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Emotion

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Altering Experienced Utility by Incidental Affect: The Interplay of Valence and Arousal in Incidental Affect Infusion Processes

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The way we evaluate an experience can be influenced by contextual factors that are unrelated to the experience at hand. A prominent factor that has been shown to infuse into the evaluation processes is incidental affect. Prior research has examined the role of such incidental affect by either focusing on its valence *or* its arousal, while neglecting the interplay of these two components in the affect infusion process. Based on the affect–integration–motivation (AIM) framework from affective neuroscience, our research proposes a novel arousal transport hypothesis (ATH) that describes how valence and arousal of an affective state *jointly* influence the evaluation of experiences. We test the ATH in a set of multimethod studies combining functional magnetic resonance imaging (fMRI), skin conductance recording, automated facial affect recording, and behavioral approaches across a range of sensory modalities including auditory, gustatory, and visual. We find that positive incidental affect, induced by viewing affect-laden pictures (vs. neutral pictures) or winning (vs. not winning) monetary rewards, enhances how much an experience (i.e., listening to music, consuming wines, or looking at images) is enjoyed. Tracking moment-based changes of affective states at the neurophysiological level, we demonstrate that valence mediates reported enjoyment and that arousal is necessary to implement and moderate these mediating effects. We rule out alternative explanations for these mediation patterns such as the excitation transfer account and the attention narrowing account. Finally, we discuss how the ATH framework provides a new perspective to explain divergent decision outcomes caused by discrete emotions and its implications for effort-based decision-making.

Keywords: affect infusion, arousal transport hypothesis, functional magnetic resource imaging, skin conductance recording, facial affect recording

Supplemental materials: <https://doi.org/10.1037/emo0001241.supp>

Imagine you are driving while listening to a new song being played on the radio. Will your enjoyment of the new song be influenced by your current affective state shaped by factors such as the weather, the scene of a car accident or a beach filled with happy children—although these events are unrelated to the quality of the song? This question is fundamental to our understanding of human judgment and decision-making. Whereas traditional rational choice

theory from economics (Becker, 1962; Simon, 1955) suggests that such unrelated information should not influence an individual's choices and evaluations, a large body of research in psychology has demonstrated that feelings unrelated to evaluations and decisions at hand can influence preferences and choices (Andrade & Ariely, 2009; Chang & Pham, 2013; Forgas, 1995; Greifeneder et al., 2011; Lerner et al., 2015; Loewenstein & Lerner, 2003;

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Study 1 was preregistered on the Open Science Framework at https://osf.io/9m3qw/?view_only=4358b20795074779a7e5ba03e617c2e9. The data for all these studies are available on the Open Science Framework at https://osf.io/g3jv8/?view_only=8be3593ed3d145979eefc6ba7259e1d9. There is no conflict of interest to report.

Aiqing Ling served as lead for conceptualization, data curation, formal analysis, investigation, methodology, software, validation, visualization, writing–original draft, and writing–review and editing. Hilke Plassmann

contributed equally to data curation, formal analysis, validation, and visualization. Nathalie George, Baba Shiv, and Hilke Plassmann equally contributed to conceptualization, methodology, supervision, writing–original draft, writing–review and editing, and investigation.

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Loewenstein et al., 2001; Peters et al., 2006; Pham et al., 2015; Schwarz & Clore, 2007).

Prior research in psychology has investigated the mechanisms of such affect infusion processes across three broad areas: (a) research that examines the valence of the induced affective state (i.e., the positivity or negativity of the affective state), delineating the affect-as-information hypothesis to explain affect infusion (Forgas, 1995; Pham, 1998; Schwarz & Clore, 2007); (b) research that focuses primarily on the role of arousal (i.e., the physiological and psychological excitation of the affective state) in judgment and decision-making (Di Muro & Murray, 2012; Mano, 1992; Paulhus & Lim, 1994; Pham, 1996; Vosgerau, 2010; White et al., 1981; Zhu & Ratner, 2015); and (c) research that investigates how specific emotions that have the same valence (e.g., anger, anxiety, and fear are all negative in valence) but are different in felt arousal (and their overall affective meaning), impact unrelated choices and judgments (Cryder et al., 2008; Dorison et al., 2020; Garg & Lerner, 2013; Lerner & Keltner, 2001; Lerner et al., 2004; Minton et al., 2021; Raghunathan & Pham, 1999; Schulreich et al., 2016; Wilcox et al., 2011).

The main contribution of this research to the literature on affect infusion is to combine areas (a) and (b) and focus on the potential interplay of both valence *and* arousal in the affect infusion process by drawing upon work in affective neuroscience (Knutson & Greer, 2008; Knutson, Wimmer, Rick, et al., 2008; Winkielman et al., 2022). We propose a novel arousal transport hypothesis (ATH), which proposes that arousal works as a courier to transport the valence to execute its influences on the evaluative targets. We empirically tested the ATH in three studies across different types of positive affect inducers (affect-laden pictures and incidental monetary gains) and evaluative targets (music, wines, and pictures) using a multimethod approach (brain imaging, skin conductance and facial affective recording, and more traditional experimental approaches). These studies provide convergent and robust evidence for the validity of the ATH and how the ATH is different from alternative explanations. In addition, the ATH also contributes to area by providing a new perspective to explain divergent decision outcomes caused by discrete emotions.

The remainder of the article is organized as follows. First, we review the relevant interdisciplinary literature on how valence and arousal of incidental affect influence judgments and evaluations. On this basis, we describe the ATH, which proposes an interplay of valence and arousal for affect infusion to occur, and how it relates to other existing theoretical accounts. We then present three studies testing the ATH and alternative psychological processes at play. We conclude with a discussion of our findings and related research, acknowledge the limitations, and provide suggestions for future research.

Valence and Arousal as Distinct Components for Affect Infusion

Extant research has found that affect felt prior to making a judgment, despite being induced by unrelated events (i.e., being incidental), can be misattributed to influence subsequent judgments and evaluations (Cohen et al., 2008; Knutson, Wimmer, Kuhnen, & Winkielman, 2008; Schwarz & Clore, 1983, 2007; Winkielman et al., 2022). One prominent idea in this research is the affect-as-information hypothesis, which suggests that rather than computing the utility of an object solely based on its attributes (e.g., the

melody of a song), people refer to their affective state as an informational source to make evaluations. In other words, feeling happy because of sunny weather, for instance, would be included as diagnostic information when evaluating the song. Consequently, the listener's affective state would color the evaluation of the new song in a valence-congruent fashion (i.e., making it more enjoyable).

This work on how the valence of incidental affect color evaluations is complemented by another line of research suggesting that arousal influences evaluations in different ways than valence does (Di Muro & Murray, 2012; Mano, 1992; Paulhus & Lim, 1994; Pham, 1996; Vosgerau, 2010; White et al., 1981; Zhu & Ratner, 2015). This line of work is grounded on the affect circumplex model, which conceptualizes affect as two orthogonal continua: valence and arousal (Russell, 1980; Russell & Barrett, 1999).¹ These two affective components are qualitatively different: valence classifies the pleasantness of an affective state (i.e., its positivity or negativity), whereas arousal constitutes the physiological or psychological activation of this state (i.e., whether it is high or low). One key finding from this research is that arousal (e.g., the excitement of going on a long-awaited road trip) amplifies the affective features of the evaluative targets, such as the melody of a song, thereby influencing how the song is evaluated (Humphreys & Revelle, 1984; Paulhus & Lim, 1994; Pham, 1996; Sanbonmatsu & Kardes, 1988; Zhu & Ratner, 2015). Thus, higher arousal enhances the attractiveness of a song that is liked and diminishes the attractiveness of a song that is disliked, resulting in polarized evaluations. According to this research, arousal will not influence ambiguous or neutral evaluative targets that have no clear affective feature to be amplified. Research has also demonstrated that this amplification effect of arousal is independent of the valence of incidental affect (Gorn et al., 2001). Taken together, prior research has demonstrated the distinct roles of valence and arousal in affect infusion.

In addition, studies in affective and decision neuroscience have shed light on the dissociable neural correlates underlying the affect circumplex model for the conjoint activation of positive and negative arousal (Knutson & Genevsky, 2018; Knutson & Greer, 2008; Knutson et al., 2014). This line of research suggests that there are multiple ways to capture the valence and arousal components of affect separately, providing us with the essential foundation to investigate the *process* of how valence and arousal interact, which we discuss next.

Valence

On the brain level, convergent evidence from neuroimaging studies has identified the brain's valuation system (BVS)—consisting primarily of the ventromedial prefrontal cortex (vmPFC) and the striatum—to represent the valence of affect (Berridge, 2019; Berridge & Kringelbach, 2015; Winecoff et al., 2013). Several studies have demonstrated that the neural activity in the vmPFC encodes the valence of affect independent of the intensity that is coupled with the valence (Litt et al., 2011; Plassmann et al., 2010). On a physiological level, the valence of affective states is associated with expressive motor behavior such as the movement of facial muscles around eyebrows, eyes, and cheeks (Cacioppo et al., 1988; Ekman et al.,

¹ Another school of psychologists conceptualize affect by its temporal sequence of physiological responses and subjective feelings. This is known as the James-Lange theory and the Cannon-Bard theory (Dalgleish, 2004).

1990; Lang et al., 1993). Recently, automated facial analysis programs have been developed using artificial intelligence algorithms to quantify facial expressions in video footages. The decoding accuracy of commercially available software, such as Noldus FaceReader,² has been reported to be as high as 88% in detecting basic emotions in human facial emotion databases, approximating the accuracy of professional human coders in the Facial Action Coding System (FACS) test (Lewinski et al., 2014; Teixeira et al., 2012).

Arousal

On the brain level, meta-analyses have indicated that the arousal of affect is represented in a distributed network in the brain (i.e., the brain's arousal system [BAS]); this network includes the amygdala, anterior insula, dorsal anterior cingulate cortex (dACC), thalamus, and hypothalamus, among other regions (Lang & Bradley, 2010; Lewis et al., 2006; Lindquist et al., 2012; Phan et al., 2004). On a physiological level, the arousal is reflected by the activation of the autonomic nervous system, which can be sampled by electrodermal reactivity such as skin conductance responses (SCRs).

Interplay of Valence and Arousal: The ATH

Several studies in affective neuroscience suggest that valence and arousal of an affective state may interact and jointly influence decisions and evaluations. For example, brain activation in regions mapping to positive arousal (Knutson et al., 2014) prior to making a choice predicts how much risk participants would take in a financial decision-making task (Kuhnen & Knutson, 2005, 2011), whether participants would purchase a product or not (Knutson et al., 2007) and even forecast whether other people would fund new product ideas in the real world (Genevsky et al., 2017). Importantly, research has shown that brain activity related to the encoding of positive arousal in response to seeing erotic pictures mediates how often participants make risky monetary choices (Prévost et al., 2010).

In addition to this work demonstrating the joint activation of the BVS and BAS during affect infusion, a number of neuroscientific studies suggest that the BAS may potentially moderate the impact of BVS to guide decision-making and evaluations (FeldmanHall et al., 2016; Harlé et al., 2012; Malvaez et al., 2019; Murray & Rudebeck, 2018; Phelps et al., 2014; Rolls et al., 2020; Rudebeck et al., 2013). A study in macaque monkeys, for instance, showed that lesions in the BAS (i.e., amygdala) significantly decreased valence encoding of food rewards in the BVS (i.e., vmPFC; Rudebeck et al., 2013). In humans, incidental anxiety induced by electric shocks enhanced neural activity of the BAS (i.e., anterior insula), in turn disrupting activity in the BVS (i.e., vmPFC) when encoding risk in a gambling task (Engelmann et al., 2015). Neuroimaging studies that employed emotion regulation strategies have also revealed that changes in the neural activity in the BAS network (i.e., amygdala, anterior insula, and dACC) could alter the activity in the BVS (e.g., striatum, vmPFC; Etkin et al., 2015; McRae & Gross, 2020). These results provide the initial evidence for an underexplored process of how valence and arousal may interact during decision-making and affect infusion.

Against this background, we propose the ATH framework, delineating how high versus low arousal of positive affective states colors subsequent, unrelated evaluations as compared to a neutral affective

state. Specifically, the ATH presumes that the arousal of positive incidental affect acts as a courier that transports the valence of incidental affect to execute its influences on the evaluative target. In other words, the role of arousal is analogous to a vehicle with a small transport capacity under low arousal and a large transport capacity under high arousal. For a given extent of valence, when arousal is low, less valence is transported to influence subsequent evaluations. Hence, the extent of affect infusion is curbed by the low arousal. In contrast, when arousal is high, more valence is transported to boost the extent of affect infusion.

We note that the described process of the ATH should not be confused with the notable amplification effect of arousal that has been explained by the *attention-narrowing account* (Gable & Harmon-Jones, 2008, 2013; Humphreys & Revelle, 1984; Pham, 1996; Sanbonmatsu & Kardes, 1988) or the *excitation transfer account* (Di Muro & Murray, 2012; Mano, 1992; Paulhus & Lim, 1994; Pham, 1996; Schachter & Singer, 1962; Vosgerau, 2010; Zhu & Ratner, 2015; Zillmann, 1971). The *attention-narrowing account* suggests that high arousal constrains information processing capacity, and the narrowed cognitive scope (i.e., attention) is allocated to focus on and overweight the affective features of the evaluative targets. In comparison, the ATH assumes that arousal executes the impact on the valence of incidental affect rather than via other cognitive intermediaries such as narrowed attention. The *excitation transfer account* suggests that the experienced arousal is transferred to accentuate the affective features of the evaluative targets. In contrast, the ATH presumes that arousal transports valence and that arousal and valence *jointly* influence the evaluative targets, independent of their affective features. In the current research, we pit the ATH against the *attention narrowing account* and the *excitation transfer account* to demonstrate the uniqueness of the ATH in explaining the affect infusion process.

The Overview of Studies

We report three studies to test the ATH. Study 1 aims to establish whether the enjoyment of music excerpts could be altered when participants are in different affective states. In study 1, we manipulate valence and arousal of participants' affective states by exposing them to affect-laden images that vary systematically on these two dimensions (Schmidt et al., 2009). We also employ a thought-listing task to test the viability of the *attention-narrowing account*, which suggests that high arousal constrains processing capacity. Study 2 investigates the underlying mechanism of affect infusion as highlighted by ATH: (a) whether valence mediates affect infusion and (b) whether the mediation is moderated by arousal. In study 2, we employ an incidental-reward paradigm to induce different levels of positive incidental affect in a wine-tasting task (Eldar & Niv, 2015) and measure valence and arousal at a neurophysiological level using fMRI. We further test the viability of the *attention-narrowing account* by measuring reaction times, that are often a surrogate for the extent of the processing capacity. Reaction times are often a surrogate for processing capacity—longer reaction times signify deeper processing as compared with shorter reaction times (Evans & Stanovich, 2013). Study 3 builds on study 2 by including

² In addition to FaceReader, there are other automated facial affect analysis programs based on similar technology, such as IntraFace, Face Tales, and Emotient.

evaluative targets related to the visual (aesthetic) domain and that differ in valence. This design not only allows us to test whether and how the impact of incidental affect is generalizable to a broader array of evaluative targets but also helps to differentiate the transporter role of arousal in the ATH from the *excitation transfer account*. In addition, study 3 supplements study 2 methodologically by employing two independent psychophysiological measures with a higher temporal resolution to sample valence (facial affect responses [FARs]) and arousal (SCRs). This provides us with fine-grained details to examine whether the valence and arousal experienced exactly at the time when incidental affect is induced (by the lottery outcomes) are linked to the behavioral effects of affect infusion at the time of image evaluation. Across studies 2 and 3, we conduct several robustness analyses to demonstrate the moderating and mediating effects of valence and arousal at different levels. These analyses are detailed in the online supplemental materials (these include a set of robustness analyses for three studies; Figures S1–S15 and Tables S1–S9).

Transparency and Openness

The data and the analytic scripts of all reported studies are publicly available on the Open Science Framework at https://osf.io/g3jv8/?view_only=8be3593ed3d145979eefcfdba7259e1d9. In addition, Study 1 was preregistered via the Open Science Framework (https://osf.io/9m3qw/?view_only=4358b20795074779a7e5ba03e617c2e9).

Study 1

Method

Participants

A total of 1,205 participants from the Prolific platform participated in this study. Participants were excluded based on the following preregistered exclusion criteria: (a) failing to recognize the affect induction pictures ($N = 34$), (b) failing to recognize the musical instruments ($N = 18$), (c) failing to pass the instructional attention check ($N = 248$), (d) not perceiving erotic images of the opposite sex as attractive ($N = 166$; Kühn & Gallinat, 2014; Politis et al., 2013; Stoléru et al., 2012), and (e) taking an extremely long time ($>3 SD$) to complete the study ($N = 17$). Statistical analyses were performed on the remaining 722 participants (females = 272; $M_{\text{age}} = 25.43$, $SD_{\text{age}} = 8.08$). The study was approved by the INSEAD Ethical Review Committee, and all participants provided informed consent.

Selection of Affect Inducers and Evaluative Stimuli

We ran two pretests on Amazon Mechanical Turk (MTurk) to select images that would induce different levels of valence and arousal based on the gender-specific valence scores and arousal scores from the International Affective Picture System (IAPS) database ($N_{\text{Pretest1}} = 290$ participants; female = 135; $M_{\text{age}} = 34.74$, $SD_{\text{age}} = 9.79$; $N_{\text{Pretest2}} = 387$ participants; female = 143; $M_{\text{age}} = 36.11$, $SD_{\text{age}} = 11.09$). Participants viewed a total of 15 images one at a time and rated their perceived happiness (i.e., valence) and felt excitement (i.e., arousal) using the 9-point Self-Assessment Manikin (SAM) scale. The images were randomly drawn from a pool of 45 images, and each image was presented for 7.5 s. Table S1 in the online

supplemental materials summarizes the valence scores and the arousal scores of these images for both genders.

The same participants listened to and rated their liking of lyrics-free music excerpts using a 9-point scale (1 = *not at all*, 9 = *very much*). These music excerpts were truncated from their original versions to 25- to 30-s clips. A total of 18 music excerpts were pretested; one of them was randomly selected to play for the participants to rate. We selected three music excerpts that were moderately liked ($M_{\text{pleasant 1}} = 6.3$; $M_{\text{pleasant 2}} = 6.15$; $M_{\text{pleasant 3}} = 5.92$) as the evaluative targets.

Design and Procedure

The study employed a 2 (arousal: low vs. high) \times 2 (valence: positive vs. negative) between-participants design that also included a neutral affect condition as a control. Participants were informed that the study consisted of several unrelated sections to test their memories of and emotional reactions to visual and auditory stimuli. Participants first reported their gender and then saw a sequence of five images (either all negative high-arousal, negative low-arousal, neutral, positive low-arousal, or positive high-arousal) that were adapted for their gender. In reality, viewing these images was the manipulation of participants' incidental affect (Schmidt et al., 2009). Each image was presented for 7.5 s and automatically proceeded to the next one. After viewing these images, participants listened to a music excerpt and provided their enjoyment ratings of the music on a 9-point scale (1 = *not at all*, 9 = *very much*; see Sections 1.2 and 1.4 in the online supplemental materials for the manipulation check, additional measures, and analyses). Next, participants were asked to list their thoughts and feelings while they were listening to the music. This approach has been employed in previous research to assess the loading on participants' processing capacity (Gorn et al., 2001). To verify that participants paid attention to the experimental instructions, we asked them to recall the images they viewed from a set of six images and to indicate the main instrument that was used to play the music they listened to, and then passed them on to the instructional manipulation check (Oppenheimer et al., 2009).

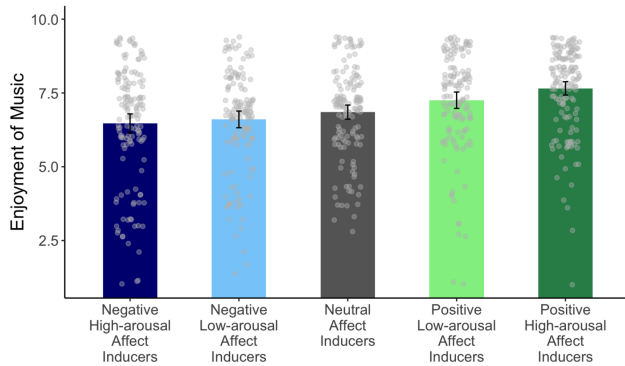
Statistical Analyses

We employed various preregistered one-way between-subject ANOVAs to test various aspects of our ATH framework. We also conducted planned contrast analyses to investigate (a) whether positive (negative) incidental affect would increase (decrease) participants' reported music enjoyment and (b) whether participants listed fewer thoughts and feelings when they were in a high-arousal versus a low-arousal state.

Results and Discussion

We first analyzed whether participants being in different arousal and valence states would alter their enjoyment of music in this unrelated evaluation task. We found a significant effect of affect-induction conditions on music enjoyment, $F(4, 717) = 12.87$, $p < .001$, $d = 0.72$, such that the higher the arousal in the positive domain the higher the reported music enjoyment ($M_{\text{positive high-arousal}} = 7.65$ vs. $M_{\text{positive low-arousal}} = 7.25$), $F(1, 717) = 4.27$, $p = .039$, $d = 0.24$, 95% CI: [0.02, 0.779], and that negative high arousal led to the lowest evaluation ($M_{\text{negative high-arousal}} = 6.46$ vs. $M_{\text{neutral}} = 6.85$), $F(1, 717) = 4.00$, $p = .045$, $d = 0.23$, 95% CI: [0.007, 0.764]; see Figure 1 and also

Figure 1
Reported Enjoyment of Music Conditional on Five Types of Affect Inducers



Note. Bars depict mean enjoyment ratings by affect inducer conditions. Dots represent ratings by individual participants. Error bars represent 95% confidence intervals. See the online article for the color version of this figure.

Table S2 and Sections 1.3 and 1.6 in the online supplemental materials for details and robustness analyses).

The *attention-narrowing account* suggests that higher arousal constrains information processing capacity (Gable & Harmon-Jones, 2008, 2013; Humphreys & Revelle, 1984; Pham, 1996; Sanbonmatsu & Kardes, 1988; Siemer & Reisenzein, 1998). Thus, individuals may think less about the evaluative targets when arousal is high versus low. We tested whether higher arousal could be linked to such narrowed information processing by analyzing how many thoughts participants listed. We found that the affect inducer condition was insignificant for the number of thoughts, $F(4, 717) = 1.22$, $p = .301$, $d = 0.21$. Contrast analyses further revealed that being in two high-arousal conditions did not reduce the number of thoughts compared with the low-arousal conditions ($M_{\text{high-arousal}} = 3.46$ vs. $M_{\text{low-arousal}} = 3.51$), $F(1, 717) = 0.09$, $p = .77$, $d = 0.03$, 95% CI: $[-0.527, 0.712]$, or the neutral condition ($M_{\text{high-arousal}} = 3.46$ vs. $M_{\text{neutral}} = 3.25$), $F(1, 717) = 1.33$, $p = .24$, $d = 0.12$, 95% CI: $[-0.593, 0.153]$.

Taken together, study 1 provides initial evidence in support of the ATH in that, while the affective valence of participants' states determines the direction of affect infusion in a valence-congruent way, the strength of affect infusion depends on the arousal level of the participants' affective state. Study 1 also ruled out the *attention-narrowing account* that high arousal is necessarily linked to fewer thoughts when evaluating the music due to limited processing capacity.

Study 2

Method

Participants

Twenty-one participants (females = 7; $M_{\text{age}} = 25.25$, $SD_{\text{age}} = 2.89$) from a major U.S. university were recruited for the experiment. One participant was excluded from the analysis due to technical issues with the fMRI acquisition. All participants were screened as occasional wine drinkers and were required to show their official identification to verify their age. To ensure that participants were

not intoxicated, their blood alcohol concentration was measured before and after the experiment.

Evaluative Stimuli

Two California Cabernet Sauvignons from different vineyards and an affectively neutral tasteless control solution that consisted of the main ionic components of human saliva (25 ml KCl and 2.5 ml NaHCO_3 ; O'Doherty et al., 2002) were administered during this experiment (see Section 2.2 in the online supplemental materials for experimental apparatus and how the liquid was delivered to participants in the MRI machine). Each trial consisted of 1 ml of wine, so each participant consumed less than 100 ml of wine in total.

fMRI Data Acquisition

Whole-brain fMRI data were acquired on a 3T Siemens Trio MRI scanner (Siemens, Germany). T2-weighted echo-planar images (EPI) were acquired using an eight-channel phased array coil that increases 40% signals in the prefrontal lobe. Acquisition was tilted at 30° to the anterior commissure-posterior commissure line. The EPI sequence acquired 32 axial slices in 3 mm thickness (TR = 2,000 ms; TE = 30 ms; FOV = 205 mm; flip angle = 70° ; voxel size = $3.2 \times 3.2 \times 3.2$ mm). A high-resolution T1-weighted structural image was also acquired for each participant (TR = 1,500 ms; TE = 3.05 ms; flip angle = 10° ; voxel size = $1 \times 1 \times 1$ mm).

Design and Procedure

The study employed a one-factorial within-participant design with incidental affect manipulated by three levels of incidental rewards (\$0, \$50, and \$200). Participants were informed that the goal of the experiment was to study their neural responses to different types and magnitudes of rewards, that is, primary (e.g., tasting wines) and secondary (e.g., winning or not winning different amounts of money) rewards (Chib et al., 2009; Sescousse et al., 2013; Verdejo-Román et al., 2017). They received a \$25 show-up fee for their participation in the experiment and were informed that they could win an additional monetary payoff (\$0, \$50, or \$200 with equal probability). They were instructed that at the end of the experiment they would find out which lottery outcome would be paid out for real; it was determined by the draw of a random trial number at the end of the experiment. In other words, if the trial that was randomly drawn promised a \$50 payoff, the participant received the \$25 show-up fee plus this additional \$50. Unbeknownst to participants, the lotteries shown in the experiment were used as rewards to induce different affective reactions on a trial-to-trial basis that were incidental to the wine-tasting evaluation (Eldar & Niv, 2015).

Each trial started with a lottery followed by wine tasting and evaluation on an 8-point scale (1 = *not at all*, 8 = *very much*; see Figure S2 in the online supplemental materials for detailed event sequences and their timing). Two wines were paired with all lottery outcomes (\$0, \$50, or \$200), and each pair was repeated 5 times in a random order, resulting in 30 trials per experimental session. A total of three fMRI experimental scanning sessions were performed (i.e., the task consisted of a total of 90 trials). The neutral control solution was always paired with a \$0 reward (five trials per session) and did not require a taste evaluation. Thus, neutral control solution trials were discarded from the analyses; their only purposes were to avoid taste habituation and to determine a neutral baseline.

Statistical Analyses

For the behavioral data, we used a multilevel mixed-effects regression to test whether receiving incidental rewards enhanced reported tasting experiences of wines. In this model, each wine-tasting trial was treated as the fixed effect (first-level variable) and was nested within each participant (second-level variable) to estimate random effects to assess the impact of receipt of incidental rewards on reported enjoyment of the wines. The model was estimated by the *mixed* function in Stata (StataMP 15.1) using a restricted-maximal likelihood approach.

For fMRI data preprocessing, the first four volumes of functional images were discarded to allow for signal equilibration. The remaining functional images were preprocessed and analyzed using SPM implemented in Matlab (R2015b, Mathworks). Preprocessing consisted of slice-time correction, realignment to the first EPI image, coregistration to the T1-weighted anatomical image, spatial normalization, and smoothing using a Gaussian kernel with full width at half maximum of 8 mm and temporal filter cutoff at 128 s. We also created a vector indicating the quality of each EPI image assessed by the NeuroElf (v1.5062) quality assessment function.

The univariate fMRI analyses were then carried out to examine how the reported wine-tasting experiences were influenced by the receipt of different amounts of incidental rewards. To do so, we developed a general linear model (GLM) to examine on a whole-brain level the neural correlates of incidental rewards during the lottery outcome period and the wine-tasting period in three steps. In the first step, we estimated the GLM with AR(1) with eight regressors for each of the three sessions: (a) I_{outcome} ; (b) $I_{\text{outcome}} \times \text{Reward}$; (c) $I_{\text{wine tasting}}$; (d) $I_{\text{wine tasting}} \times \text{Reward}$; (e) regressors of no interest; (f) six motion regressors; (g) outlier scans; and (h) three session constants (see Section 2.3 in the online supplemental materials for how these regressors are defined in details). Each of these regressors was convolved with a canonical hemodynamic response function (HRF). Second, we calculated the following first-level single-subject contrasts: (a) modulation by the amounts of incidental rewards at the lottery outcome period (regressor 2) and (b) modulation of wine tasting by the amounts of incidental rewards (regressor 4). Finally, we calculated second-level group contrasts using one-sample *t*-tests for each of the first-level contrasts.

For our main fMRI analyses, we employed a single-trial analysis approach to quantify neural activity associated with wine-tasting experiences on a trial-by-trial basis. This approach is sensitive to capture the variability of hemodynamic responses (HRs), especially when HRs vary unpredictably from trial to trial (Duann et al., 2002). This approach is also typically used to accommodate multilevel mediations of the fMRI data in previous research (Atlas et al., 2010; Schmidt et al., 2017; Woo et al., 2015). We constructed the trial-by-trial-based GLM by including each wine-tasting period for each participant. The wine-tasting period was fit with a canonical HRF and modeled with a boxcar function of 5.5 s. In addition, the trial-based GLM included 27 nuisance regressors reflecting six head motion dimensions (*x*, *y*, *z*, roll, pitch, and yaw) and these vectors squared, derivatives of these vectors, squares of the derivatives of these vectors, and three session constants to account for data acquisition artifacts. We also calculated variance inflation factors (VIFs) for this specification to quantify the collinearity due to the inclusion of these nuisance regressors. In accordance with previous studies, any trials with VIFs above 2 were excluded from the trial-based model (Atlas et al.,

2010; Schmidt et al., 2017). Only one trial was excluded across all trials and all participants ($M_{\text{VIFs}} = 1.027$; $SD_{\text{VIFs}} = 0.0003$). The remaining eligible trials then were passed into first-level GLM analyses, by which we obtained GLM beta estimates for each trial in each voxel for each participant using SPM.

We then conducted the multilevel mediation and moderated mediation analyses based on these trial-based beta estimates extracted from predefined regions of interest (ROIs; see Section 2.4 in the online supplemental materials for detailed model specifications). Rather than focusing on specific brain regions, we adopted the recent view of using a multivariate approach to examining neural networks that encode valence and arousal (Coll et al., 2022). The ROIs of the BVS were defined by the mask from a meta analysis on neural correlates of subjective value (Bartra et al., 2013). The ROIs of the BAS were based on the Neurosynth term-based meta-analysis for the term *arousal* (<http://neurosynth.org/analyses/terms/arousal>; Yarkoni et al., 2011). All these masks were thresholded using a false discovery rate at $p_{\text{FDR corrected}} < .01$. To make sure that the BVS mask did not overlap the BAS, we further removed overlapping voxels between the BVS mask and the BAS mask. The coefficients of the mediation model and the moderated mediation model were estimated by the *mixed* function in Stata (StataMP 15.1) using a restricted-maximal likelihood approach. The bias-corrected bootstrapping procedure was used to test the significance of the direct effects, the indirect effects, and the moderated indirect effects at 95% confidence intervals in respective models. We report moderated mediation results at conventional ± 1 SD levels with bias-corrected confidence interval (BCI) and results at ± 0.5 SD and ± 1.5 SD levels in Section 2.5 in the online supplemental materials.

Results and Discussion

We first tested whether we could conceptually replicate the behavioral results from study 1. We found a significant main effect of the incidental rewards on reported enjoyment of the wines ($M_{\$0} = 4.17$, $M_{\$50} = 4.41$, $M_{\$200} = 4.77$, $\beta_{\text{reward}} = 0.003$, $p < .001$, $d = 0.75$, 95% CI: [0.002, 0.004]). This indicated that incidental affect, induced by incidental rewards from the lottery game, effectively enhanced participants' reported enjoyment of wines.

The univariate fMRI analyses revealed that during the lottery outcome period, neural activity in regions encoding positive arousal according to the AIM framework (i.e., the striatum, bilateral insula, and dACC) positively correlated with the magnitude of incidental rewards (cluster level corrected at $p_{\text{FWE}} < .05$; see Figure S7 in the online supplemental materials; Table S3 in the online supplemental materials provides a list of activation regions). Put differently, our incidental affect induction did indeed recruit brain regions that are part of the (e.g., striatum) and the BAS (e.g., bilateral insula and dACC) BVS network.

In addition, we found that when participants were tasting the wines, the bilateral anterior insula, the left putamen, the ACC, and the dACC showed significant positive correlations with how much money the participants won for this trial (cluster-level corrected at $p_{\text{FWE}} < .05$; see Figure S8 in the online supplemental materials; Table S4 in the online supplemental materials provides a list of activation regions). Again, these brain regions are part of the BVS (e.g., left putamen) and the BAS (e.g., bilateral anterior insula, ACC, and dACC) networks.

Based on the AIM framework, we also tested whether an affect composite, generated by rotating the BVS and the BAS 45°, would mediate the impact of incidental reward on the wine-tasting experience. Indeed, we found this mediation was significant ($\beta_{\text{indirect}} = 0.00018$, 95% BCI: [0.00014, 0.00019]). This result is aligned with the prediction of the AIM framework but is independent of ATH's moderated mediation interplay that we hypothesized. Taken together, these results illustrate that the wine-tasting experiences were influenced by brain regions, whose activities were triggered by the receipt of different amounts of incidental rewards and that this was mediated by positive arousal on the neural level.

Following the univariate results, we took a brain system approach to verify whether the receipt of incidental rewards effectively altered participants' affective states at different levels by examining the neural activity of the BVS and the BAS. We found significant main effects of lottery amounts on neural activity of the BVS ($M_{\$0} = 1.351$, $M_{\$50} = 1.573$, $M_{\$200} = 1.729$, $\beta = 0.0017$, $p = .04$, $d = 0.40$, 95% CI: [0.00008, 0.0033]; see Figure S4 in the online supplemental materials) and the BAS ($M_{\$0} = 0.519$, $M_{\$50} = 0.686$, $M_{\$200} = 0.909$, $\beta = 0.0019$, $p = .011$, $d = 0.44$, 95% CI: [0.0004, 0.0033]; see Figure S5 in the online supplemental materials). As the experimental manipulation intended, we found that the magnitude of the incidental rewards was associated with the significantly increased neural activity of the BVS and the BAS.

To test the ATH, we first ran a multilevel mediation analysis to examine whether the changes in reported enjoyment of the wines were mediated by the neural activity in the BVS. Results showed that the mediation effect and the direct effect were both significant ($\beta_{\text{indirect}} = 0.0002$, 95% BCI: [0.0001, 0.0002]; $\beta_{\text{direct}} = 0.0028$, 95% BCI: [0.0019, 0.0037]; see Figure S3 in the online supplemental materials), suggesting that neural activity in the BVS, reflecting the experience of positive valence, explained (i.e., partially mediated) how receipt of incidental rewards increased the reported enjoyment of the wines.

Next, we tested whether the mediation effect of valence was dependent on the extent of arousal. We ran a moderated mediation analysis in which neural activity related to valence was the mediator of our behavioral effects and neural activity related to arousal was the moderator of this mediation. We found that the mediation effect by the BVS was positive and significant when the neural activity of the BAS was 1 *SD* above the mean value ($\beta_{\text{indirect high}} = 0.0011$, 95% BCI: [0.0003, 0.0017]). The coefficient was negative and significant when the neural activity of the BAS was 1 *SD* below its mean ($\beta_{\text{indirect low}} = -0.0007$, 95% BCI: [-0.0013, -0.0002]; see Section 2.5 in the online supplemental materials for results of moderated mediation analyses at other levels). The contrasts between these two coefficients and the direct effect were both significant ($\beta_{\text{indirect high vs. low}} = 0.0018$, 95% BCI: [0.0006, 0.0029]; $\beta_{\text{direct}} = 0.0028$, 95% BCI: [0.0019, 0.0037]). These results indicated that while the reported enjoyment of wines was partially explained by the neural activity of the BVS, the mediating impact of the BVS was greater when the BAS was more active, whereas the mediating impact was suppressed when the BAS was less active (see Figure 2). These results are in line with the ATH, suggesting that arousal plays the role of the valence transporter enabling the affect infusion processes.

In the ATH, we proposed that valence (represented by the BVS) would mediate the reported enjoyment of wines and that such mediation would be moderated by arousal (represented by the BAS). However, one might question the specificity of these two systems

in the affect infusion processes. One plausible alternative model is that the BAS could be the mediator and the BVS could be the moderator of the mediator. We tested this alternative moderated mediation model. We found an insignificant negative coefficient when the BVS was more active ($\beta_{\text{indirect } +1 \text{ SD}} = -0.0005$, 95% BCI: [-0.0011, 0.00003]) and a significant positive coefficient when the BVS was less active ($\beta_{\text{indirect } -1 \text{ SD}} = 0.0006$, 95% BCI: [0.00004, 0.0011]; see Figure S6 in the online supplemental materials). Such results were inconsistent with the consensus that positive valence of incidental affect (i.e., greater neural activity of the BVS) should contribute to product evaluations in the previous literature (Cohen et al., 2008; Forgas, 1995). Therefore, this analysis demonstrated the specificity of valence and arousal in mediating and moderating the reported enjoyment of wines as the ATH suggests.

Finally, we tested whether high arousal may constrain processing capacity leading to fast responses (i.e., less thoughtful responses) when evaluating the wines. We found no evidence of a correlation between the neural activity of the BAS and reaction times for making wine evaluations ($r_{(20)} = -.005$, $p = .232$). This result is inconsistent with the *attention-narrowing account*.

Study 3

Method

Participants

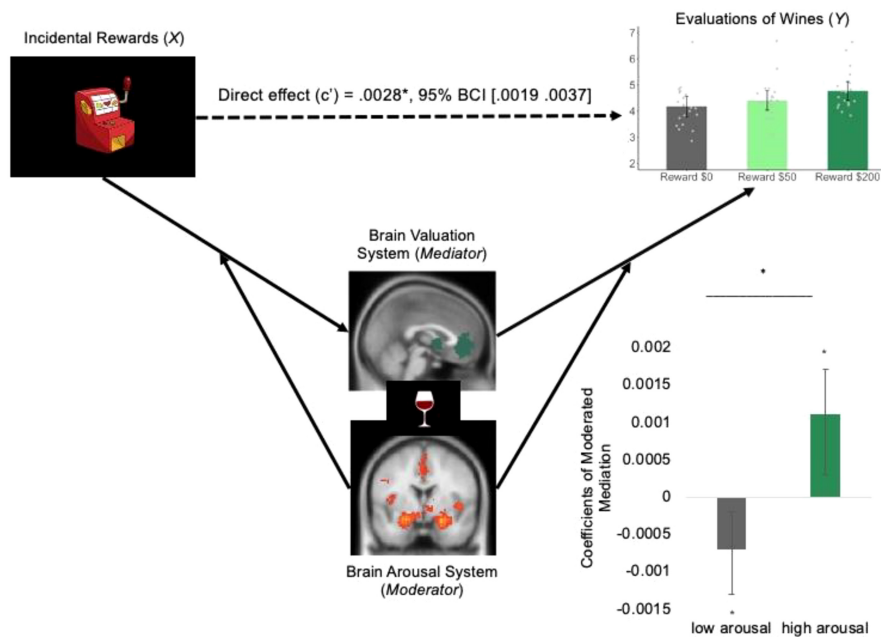
Sixty male participants were recruited from a university participant pool. The sample size was determined by the effect size of study 2 ($d = 0.52$). We estimated that a sample of 41 participants was required to achieve the statistical power at 0.90 with type I error of 0.05. We decided to oversample in case of no-shows or potential technical issues requiring exclusion.

We recruited only male participants with a low level of facial hair to control for gender differences in affective responses toward preselected experimental stimuli and ensure data quality for the facial affective response measures, as required by the software that we used. Fifty-two participants ($M_{\text{age}} = 22.07$; $SD_{\text{age}} = 3.02$) completed this study. Participants were excluded based on two predefined exclusion criteria: (a) exhibiting lower FAR valence in responding to positive images than neutral or negative images and (b) having SCRs that were higher when viewing neutral images than negative or positive images during the baseline phase. Such psychophysiological patterns could have been anomalous due to idiosyncratic facial angles, hairstyles, facial features, or skin situations. Five participants were removed, leaving 47 participants in the sample. All participants in the studies provided informed consent approved by the INSEAD Ethical Review Committee.

Evaluative Stimuli

Fifty-eight images, taken from the IAPS database, were pretested by an independent sample of 75 males ($M_{\text{age}} = 23.13$; $SD_{\text{age}} = 3.63$) from the same participant pool as the main study. These participants were instructed to use the 9-point SAM scale to rate their experienced happiness (i.e., valence) and their experienced excitement (i.e., arousal) after viewing these images. Images were presented one at a time in a random order. Twelve images with moderate values on valence and arousal were used in the baseline phase. Mixed-effects regressions revealed main effects of valence and

Figure 2
Multilevel Moderated Mediation With the Brain's Valence System (BVS) Moderated by the BAS



Note. In this model, the mediator represents beta estimates from the brain's arousal system (BVS) and the moderator represents beta estimates from the BAS, both during the wine-tasting period. The strength of the mediation was enhanced when the BAS was more active (1 *SD* above the mean, classified as high arousal), and the strength was suppressed when the BAS was less active (1 *SD* below the mean, classified as low arousal). Error bars represent 95% confidence intervals. See the online article for the color version of this figure.

* $p < .05$ Under bootstrapping. BAS = brain's arousal system.

arousal of these images ($\beta_{\text{valence}} = 1.705$, $p < .001$, 95% CI: [1.587, 1.822]; $\beta_{\text{arousal}} = -0.356$, $p < .001$, 95% CI: [-0.498, -0.215]) on SAM ratings. Another 24 images with similar scores on valence and arousal were used for evaluating aesthetic experiences in an incidental reward task. Mixed-effects regressions confirmed a main effect of valence ($\beta_{\text{valence}} = 1.746$, $p < .001$, 95% CI: [1.665, 1.828]) and a main effect of arousal ($\beta_{\text{arousal}} = -0.525$, $p < .001$, 95% CI: [-0.633, -0.418]) on the SAM ratings of these images (see Table S9 and Figure S14 in the online supplemental materials for SAM scores of the images used in the baseline phase and in the incidental reward task).

Acquisition of Facial Affect and SCRs

Participants' facial expressions were recorded by a Microsoft LifeCam Studio at a resolution of 640×480 and a frame rate of 33/s. After the incidental reward task, participants were instructed to perform facial expressions with different valences and a neutral expression for facial calibrations. Unbeknownst to participants, only the neutral expression was required; it was used for individual facial calibrations by FaceReader 6.

Two silver-silver chloride electrodes (Ag-AgCl) pregelled with isotonic gel by the manufacturer (BIOPAC) were attached to the second knuckle of the index and middle fingers of each participant's nondominant hand (Dawson et al., 2000). Skin conductance (in microSiemens, or μS) was measured using the BIOPAC Systems

Bionomadix BN-PPGED device (BIOPAC Systems Inc.) that uses a 0.5 V constant voltage excitation and recorded using the AcqKnowledge software (v4.4) at 10 Hz.

Design and Procedure

The study employed a 2 (lottery outcomes: €0 vs. €15) \times 3 (evaluative targets: negative, neutral, or positive images) within-participant design. Participants were informed that the goal of our research was to test their physiological reactions to primary rewards (i.e., viewing a range of different images displaying neutral objects, puppies, disasters, and disturbing animals) and secondary rewards (i.e., winning or not winning money). They received a €10 show-up fee for their participation and were informed that they could receive an additional monetary payoff (either €0 or €15 with equal probability) determined by the lottery outcome from one of the trials. Like in study 2, the lottery outcomes shown in the experiment were used to induce different affective reactions on a trial-by-trial basis that were incidental to the aesthetic evaluation of images (Eldar & Niv, 2015). Participants were paid from one of the lotteries by the draw of a random trial number at the end of the experiment.

The experiment consisted of a baseline phase followed by the main incidental reward task (see Figure S9 in the online supplemental materials for detailed event sequences and their timing). During the baseline phase, participants passively viewed 12 images (four in each category) that were presented in random order. Each image was

presented for 7.5 s. For the main incidental reward task, 24 images (eight in each category) were randomly presented for aesthetic evaluations. Each image was displayed once after a lottery outcome of €15 and once after a lottery outcome of €0, resulting in 48 trials in total. Participants provided their evaluation of each image on a 9-point scale using a keyboard (1 = *not at all*, 9 = *very much*).

Statistical Analyses

For behavioral data, we applied a multilevel mixed-effects regression to analyze whether the aesthetic evaluation of images was enhanced by the receipt of incidental rewards (see Section 3.2 in the online supplemental materials for additional analyses).

The procedure of facial affect and skin conductance data preprocessing is as follows. Participants' neutral expressions were extracted and imported into Noldus FaceReader 6 to characterize the unique facial features of each individual. The software then decoded facial footage that was recorded during the experiment and generated FAR valence values for each video frame. The FAR valence data were averaged over the incidental reward and image-viewing periods for each trial and for each participant for statistical analyses (Chan et al., 2014).

The raw skin conductance went through 1 Hz low-pass filtering to reduce noises. Skin conductance amplitudes were computed as the difference scores between the peak amplitude (2–6 s after event onset) and the baseline amplitude (0–2 s after event onset) during incidental reward and image-viewing periods for each trial and for each participant (Figner & Murphy, 2011). The amplitudes were then log-transformed ($\log(\text{SCR amplitude} + 1)$) to normalize the data (Conty et al., 2010). We used this method to quantify SCRs as the arousal measure in the experiment.

Combined with psychophysiological data, we developed a sequential mediation model to test the joint impact of FAR valence at the lottery outcome phase and image-viewing phase in explaining the relationship between receipt of incidental rewards and aesthetic evaluation of images. In addition, we built a moderated sequential mediation model to further test whether the mediating effect of FAR valence is dependent on the arousal of incidental affect that was triggered by incidental rewards as measured by SCRs (see Section 3.3 in the online supplemental materials for detailed model specifications). The coefficients of the mediation models were estimated by the *sem* function in Stata (StataMP 15.1) using a maximum likelihood approach. The bias-corrected bootstrapping procedure was used to test the significance of the direct effects and the indirect effects at 95% confidence intervals in respective models. We reported moderated mediation results at conventional ± 1 SD levels and reported results at ± 0.5 SD and ± 1.5 SD levels in Section 3.5 in the online supplemental materials.

Results and Discussion

We found a significant main effect of the incidental rewards on the enjoyment of looking at the different images ($\beta_{\text{reward}} = 0.323$, $p < .001$, $d = 0.44$, 95% CI: [0.188, 0.458]). This result conceptually replicated behavioral findings in studies 1 and 2 in another consumption domain.

Our psychophysiological measures of valence and arousal were sampled through two independent channels. This helped us to dissociate these two affect components when examining their

contribution and interplay in the affect infusion processes. We ran several correlational analyses to verify whether the valence measure and the arousal measure were truly independent. We found that the valence measure and the arousal measure are indeed uncorrelated during the lottery outcome period and image viewing period ($ps > .5$). The results of these correlational analyses are summarized in Table S8 in the online supplemental materials.

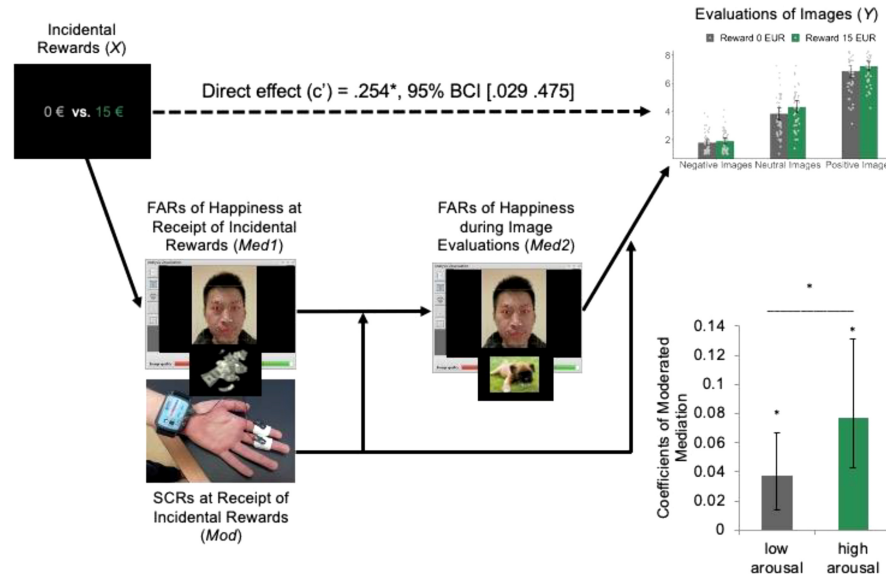
We then ran a sequential mediation model to test whether the changes in the aesthetic evaluation of images were mediated by the FAR valence during the lottery outcome and image-viewing periods jointly (see Figure S15 for temporal dynamics of FAR valence over key experimental events). We found that the sequential mediation effect and the direct effect were both significant ($\beta_{\text{sequential indirect}} = 0.022$, 95% BCI: [0.013, 0.039]; $\beta_{\text{direct}} = 0.313$, 95% BCI: [0.164, 0.456]; see Figure S10), supporting the ATH that affect valence in responding to the incidental rewards and viewing images explained the promotion of aesthetic enjoyment of the images (see Section 3.4 in the online supplemental materials for testing the robustness of the FAR valence on mediating aesthetic evaluation of images).

Next, we tested whether this sequential mediation of valence would depend on the arousal experienced when receiving information about lottery outcomes. We found that the moderated sequential effects were significant when arousal, measured by SCRs, was 1 SD below and above its mean value ($\beta_{\text{sequential indirect low}} = 0.037$, 95% BCI: [0.015, 0.068]; $\beta_{\text{sequential indirect high}} = 0.077$, 95% BCI [0.044, 0.134]). The coefficient of the direct effect was also significant ($\beta_{\text{direct}} = 0.254$, 95% BCI: [0.029, 0.475]), indicating a partial mediation of the model (see Figure 3). Critically, the contrast between the moderated coefficients was significant ($\beta_{\text{sequential indirect high vs. low}} = 0.039$, 95% BCI: [0.003, 0.094]), consolidating the ATH that the higher the incidental affect-induced arousal, the stronger the mediation effects of affective valence (see Section 3.5 in the online supplemental materials for results of sequential moderated mediation analyses at other levels). In other words, higher arousal induced by incidental affect caused a greater infusion of affective valence on the evaluations of images.

As in study 2, we tested whether the mediation role was exclusive to the valence of incidental affect that was captured by FAR valence. For doing that, we replaced the FARs with SCRs at receipt of incidental reward and image viewing periods in the sequential mediation model. We tested the significance of the model using the same procedure. We found that the sequential mediation path was negative and insignificant ($\beta_{\text{sequential indirect}} = -0.004$, 95% BCI: [-0.0124, 0.0002]; see Figure S11). This result indicated that the mediation role in affect infusion processes is specific to the valence of incidental affect rather than the arousal of incidental affect.

According to the *excitation transfer account*, arousal influences affect infusion by *directly* amplifying the affective features of the evaluative targets (Di Muro & Murray, 2012; Mano, 1992; Paulhus & Lim, 1994; Pham, 1996; Schachter & Singer, 1962; Vosgerau, 2010; Zhu & Ratner, 2015; Zillmann, 1971). We examined whether arousal plays such an amplification role. To do so, we first computed the changes in arousal and the changes in evaluation given the lottery outcomes for each type of image and for each participant. We then regressed the changes in arousal on the changes in evaluation for each type of image. If the arousal merely plays the amplification role based on the affective features of the evaluative targets, we would expect the regression coefficient to be (a) positive for positive images (i.e., higher arousal is associated with higher

Figure 3
Sequential Moderated Mediation With Facial Affect Responses (FARs) Moderated by Skin Conductance Responses (SCRs)



Note. In this model, the path between *Med1* and *Med2* and the path between *Med2* and *Y* are moderated by SCRs at the lottery outcome period (*Mod*). The coefficient of the moderated mediation was significantly higher for high arousal (1 *SD* above its mean) than for low arousal (1 *SD* below its mean). Error bars represent 95% confidence intervals. We obtained permission to use the photo of this person to create this figure for illustrative purposes. See the online article for the color version of this figure.

* $p < .05$ under bootstrapping.

evaluation for positive images), (b) negative for negative images (i.e., higher arousal is associated with lower evaluation for negative images), and (c) flat for neutral images (i.e., arousal has minimal effects on the evaluation of neutral images).

We found that the changes in arousal positively and significantly enhanced the evaluation of *both* positive images ($\beta_{\text{positive}} = 1.182$, $p = .05$, $d = 0.59$, 95% CI: [0.002, 2.362]) and neutral images ($\beta_{\text{neutral}} = 7.764$, $p < .001$, $d = 1.11$, 95% CI: [3.571, 11.956]). Critically, the coefficient was significantly greater for neutral images than for positive images ($\beta_{\text{neutral}} = 7.764$ vs. $\beta_{\text{positive}} = 1.182$, $Z = 3.045$, $p < .001$, $d = 0.99$). Although the coefficient for the negative images showed only a trend ($\beta_{\text{negative}} = 1.357$, $p = .077$, $d = 0.53$, 95% CI: [-0.154, 2.87]), the sign of the coefficient was positive. These results are incompatible with the *excitation transfer account* that arousal is *directly* transferred to amplify the affective features of the evaluative targets.

Finally, we tested the correlation between the level of SCR arousal and the reaction times for evaluating the images and found that it was insignificant ($r_{(47)} = .092$, $p = .321$). This result rejected again that high arousal necessarily limits processing capacity as predicted by the *attention-narrowing account*.

General Discussion

Prior research that has investigated affect infusion on judgment and decision-making has approximated incidental affect through either its valence or arousal (Cohen et al., 2008; Gable & Harmon-Jones, 2008, 2013; Humphreys & Revelle, 1984; Paulhus

& Lim, 1994; Pham, 1996, 1998; Pham et al., 2015; Sanbonmatsu & Kardes, 1988; Schwarz & Clore, 2007; Vosgerau, 2010; Zhu & Ratner, 2015) while largely neglecting to delve into the interplay of these two components. Here, we propose the ATH delineating the possibility that valence and arousal make interactive contributions to the affect infusion processes. Across three studies, we provide converging evidence that incidental affect, manipulated by the exposure to affect-laden images (study 1) or winning money from a lottery game (studies 2 and 3), could alter participants' reported enjoyment in seemingly unrelated tasks when they listened to different music, drank different wines, and saw different images. Critically, we demonstrate that changes in reported experienced enjoyment were underpinned by neuro- and psycho-physiological responses that reflect the moment-based affective states (i.e., valence and arousal) of the participants.

Our work replicates and extends the AIM framework from affective neuroscience. At the process level, AIM suggests that valence and arousal could be combined into an affect composite to influence subsequent decisions. We replicated the mediation effect of such affect composite on the wine-tasting experience (study 2) and demonstrated another unique way that valence and arousal interplay: the BAS moderated the mediation of the brain's valence system. Supporting the idea of the ATH, we found that the valence of incidental affect felt as the outcomes of the lottery game, measured by the neural activity of the BVS (study 2) and FAR valence (study 3), mediated how much participants enjoyed drinking different wines and looking at different images. In addition, by means of moderated mediation analyses, we found that the magnitude of

arousal induced by the lottery outcomes, measured by the neural activity of the BAS (study 2) and SCRs (study 3), facilitated the infusion of affective valence on these consumption experiences.

The ATH assumes a transporter role of arousal in regulating the extent of affect infusion. We examined this transporter role against alternative explanations (e.g., constraining cognitive processing capacity and amplifying the affective features of the evaluative targets), and corroborated that this transporter role of arousal in the ATH is truly distinctive. Specifically, we found no evidence that participants thought fewer (study 1) or responded faster (studies 2 and 3) when evaluating their consumption experiences. These analyses spoke against the *attention-narrowing account* that higher arousal necessarily constrains processing capacity and causes faster and less thoughtful responses. One possible explanation might be that the narrowing of processing capacity only occurs for very high arousal elicited by performing physical exercises (Gable & Harmon-Jones, 2013; Sanbonmatsu & Kardes, 1988), or listening to a continuous 90-dBA noise (Paulhus & Lim, 1994). Some researchers also suggested that the narrowing of cognitive scope is caused by motivational intensity rather than arousal *per se* (Gable & Harmon-Jones, 2010, 2013). We call for future research to clarify the premises for the attention-narrowing effect to occur. In study 3, we included evaluative targets with different valence to test the transporter role versus the amplification role of arousal. We found no reliable evidence to support the *excitation transfer account* that arousal could only influence evaluation by amplifying the affective features of the evaluative targets.

An additional interesting observation in study 3 is that we did not find consistent evidence for affect infusion on negative evaluative targets (see Section 3.2 in the online supplemental materials for additional analyses; the finding holds for other studies that we have reported elsewhere). One possible explanation is that a negative evaluative target might lead individuals to suppress any type of information processing so that arousal and valence transfer are blocked. Indeed, prior research has found that the extent of affect infusion could be influenced by certain characteristics of the evaluative targets, such as the specificity of the targets (also see Section 1.2 in the online supplemental materials for additional measures and analyses using self-referential vs. object-referential scales), the familiarity of the targets, and the stereotypicality of the targets (Forgas, 1990; Gorn et al., 1993, 2001). The general consensus is that the impact of affect infusion is augmented if the evaluative target is open for subjective interpretation (Greifeneder et al., 2011). For example, for the same degree of incidental affect, the impact is greater on the evaluation of general life satisfaction than on the satisfaction of a specific life event.

Implications for Discrete Emotion Research and Effort-Based Decision-Making

Apart from being a new mechanism of the affect infusion processes, the ATH may also provide a new perspective to explain previous findings in the discrete emotion literature in which emotions of the same valence caused divergent behavioral outcomes (Lerner et al., 2004; Lerner & Keltner, 2001; Raghunathan & Pham, 1999). For example, inducing either disgust or sadness, two emotions that are both negative in valence, would lead to different decisions in an endowment game (Lerner et al., 2004). Disgust was found to reduce both selling prices and choice prices in an endowment

game, whereas sadness reduced only selling prices. Previously, these results were explained by the appraisal themes of these emotions (Lerner & Keltner, 2000; Smith & Ellsworth, 1985); sadness is assumed to engender a need for change, so individuals are more willing to “let go” of a product and more eager to acquire a new product. Disgust, on the other hand, represents a tendency to expel and avoid, so it results in a reduction in both selling and choice prices. Viewed through the lens of the ATH, such results are also compatible with how effectively valence of affect is transported by the arousal of affect. Specifically, although disgust and sadness are both negative in valence, disgust is more arousing than sadness. Assuming that negative valence decreases liking and evaluation of products, this would result in repulsion toward holding or taking the products. Consequently, the greater reduction in both selling and choice prices could be explained by the higher arousal of disgust; the lower arousal of sadness might influence only the selling prices. Similarly, the ATH could also explain why being in a positive mood could make individuals both resist and give in to temptation, which has been explained previously by self-control depletion under high arousal (Fedorikhin & Patrick, 2010). Under the ATH, it could be that, as the arousal is elevated, high arousal transports more valence, making tempting products more irresistible.

The transporter role of arousal also broadly pertains to the recent suggestion that arousal mobilizes efforts in making choices and decisions (Kurniawan et al., 2021; Meyniel et al., 2013; Schmidt et al., 2009; Sheng et al., 2020; Vinckier et al., 2018). For example, exposure to highly arousing pictures increased participants’ persistence in performing a physically effortful task irrespective of the monetary incentives (Schmidt et al., 2009). In an experiment where participants could choose between squeezing a hand grip to get a large reward or accepting a noneffortful small reward, Kurniawan et al. (2021) documented that high arousal, indexed by the enlarged pupil size, is associated with a high tendency to choose effortful options. In the light of our ATH, these results could be seen as the arousal transports required or anticipated efforts for doing these tasks instead of the valence in the context of the affect infusion processes. Interestingly, the mobilized efforts are not limited to physical. Sheng et al. (2020) reported that decision-makers whose pupil dilation is enlarged (i.e., indicating a high arousal state) were more likely to overcome the mental inertia of accepting the default option in a choice task.

Limitations and Future Research

Several limitations in the current research should be acknowledged. First, the transporter role of arousal is assumed to be effective for both positive and negative valence. Although study 1 provided initial evidence that being in a negative high-arousal state reduced enjoyment of music in comparison to a neutral state, we did not find that a negative low-arousal state had the same significant effect. This result could have been caused by the hedonic nature of the music excerpts that we used in the study, which potentially erased the negative low-arousal state. This speculation is in line with findings in consumer research, suggesting a “retail therapy” when consumers’ mood is down (Atalay & Meloy, 2011; Rick et al., 2014). For example, sadness triggers increased consumption of unhealthy food and money spent as a means to uplift or “repair” the unpleasant affective state (Cryder et al., 2008; Garg & Lerner, 2013). These results also hint at a complicated interaction that is still understudied

between the infused incidental affect and the nature of the consumption experiences for future research.

The second limitation is that we tested the ATH when the arousal of incidental affect facilitates the affect infusion for making evaluations. One would expect that the impact of incidental affect would be reduced when the arousal level is suppressed or even blocked. Future research is needed to investigate how casually “knocking out” the arousal system—for example, through pharmacological interventions such as using beta-blockers (Cahill et al., 1994)—would impair the transport of valence on subsequent judgments and evaluations. Low levels of arousal could also be caused by individuals’ baseline psychophysiological states, such as chronic stress (McEwen, 2017), depression-related symptoms (Williams, 2016), or sleep deprivation (Foster, 2020). These conditions are all ubiquitous in modern society and we call for future research to investigate the ATH in more settings related to everyday judgment and evaluation.

To conclude, this research demonstrates a nuanced interplay of valence and arousal for affect infusion to occur. Our findings provide an integrative, biologically sound understanding of how positive incidental affect, with varying arousal, could alter experienced utility across different judgment domains.

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