



Research report

A direct comparison of appetitive and aversive anticipation: Overlapping and distinct neural activation[☆]

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HIGHLIGHTS

- Neural substrates of pleasant and unpleasant anticipation are directly compared.
- Pleasant anticipation uniquely activates ventral mPFC and striatal reward regions.
- Activation in other regions (e.g., dorsal mPFC) is enhanced during pleasant or unpleasant anticipation.

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ABSTRACT

fMRI studies of reward find increased neural activity in ventral striatum and medial prefrontal cortex (mPFC), whereas other regions, including the dorsolateral prefrontal cortex (dlPFC), anterior cingulate cortex (ACC), and anterior insula, are activated when anticipating aversive exposure. Although these data suggest differential activation during anticipation of pleasant or of unpleasant exposure, they also arise in the context of different paradigms (e.g., preparation for reward vs. threat of shock) and participants. To determine overlapping and unique regions active during emotional anticipation, we compared neural activity during anticipation of pleasant or unpleasant exposure in the same participants. Cues signalled the upcoming presentation of erotic/romantic, violent, or everyday pictures while BOLD activity during the 9-s anticipatory period was measured using fMRI. Ventral striatum and a ventral mPFC subregion were activated when anticipating pleasant, but not unpleasant or neutral, pictures, whereas activation in other regions was enhanced when anticipating appetitive or aversive scenes.

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1. Introduction

Anticipation of emotional events is central to many personality and clinical disorders, with dysregulated appetitive anticipation critical in reward-seeking, gambling, and substance use (or abuse) behavior [1], while anticipatory apprehension and distress is characteristic of human anxiety disorders [2,3]. Addressing the neural mechanisms of emotional anticipation, numerous fMRI studies have found that, when individuals anticipate receiving a reward, the ventral striatum (which includes the nucleus accu-

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bens) and ventral medial prefrontal cortex (mPFC) are activated [4–11]. Conversely, anticipating exposure to an aversive stimulus (such as electric shock) activates other brain regions, including the dorsolateral prefrontal cortex (dlPFC), anterior cingulate cortex (ACC), and the anterior insula, but does not reliably activate ventral striatum or mPFC [12–15]. Although these findings suggest that different regions might be involved when anticipating pleasant or unpleasant events, the data result from comparisons across different paradigms, classes of stimuli, and participants. Thus, to more directly compare neural activity in appetitive and aversive anticipation, this study measures BOLD activity while participants anticipate arousing natural scenes containing pleasant (erotica/romance) or unpleasant (violence) content, as well as pictures depicting neutral, everyday scenes.

Studies of reward anticipation often assess neural activity when preparing to make a rewarded motor response and/or winning money. In the typical paradigm, participants are shown a cue that predicts a subsequent imperative “go” signal, and a rapid button

press to the go signal is rewarded by a monetary gain. Using this paradigm, ventral striatum and ventral mPFC activation is reliably enhanced during the preparatory interval leading up to a rewarded button press, relative to an unrewarded reaction time condition [e.g., 4–6]. Later studies reported similar results using alterations to the typical paradigm, such that receipt of reward was not so closely contingent upon behavioral performance; however, these studies nonetheless invariably involve a motor component and also a monetary reinforcer, as well as some degree of uncertainty or “chance” during the anticipatory interval [e.g., 10,11].

Studies of aversive anticipation, meanwhile, typically involve a passive conditioning paradigm, in which a conditioned signal reliably predicts the subsequent presentation of a noxious reinforcer, typically an electric shock [e.g., 12]; for a review, see [14]. Thus, although the extant research as a whole suggests possible distinctions in the neural networks that mediate reward or aversive anticipation, different activation patterns could also be the function of other paradigmatic differences, including differences in the active vs. passive nature of the paradigm or the use of secondary (money) vs. primary (shock) reinforcers. In addition, given the lack of a within-subjects comparison of pleasant and unpleasant anticipation, it could be that different patterns across studies at least partially result from individual differences across samples.

To directly compare activation during pleasant and unpleasant anticipation in the same participants, colored cues specified whether an upcoming scene would depict erotica/romance, violence, or everyday events. Emotional scenes reliably elicit measurable cardiovascular, sympathetic (e.g. pupil, electrodermal), and motor (facial EMG) activity [16], and these images also prompt heightened neural activity in both subcortical (e.g. amygdala) [17] and cortical (e.g., fusiform) [18] regions. By measuring regional changes in BOLD activity during the anticipatory period preceding the presentation of highly arousing scenes of romance or violence, this design allows a direct comparison of functional brain activity in the context of appetitive or aversive anticipation, to determine whether distinct or overlapping regions are engaged in these different anticipatory contexts. These data could help to elucidate whether the anticipatory processes involved in putatively distinct emotional phenomena (e.g., drug-seeking behavior or experience of anxiety) are distinct, or similar, processes.

2. Materials and methods

2.1. Participants

Twenty-seven undergraduate students participated for course credit. Data for 3 students were excluded due to excessive movement ($n = 1$) or equipment failure ($n = 2$), leaving a sample of 24 participants (15 female, 23 right-handed; $M_{\text{age}} = 19.0$ yrs) with complete data.

2.2. Design and materials

Forty-two grayscale pictures were selected from the International Affective Picture System [19] to comprise three hedonic contents: “romance” (erotica and romantic scenes), “violence” (mutilated bodies and attack scenes), and “everyday events” (people at work or engaged in mundane activities).¹ Based on normative ratings [19], picture sets were constructed such that: 1) compared to everyday events, pictures of violence were rated as significantly

more unpleasant and pictures of romance were rated as significantly more pleasant, and; 2) pictures of violence and pictures of romance were each rated as significantly more arousing than everyday events, and did not differ from each other.

Cues were red, blue, or green rectangles presented full-screen (1024×768 pixels), with the color signalling the content of the upcoming picture (e.g., blue = romance, red = violence, green = everyday event) that would be presented following the anticipatory interval. Colors were counterbalanced such that, across participants, each content was cued by each color. Cues were presented for 9 s and were followed by a 3-s scene presentation, and then a variable-length inter-trial interval (15 or 18 s). For each content, there were 7 anticipatory trials; another 7 trials were un-cued and are not presented here.

The order of cues was counterbalanced such that no more than two cues signalling erotica, violence, or everyday events occurred in a row. Different presentation orders were generated such that each block of 6 trials contained one cued and one un-cued picture from each hedonic content (i.e., romance, violence, everyday events). Presentation orders were constructed such that, across orders: 1) each trial type occurred equally often as the first trial of the experiment, 2) each trial type occurred equally often in each block position (1st, 2nd, 3rd, 4th, 5th, or 6th trial), and; 2) each IAPS image was presented equally often in the beginning, middle, and end of the experiment. Finally, one foil trial occurred in each half of the experiment.

2.3. Procedure

Prior to the study, participants were informed that different colors would signal the hedonic content of the upcoming picture, such that one color would be followed by presentation of a romance scene, another color would be followed by presentation of a violent scene, and a third color would be followed by an everyday event. Correct report of the color cuing each category was required of the participant prior to starting the experiment. To encourage maintenance of the hedonic cue throughout the anticipatory interval, the participant was instructed to press a button if a cue was *not* followed by the anticipated content; this occurred on 2 foil trials which were not included in the data analysis.

After removal from the scanner, the participant rated the pleasantness of anticipating each content on a Likert scale that ranged from 1 (very unpleasant) to 7 (very pleasant) (4 = neutral). Anticipating violent scenes was rated as more unpleasant than anticipating everyday events ($t(24) = 5.41$, $p < 0.001$), whereas anticipating romantic scenes was rated as more pleasant than everyday events ($t(23) = 4.65$, $p < 0.05$).

2.4. fMRI data collection

Data were collected in a 3-T Philips scanner with a 32-channel head coil. The scanning sequence began with acquisition of a 160-slice sagittal scout set using a standard T1-weighted fast-field echo sequence. Functional images comprised 53 coronal slices (3 mm width, 0.5 mm gap; voxel size = 2.5×2.5 mm) covering the whole brain. Functional images were acquired using a T2*-weighted echo planar sequence ($180 \times 180 \times 185$ mm FOV, 90° flip angle, TE 30 ms, TR 3000 ms).

2.5. Data preprocessing and analysis

Raw functional time series data for each participant were aligned with the (skull-stripped) structural volume for that participant, slice-time corrected, and spatially filtered with a 2-voxel (5.0 mm) full-width-at-half-maximum kernel using AFNI software [20]. Outliers were calculated using an AFNI procedure that identi-

¹ IAPS numbers: *Romance*, 4003, 4008, 4085, 4290, 4470, 4505, 4530, 4575, 4647, 4658, 4660, 4668, 4695, 4698; *Violence*, 3010, 3017, 3051, 3060, 3068, 3191, 3225, 3261, 3530, 6350, 6520, 6561, 9420, 9900; *Everyday*, 2038, 2102, 2104, 2190, 2220, 2222, 2305, 2312, 2377, 2397, 2515, 2579, 2595, 2850.

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