compared to the negative mood condition (M = 1.66, SD = .30), $t(47) = 1.15$, $p = .13$, $d = .33$.

6. Core analyses repeated in participants for whom the experimental manipulation produced the intended effects on subjective mood

To assess whether the effectiveness of the mood manipulation influences results, we conducted additional exploratory analyses using only data from participants for whom the experimental manipulation of mood had the intended effects on *self-report* mood (i.e., that sadness scores increased, while happiness scores decreased, in the negative mood condition and vice versa for the positive mood condition). Overall, these (underpowered) analyses suggest that the manipulation of mood does alter EA rates in the hypothesised direction, but only for the tobacco-unrelated alternative (hypothesis 4).

Pre-registered analyses

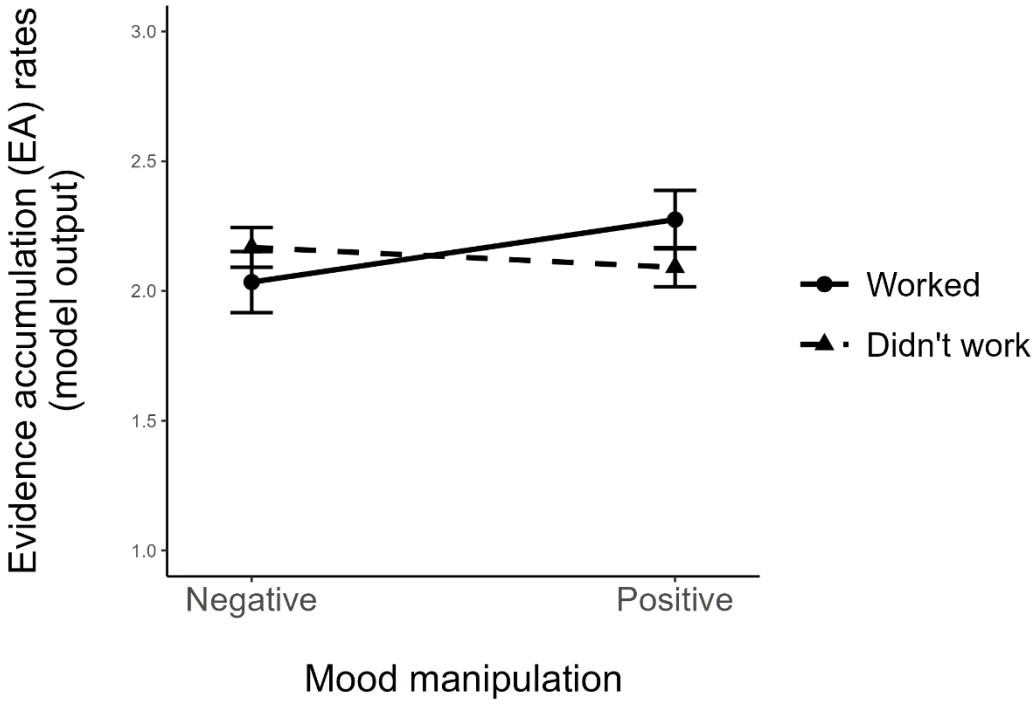
Hypothesis 1: When primed to experience a negative mood, participants did not have significantly higher tobacco EA rates (M = 1.87 SD = .64) compared to tobacco-unrelated (animal) EA rates (M = 2.03, SD = .42), $t(12) = 1.11$, $p = .86$, $d = .31$. Furthermore, participants did not have significantly lower tobacco response thresholds (M = 1.63, SD = .22) compared to tobacco-unrelated (animal) thresholds (M = 1.64, SD = .32), $t(12) = .04$, $p = .48$, $d = .01$.

Hypothesis 2: When primed to experience a positive mood, participants had significantly higher tobacco-unrelated (animal) EA rates (M = 2.28, SD = .41) compared to tobacco EA rates (M = 1.88, SD = .42), $t(12) = 4.15$, $p < .001$, $d = 1.15$. However, they did not have significantly lower tobacco-unrelated (animal) response thresholds (M = 1.59, SD = .26) compared to tobacco response thresholds (M = 1.58, SD = .22); $t(12) = .25$, $p = .60$, $d = .07$.

Hypothesis 3: When choosing between tobacco images, EA rates in the negative mood condition (M = 1.87, SD = .64) were not significantly higher compared to in the positive mood condition (M = 1.88, SD = .42); $t(12) = .08$, $p = .53$, $d = .02$. Furthermore, response thresholds were not significantly lower in the negative mood condition (M = 1.63, SD = .22) compared to in the positive mood condition (M = 1.58, SD = .22), $t(12) = .66$, $p = .74$, $d = .18$.

Hypothesis 4: When choosing between tobacco-unrelated (animal) images, EA rates were significantly higher in the positive mood condition (M = 2.28, SD = .41) compared to the negative mood condition (M = 2.03, SD = .42), $t(12) = 1.94$, $p = .04$, $d = .54$. However, response thresholds were not significantly lower in the positive mood condition (M = 1.59, SD = .26) compared to the negative mood condition (M = 1.64, SD = .32), $t(12) = .53$, $p = .30$, $d = .15$.

Figure S1. Evidence accumulation (EA) rates for tobacco-unrelated (animal) choices split by participants for whom the manipulation had the intended effects on mood (solid black line; circle) and those for whom it did not (dashed black line; triangle).


Evidence accumulation (EA) rates
(model output)
3.0
2.5
2.0
1.5
1.0
Negative
Positive
Mood manipulation
Worked
Didn't work

7. Order of experimental manipulation of mood: does this matter?

The order of experimental manipulation of mood was counterbalanced, such that for half of the sample, negative mood was induced first, while for the other half positive mood was induced first. To explore whether the order by which participants completed the study impacted the findings, we conducted mixed two-way ANOVAs between condition (2: positive mood; negative mood) and order of experimental manipulation (2: negative first; positive first) on EA rates and response thresholds. In the data, negative first is coded as 1 and positive first is coded as 2. As in the Chapter 5, if data violated assumptions of sphericity, F values were derived using a correction (Huynh-Feldt correction if the Greenhouse-Geisser epsilon (ε) > 0.75, otherwise if $\varepsilon < 0.75$ the Greenhouse-Geisser correction was used).

Tobacco-unrelated (animal) EA rates

There was a significant interaction between condition and order on animal EA rates ($F(1, 47) = 30.05$, $p < .001$, $\eta_p^2 = .39$). Post-hoc tests revealed that in the negative mood condition, animal EA rates were significantly higher in order 2 (M = 2.38, SD = .34) compared to order 1 (M = 1.89, SD = .41, $p < .001$). In the positive mood condition, there were no significant differences in animal EA rates between order 1 (M = 2.23, SD = .45) and order 2 (M = 2.05, SD = .42, $p = .38$). In order 1, animal EA rates were significantly increased in the positive mood condition compared to in the negative mood condition ($p < .01$). In order 2, animal EA rates were significantly increased in the negative mood condition compared to in the positive mood condition ($p < .01$). Another way to interpret these analyses is that animal EA rates were higher in the experimental condition that was completed second. There were no significant main effects of condition ($F(1, 47) = .00$, $p = .99$, $\eta_p^2 = .00$) or order ($F(1, 47) = 2.44$, $p = .13$, $\eta_p^2 = .05$) on animal EA rates.

Tobacco EA rates

There was a significant interaction between condition and order on tobacco EA rates ($F(1, 47) = 24.29$, $p < .001$, $\eta_p^2 = .34$). Post-hoc tests revealed that in the negative mood condition, tobacco EA rates were *marginally* higher in order 2 (M = 2.01, SD = .42) compared to order 1 (M = 1.66, SD = .50, $p = .05$). In the positive mood condition, there were no significant differences in tobacco EA rates between order 1 (M = 1.85, SD = .55) and order 2 (M = 1.65, SD = .39, $p = .44$). In order 1, there were no significant differences in tobacco EA rates in the positive mood condition compared to in the negative mood condition ($p = .07$). However, in order 2, tobacco EA rates were significantly increased in the negative mood condition compared to in the positive mood condition ($p < .001$). This analysis shows that tobacco EA rates were higher when the negative mood induction was completed second. There were no significant main effects of condition ($F(1, 47) = 2.24$, $p = .14$, $\eta_p^2 = .05$) or order ($F(1, 47) = .41$, $p = .53$, $\eta_p^2 = .01$) on tobacco EA rates.

Tobacco-unrelated (animal) response thresholds

There was a significant interaction between condition and order on animal response thresholds ($F(1, 47) = 11.22$, $p = .002$, $\eta_p^2 = .19$). Post-hoc tests revealed that in the negative mood condition, there were no significant differences in animal response thresholds between order 1 (M = 1.66, SD = .30) and order 2 (M = 1.47, SD = .30, $p = .15$). Similarly, in the positive mood condition, there were no significant differences in animal response thresholds between order 1 (M = 1.51, SD = .27) and order 2 (M = 1.56, SD = .32, $p = 1.00$). In order 1, animal response thresholds were significantly increased in the negative mood condition compared to in the positive mood condition ($p = .02$). This analysis shows that animal response thresholds were higher when the negative mood induction was completed first. However, in order 2, there were no significant differences in animal response thresholds in

the negative mood condition compared to in the positive mood condition (p = .38). There were no significant main effects of condition (F(1, 47) = .82, p = .37, η_p^2 = .02) or order (F(1, 47) = .80, p = .37, η_p^2 = .02) on animal response thresholds.

Tobacco response thresholds

There was a *marginally* significant interaction between condition and order on tobacco response thresholds (F(1, 47) = 3.99, p = .05, η_p^2 = .08). Post-hoc tests revealed that in the negative mood condition, there were no significant differences in tobacco response thresholds between order 1 (M = 1.64, SD = .30) and order 2 (M = 1.49, SD = .30, p = .48). Similarly, in the positive mood condition, there were no significant differences in tobacco response thresholds between order 1 (M = 1.51, SD = .31) and order 2 (M = 1.52, SD = .29, p = 1.00). In order 1, there were no significant differences in tobacco response thresholds in the negative mood condition compared to in the positive mood condition (p = .15). Similarly, in order 2, there were no significant differences in tobacco response thresholds in the negative mood condition compared to in the positive mood condition (p = 1.00). There were no significant main effects of condition (F(1, 47) = 1.53, p = .22, η_p^2 = .03) or order (F(1, 47) = .73, p = .40, η_p^2 = .02) on tobacco response thresholds.

8. Order of trial block completion: does this matter?

The order of blocks in the decision-making task were randomised, such that for some participants the tobacco-unrelated (animal) trials were completed first, whilst for others the tobacco-related trials were completed first. To explore the importance of order of blocks presented in the decision-making task, we conducted independent samples *t*-tests on EA rates and response thresholds with block order (2: animal first; tobacco first) as the between-subjects variable. In the data, animal first is coded as 1 and tobacco first is coded as 2. The within-subject design of this study means that each participant completed the VBDM task twice (once in each experimental condition), and therefore we split the analyses below by experimental condition. This is because a participant may have completed the animal block of trials first (and tobacco block of trials second) in the negative mood condition, but then completed the tobacco block of trials first (and animal block of trials second) in the positive mood condition. Overall, for EA rates and response thresholds for both animal and tobacco decisions, there was minimal evidence to suggest that the order in which participants completed the blocks altered the decision-parameters (see below).

Positive mood condition

There were no significant differences between those who completed the animal block first compared to those who completed the tobacco block first for tobacco EA rates ($t(47) = .51$, $p = .61$, $d = .14$), tobacco-unrelated (animal) EA rates ($t(47) = -.02$, $p = .99$, $d = .01$), or tobacco response thresholds ($t(47) = .54$, $p = .59$, $d = .15$). There was however a marginally significant difference for tobacco-unrelated (animal) response thresholds ($t(47) = 2.02$, $p = .05$, $d = .58$), with the mean being slightly higher when the animal block was completed first.

Negative mood condition

There were no significant differences between those who completed the animal block first compared to those who completed the tobacco block first for tobacco EA rates ($t(47) = -1.48$, $p = .15$, $d = .42$), tobacco response thresholds ($t(47) = -.13$, $p = .90$, $d = .04$), and tobacco-unrelated (animal) response thresholds ($t(47) = 1.85$, $p = .07$, $d = .53$). There was however a significant difference for tobacco-unrelated (animal) EA rates ($t(47) = 2.97$, $p < .01$, $d = .85$), with the mean being higher when the animal block was completed second.

9. Exploratory ANOVAs including gender

We conducted exploratory repeated-measure ANOVAs on EA rates and response thresholds using within-subject factors of image type (2: tobacco-unrelated (animal); tobacco) and experimental condition (2: positive; negative), and a between-subject factor of gender (male; female).

EA rates

The main effect of gender on EA rates was not significant ($F(1, 47) = .01$, $p = .92$, $\eta_p^2 = .00$) and gender did not moderate relationships between image type ($F(1, 47) = .76$, $p = .39$, $\eta_p^2 = .02$) or experimental condition ($F(1, 47) = .58$, $p = .45$, $\eta_p^2 = .01$) on EA rates. Crucially, the three-way interaction between experimental condition, image type, and gender was non-significant ($F(1, 47) = 1.69$, $p = .20$, $\eta_p^2 = .03$).

Response threshold

The main effect of gender on response thresholds was not significant ($F(1, 47) = 1.17$, $p = .28$, $\eta_p^2 = .02$) and gender did not moderate relationships between image type ($F(1, 47) = .41$, $p = .52$, $\eta_p^2 = .00$) or experimental condition ($F(1, 47) = .10$, $p = .75$, $\eta_p^2 = .00$) on response thresholds. Crucially, the three-way interaction between experimental condition, image type, and gender was non-significant ($F(1, 47) = 2.12$, $p = .15$, $\eta_p^2 = .04$).

10. Exploratory correlations between years smoked, motivation to quit, and mood manipulation effects

For the negative mood induction, there was no significant association between years smoked or motivation to quit and the effect of the manipulation on either sadness or happiness scores. For the positive mood induction, there was also no significant association between years smoked or motivation to quit and changes in sadness scores. However, there was a significant negative correlation between years smoked and change in happiness scores (r = -.42, $p < .01$), indicating that people with a longer smoking history exhibited smaller increases in happiness following the positive mood manipulation.

Figure S2. Correlation between years smoked and change in happiness scores in the positive mood induction condition.

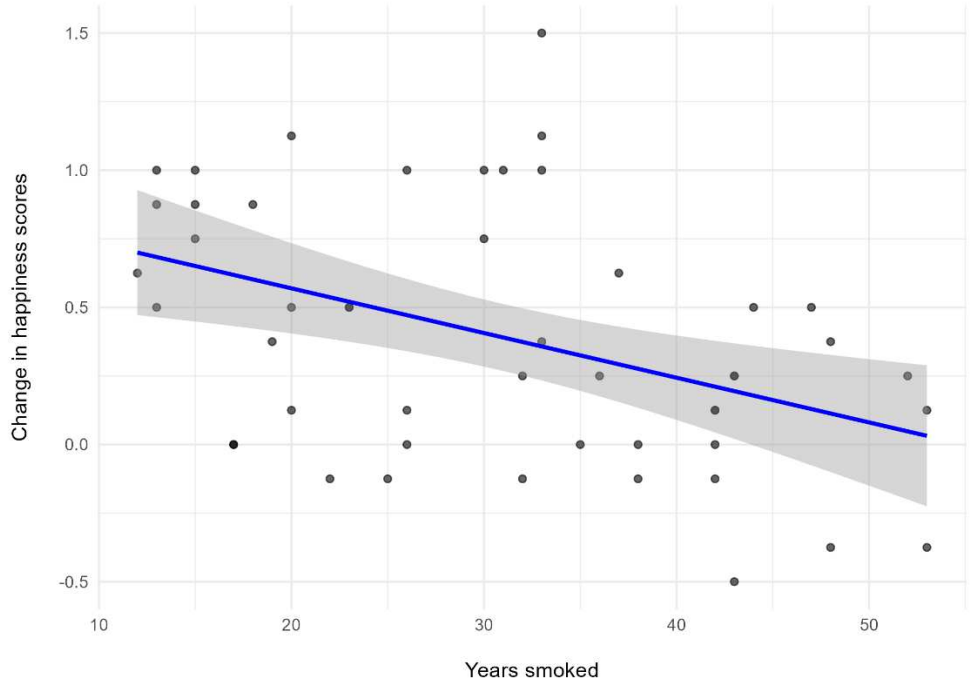
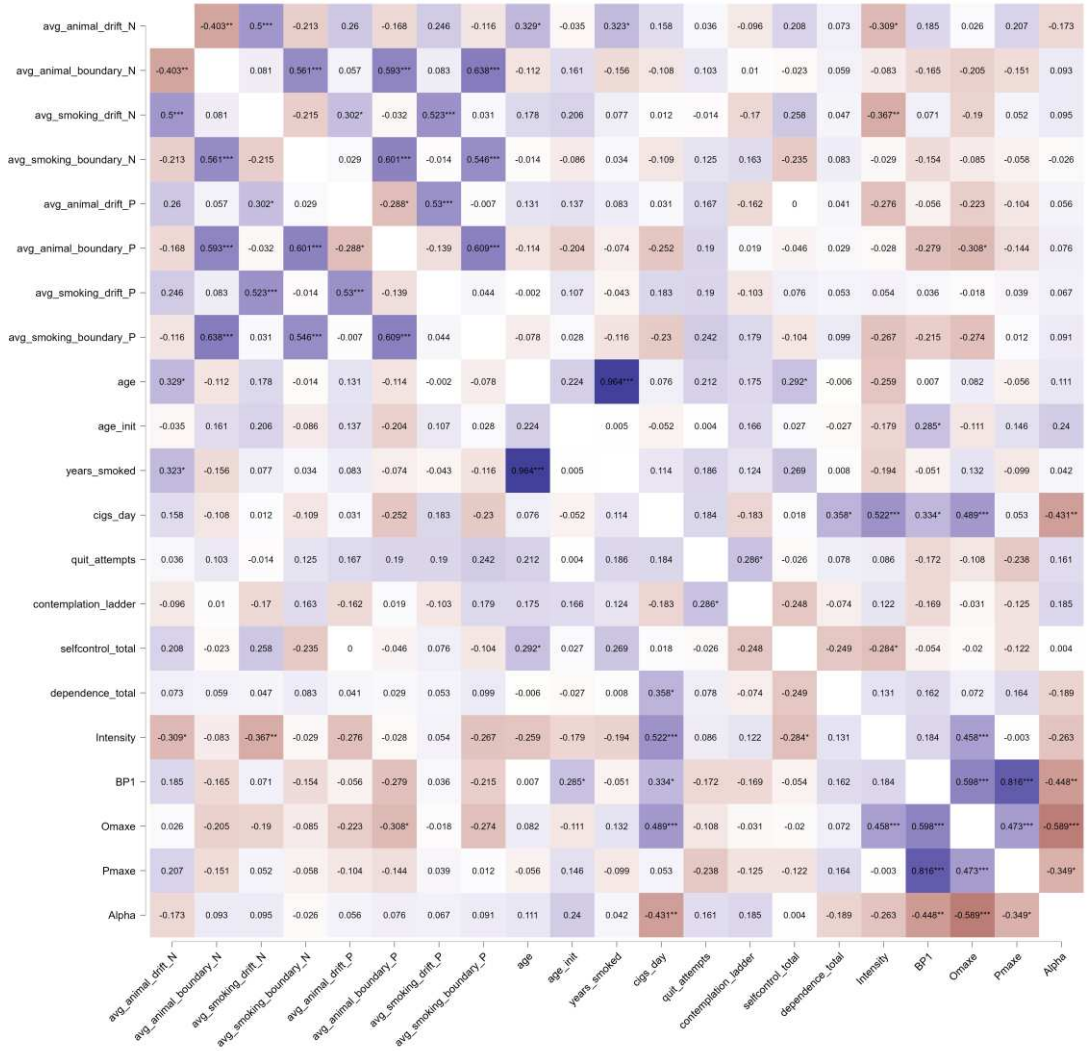


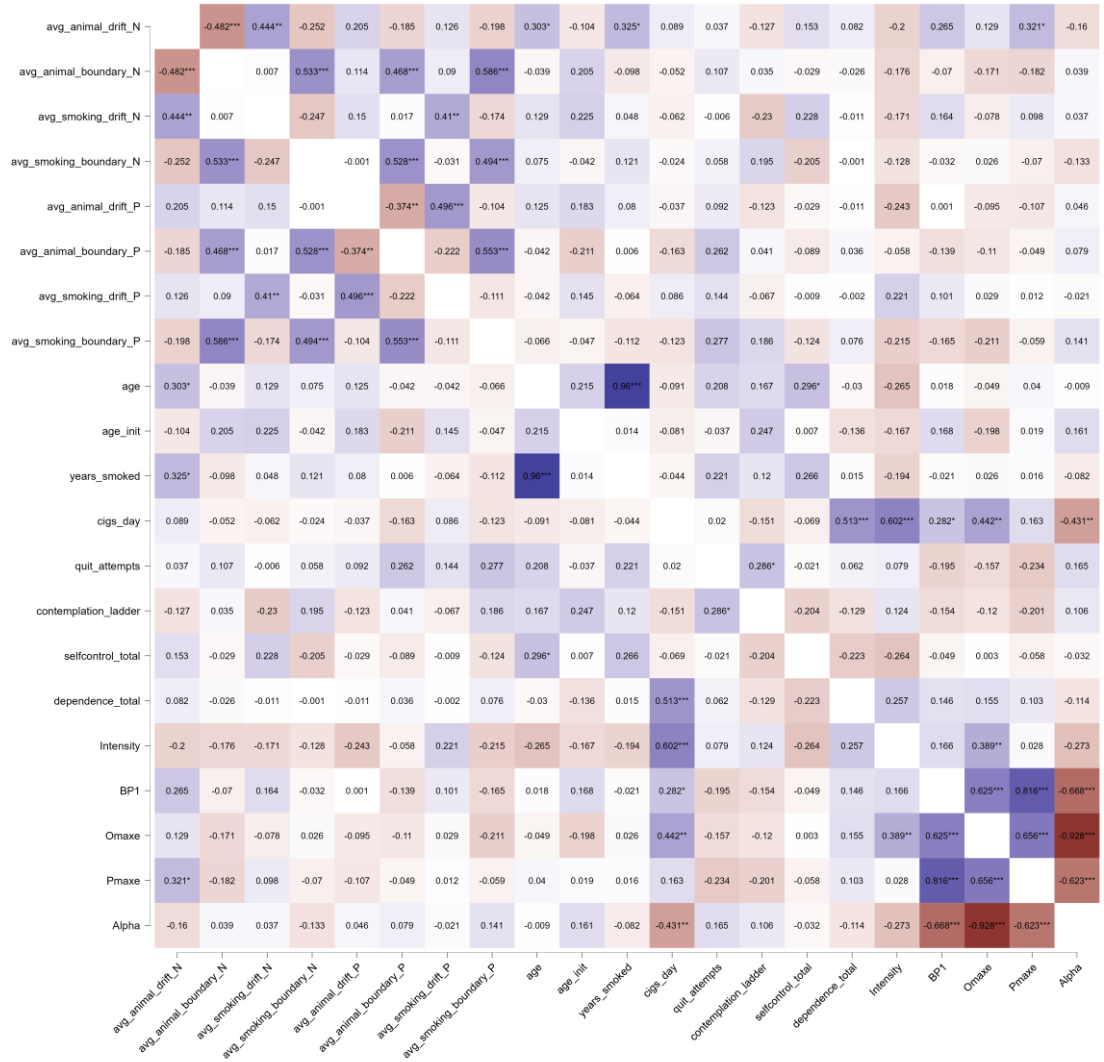
Table S4: Exploratory correlations.

Years smoked	Contemplation ladder	r = .12, p = .39

Years smoked	Change in sadness (positive)	r = .08, p = .60
Years smoked	Change in happiness (positive)	r = -.42, p < .01
Years smoked	Change in sadness (negative)	r = -.17, p = .25
Years smoked	Change in happiness (positive)	
Contemplation ladder	Change in sadness (positive)	r = -.24, p = .10
Contemplation ladder	Change in happiness (positive)	r = .14, p = .32
Contemplation ladder	Change in sadness (negative)	r = .01, p = .95
Contemplation ladder	Change in happiness (positive)	r = -.14, p = .32

11. Exploratory correlations (Figures S3 (first plot; Pearson's r) and S4 (second plot; Spearman's rho))




avg_animal_drift_N
avg_animal_boundary_N
avg_smoking_drift_N
avg_smoking_boundary_N
avg_animal_drift_P
avg_animal_boundary_P
avg_smoking_drift_P
avg_smoking_boundary_P
age
age_init
years_smoked
cigs_day
quit_attempts
contemplation_ladder
selfcontrol_total
dependence_total
Intensity
BP1
Omaxe
Pmaxe
Alpha