Emotion

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The Role of Trait Reappraisal in Response to Emotional Ambiguity: A Systematic Review and Meta-Analysis

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Individuals exhibit a systematic valence bias—a specific form of interpretation bias—in response to emotional ambiguity. Accumulating evidence suggests most people initially respond to emotional ambiguity negatively and differ only in subsequent responses. We hypothesized that trait-level cognitive reappraisal—an emotion regulation strategy involving the reinterpretation of affective meaning of stimuli—might explain individual differences in valence bias. To answer this question, we conducted a random-effects meta-analysis of 14 effect sizes from 13 prior studies ($n = 2{,}086$), identified via Google Scholar searches. We excluded studies (a) in languages other than English, (b) from non-peer-reviewed sources, or (c) nonempirical sources. We included studies with (a) the Emotion Regulation Questionnaire, (b) a putative measure of valence bias prior to any study-specific manipulations, and (c) adult human participants (i.e., 17+). Supporting our prediction, we found individuals with higher trait reappraisal exhibited a less negative bias ($r = -.18$, $z = -4.04$, $p < .001$), whereas there was a smaller, opposite effect for trait expressive suppression ($r = .10$, $z = 2.14$, $p = .03$). The effects did, however, vary across tasks with stronger effects observed among studies using the scrambled sentences task compared to the valence bias task. Although trait reappraisal accounted for only a small amount of variance, reappraisal may be one mechanism contributing to variability in response to ambiguity.

Keywords: interpretation bias, ambiguity, individual differences, emotion regulation, reappraisal

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Individuals differ in how they respond to emotionally ambiguous situations. Emotionally ambiguous signals can be interpreted as having either a positive or negative meaning, and thus require rapid responding as one considers potential threats while concurrently preparing for a variety of alternative scenarios (Neta et al., 2009). Individual differences in responses to emotionally ambiguous stimuli are informative of health and well-being through associations with physical activity (Neta et al., 2019), psychological characteristics (e.g., depression symptoms (Clinchard et al., in revision; Park et al., 2016; Petro, Tottenham, & Neta, 2021), and social connectedness (Harp & Neta, 2023; Neta & Brock, 2021). What is not yet clear, however, is what mechanisms are responsible for these individual differences.

Responses to Emotionally Ambiguous Stimuli

Emotionally ambiguous stimuli are common in everyday life, particularly in social interactions. For example, surprised facial expressions can signal both pleasant and unpleasant outcomes (Kim et al., 2003, 2004; Neta et al., 2009, 2013). Presenting such stimuli without contextual cues reveals individual differences in the tendency to interpret these cues as having a positive or negative meaning (i.e., valence bias; Neta et al., 2009). These differences in valence bias are relatively stable across time (Harp et al., 2022; Neta et al., 2009) and across stimulus categories, such as emotionally ambiguous faces, scenes, and words (Harp et al., 2021; Neta et al., 2013). Thus, valence bias is both a generalizable and stable trait-like characteristic.

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Valence bias can be seen as a form of interpretation bias. Interpretation bias is a broader construct that typically refers to the tendency to interpret either ambiguous or neutral information as negative or threatening. For example, in many studies of interpretation bias, participants are asked to make a valence decision about mono-valence ambiguity (e.g., the word "die" holds both a negative/threatening and a neutral/nonthreatening meaning, but no valid positive/rewarding meaning is available). In contrast, valence bias represents valence decisions in response to dual-valence ambiguity—stimuli for which both negative and positive meaning is valid (e.g., a surprised facial expression; Neta & Kim, 2023). Responses to ambiguous cues inform the degree to which individuals prioritize negative information over nonemotional (in the case of mono-valence cues) or positive information (in the case of dual-valence cues). Still, some measures of interpretation bias, like the scrambled sentences task (SST), present a scrambled series of words that can be resolved in either a more positive or negative light (e.g., Blanco et al., 2021; Kaleta et al., 2023; Wilson et al., 2022) and are thus very similar to measures of the valence bias. Notably, the SST shows high test–retest reliability (i.e., $r = .76$ to intraclass correlation = .89; Würtz et al., 2022), suggesting that it, like valence bias, is relatively stable and trait-like. Thus, the SST and valence bias task likely represent an overlapping underlying construct, although there remain differences in how the two tasks do so (e.g., the valence bias task presents a single cue/image with dual-valence ambiguity, the SST presents a series of words that may be constructed to resolve dual-valence ambiguity).

Because biases toward negative information are central to models of internalizing symptoms and psychopathology (e.g., depression, anxiety; Beck, 1976; Mathews & MacLeod, 2005), responses to ambiguity have numerous implications for well-being. For instance, a more negative bias is associated with heightened physiological reactivity to stressors (Brown et al., 2017) and uncertainty (Neta et al., 2017), as well as greater negative affect (Neta & Brock, 2021), all of which are associated with poorer psychological well-being. Over the longer term, a more negative valence bias is associated with higher levels of internalizing symptoms (e.g., anxiety and depression symptoms, loneliness; Harp & Neta, 2023; Neta & Brock, 2021; Park et al., 2016; Petro, Tottenham, & Neta, 2021). With regards to social well-being, a more positive valence bias is associated with greater social connectedness, by way of higher levels of empathy, extraversion, and interpersonal emotion regulation (Brock et al., 2022; Harp & Neta, 2023; Neta & Brock, 2021). Notably, research using repeated measures designs suggests that interventions that aim to foster well-being of both the mind and body by building adaptive strategies for mitigating stress reactivity (i.e., mindfulness-based stress reduction) result in a more positive valence bias (Harp et al., 2022). Similarly, cueing cognitive reappraisal use through a brief training in the strategy for clearly negative images induces a more positive bias, whereas cueing other strategies, like expressive suppression, does not (Neta et al., 2023). Given these myriad ties to well-being, it is important to understand the underlying mechanisms that support a particular valence bias.

In principle, individual differences in valence bias could arise from any one of the various component processes that make up affective responses to emotional ambiguity, including subjective feelings, physiological reactions, and cognitive appraisals. In what follows, we argue that, of these, the appraisal process, which includes both initial and subsequent (re)appraisals, may be one particularly important mechanism by which valence bias arises.

The Role of Appraisal and Reappraisal

Appraisal involves constructing an abstract representation of a motivational meaning of a situation. This process is usually iterative as an initially fleeting and course-grained appraisal is updated into a more stable and elaborate appraisal (Everaert et al., 2021). The iterative process of appraisal is sensitive not only to information about the situation but also to emotion regulation goals such as a hedonic goal to experience positive rather than negative states (Uusberg et al., 2019). For instance, this hedonic goal may motivate one who initially appraised their coworkers' chatter as criticism to consider alternative interpretations and perhaps discover that their colleagues are behaving much more amicably. The iterations of the appraisal process that are impacted by emotion regulation goals can be referred to as reappraisal (Gross, 2015; Yih et al., 2019).

Here we hypothesize that individual differences in the valence bias are in part explained by trait-level differences in the use of reappraisal. This idea stems from the working mechanistic model of valence bias, the "initial negativity hypothesis," which posits that initial responses to emotional ambiguity are negative—even for those with a more positive bias—and are later updated by regulatory processes in some individuals (Neta et al., 2009, 2021; Neta & Tong, 2016; Neta & Whalen, 2010; Petro et al., 2018). Several lines of evidence support this model. With respect to the initial negativity, negative responses to emotionally ambiguous stimuli are associated with shorter reaction times than positive responses (Neta et al., 2009; Neta & Tong, 2016; Petro, Tottenham, & Neta, 2021). Similarly, mouse-tracking techniques that capture moment-to-moment response competition show that positive responses appear to be characterized by an initial attraction to the competing (negative) response option (Brown et al., 2017; Neta et al., 2021). Also, images of surprised faces that are filtered to emphasize faster processing (images conveying low-spatial-frequency information; Bar et al., 2006) are interpreted as more negative than images that emphasize slower processing (the same images conveying high-spatial-frequency information; Neta & Whalen, 2010). Furthermore, evidence from drift diffusion modeling suggests that evidence in favor of negative responses accumulates faster than evidence for positive responses, rendering an initial negative appraisal more likely (Harp et al., 2023).

Taken together, there is converging evidence suggesting (a) that the initial response to emotional ambiguity is negative and (b) that this initial negativity is evident even for those individuals who ultimately show a more positive valence bias (i.e., there is not much variability in this initial response). Thus, the individual differences in valence bias are not likely to arise from variability in the first stage of the process. Instead, the candidate mechanism that explains variability in valence bias is likely to arise in the second stage—the updating of the initial appraisal.

One mechanism at play at the second stage of valence bias formation is cognitive reappraisal of the ambiguous stimulus that updates the initial negative response with a more positive (or less negative) one (Harp et al., 2022; Kim et al., 2003; Neta et al., 2009, 2011; Neta & Tong, 2016; Neta & Whalen, 2010; Petro et al., 2018; Petro, Tottenham, & Neta, 2021). The involvement of reappraisal is indicated by the finding mentioned earlier that cueing cognitive reappraisal—but not alternative emotion regulation strategies (e.g., expressive suppression)—results in a more positive valence bias (Neta et al., 2023). Furthermore, when the cognitive resources required for reappraisal are limited, a negative bias tends to remain. For instance, when people are instructed to deliberate about ambiguous stimuli, thereby investing more cognitive resources that could support subsequent reappraisal, they tend to respond to these stimuli less negatively

(Neta & Tong, 2016). Similarly, participants tend to feel more negatively about ambiguity under high compared to low concurrent cognitive load (Salter et al., 2023), and the SST often requires participants to maintain a string of numbers in working memory to induce a cognitive load that reduces the likelihood of demand characteristics or updated appraisals thought to be more favorable (i.e., positive) responses (Würtz et al., 2022). Likewise, inducing a state of stress, which promotes hypervigilance and reduces cognitive control, results in a more negative valence bias (Brown et al., 2017; Neta et al., 2017). These effects suggest that reappraisal helps individuals to shift away from an initially negative response which is why limiting the cognitive resources required for reappraisal tends to retain the negativity bias.

Neuroimaging studies provide an additional source of evidence for initial negative appraisals that are followed by more positive reappraisals. Specifically, neuroimaging studies report that negative responses to ambiguity are associated with greater amygdala activation, whereas more positive responses are associated with greater prefrontal activity (Kim et al., 2003; Petro et al., 2018), a pattern suggestive of emotion regulation (Ochsner et al., 2004). Furthermore, individuals who respond more positively to ambiguity show greater inverse connectivity between the amygdala and a region of the medial prefrontal cortex associated with emotion regulation (Petro, Tottenham, & Neta, 2021) and these same neural systems mediate cognitive upregulation and downregulation of negative emotion (Ochsner et al., 2004).

Altogether, a wealth of behavioral and neuroimaging findings aligns with the idea that trait reappraisal would support a more positive valence bias. These findings suggest the possibility that individual differences in valence bias might arise due to differential engagement of reappraisal. One way to test this hypothesis is to see whether individual differences in trait reappraisal correlate with valence bias such that greater trait reappraisal is associated with more positive (less negative) responses to ambiguity.

Present Research

The aim of the present research was to examine the relationship between trait reappraisal and valence bias. We pooled data from 13 published reports, comprising 14 effect size estimates, and interrogated the meta-analytic relationship between responses to ambiguity and the tendency to use reappraisal and suppression as measured by the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). Specifically, we first hypothesized that if trait reappraisal supports the subsequent reappraisal of an initially negative appraisal of emotional ambiguity, then those individuals who have a more positive valence bias should also score higher on a measure of trait reappraisal (H1). Furthermore, this correlation should be specific to reappraisal and not extend to other emotion regulatory strategies that alter affective states through processes other than appraisal. Specifically, we hypothesized that expressive suppression, a strategy that alters affective states by inhibiting their bodily expressions, should not be related to valence bias (H2). Because studies employed a variety of experimental parameters, we tested whether task type moderated the effects of interest.

Method

Transparency and Openness

We followed the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) framework (Page et al., 2021). All analyses were conducted using R (R Core Team, 2021). The meta-analytic data set and relevant code for the current study is available on the Open Science Framework (https://osf.io/35xmd; Harp, 2023). The analyses in the present report were not preregistered and a review protocol was not prepared. We report how we determined our sample size (i.e., dependent upon available data from literature search), as well as all data exclusions, manipulations, and measures in the study (i.e., inclusion/exclusion criteria below).

Literature Search and Study Selection

The key terms "valence bias" or "interpretation bias" and "emotion regulation" were used to search for published articles that included both a valence/interpretation bias task as well as the ERQ on Google Scholar in May 2023. The search yielded 2,541 results. An automated tool, Web Scraper (https://webscraper.io/), was used to retrieve article links from Google Scholar. Either the lead author or a trained undergraduate research assistant assessed each entry for exclusion criteria; articles that did not meet the exclusion criteria were reserved for full text review. Specifically, we excluded articles (a) in languages other than English, (b) from non-peer-reviewed sources (e.g., chapters, books, theses, preprints), or (c) which did not report results of original empirical studies (e.g., narrative reviews, meta-analyses, study protocols). For the 1,109 articles that remained following the initial exclusionary check, either the lead author or research assistant retrieved the full text of each result and evaluated three inclusion criteria. To move beyond full text review, articles needed to include (a) the ERQ, (b) a putative measure of valence bias (i.e., responses to dual-valence ambiguity) prior to any study-specific manipulations (e.g., mindfulness training, cognitive bias modification), and (c) include adult human participants (i.e., 17+). After examining the remaining 1,109 full-text articles, 30 articles were identified for possible inclusion (i.e., 1,079 full-text articles failed to clearly meet the three criteria above).

Data Extraction and Reduction

Of the 30 articles that appeared to meet inclusion criteria, 13 were selected as the final sample comprising 14 unique effect sizes and representing data from 2,086 unique participants. Two articles included the same sample of participants (Brown et al., 2017; Raio et al., 2021) and are thus reported as a single effect size. Other articles included either a series of studies (Neta et al., 2023), subsamples with unique characteristics (e.g., caregiving status; Wilson et al., 2022), or "mega-analysis" across many studies (Brock et al., 2022; Neta & Brock, 2021); effect sizes for individual studies were used in the present analysis. Studies that appeared to meet inclusion criteria but failed to pass final review are shown in Table 1 ($k = 17$).

The lead author extracted effect size estimates (i.e., correlations) and moderator-related information from the studies that passed final review; the senior author reviewed and confirmed the extracted data. Specifically, effect size estimates for the correlation coefficients between valence bias and both the ERQ cognitive reappraisal and expressive suppression subscales, the sample size, demographic information (i.e., $M(SD)$ of age, range of age, gender, and race/ethnicity), the sample source (e.g., undergraduate/local community, online worker), study location (i.e., in-person vs. online), pandemic context (i.e., data collected pre-COVID-19 pandemic vs. during/post-COVID-19 pandemic), and task type (i.e., valence bias vs. SST) were extracted. Of note, we only retained effect sizes at "baseline" in the event of study-specific manipulations (e.g., mindfulness

Table 1

Seventeen Articles Excluded at Final Review With Reasons

Article title	References	Reason for exclusion
Positive interpretation bias predicts well-being in medical interns	Kleim et al. (2014)	Appropriate analysis not reported; data requested but not provided.
The association between interpretation bias, emotion regulation, and covid-related anxiety: a cross-sectional study	Ghahari et al. (2022)	Bias measure is the DACOBS scale (van der Gaag et al., 2013), intended to measure cognitive biases in psychosis; not dual valence ambiguity.
Reappraisal-related downregulation of amygdala BOLD activation occurs only during the late trial window	Pierce, Blair, et al. (2022)	No ERQ collected.
How anxious are you right now? Using ecological momentary assessment to evaluate the effects of cognitive bias modification for social threat interpretations	Daniel et al. (2020)	Trait negative interpretation bias measure includes only threatening and nonthreatening interpretations (i.e., not dual valence).
Exploring valence bias as a metric for frontoamygdalar connectivity and depressive symptoms in childhood	Petro, Tottenham, and Neta (2021)	Sample includes only children.
Positivity effect in aging: evidence for the primacy of positive responses to emotional ambiguity	Petro, Basyouni, and Neta (2021)	No ERQ collected.
Negative interpretation of ambiguous bodily symptoms among illness-anxious individuals: exploring the role of developmental and maintenance constructs	Elhamiasl et al. (2023)	Bias measure included "safe" (i.e., neutral) and "unsafe" (i.e., negative interpretations); not dual valence ambiguity.
Affective flexibility as a developmental building block of cognitive reappraisal: an fMRI study	Pierce, Haque, and Neta (2022)	Sample includes only children.
The relationship between ruminating the catastrophic consequences of bodily changes and positive reappraisal and practical problem-solving strategies in individuals with illness anxiety disorder	Elhamiasl et al. (2020)	Measure of "interpretation bias" is about catastrophizing ambiguous bodily signals; not dual valence ambiguity.
Don't like what you see? Give it time: longer reaction times associated with increased positive affect	Neta and Tong (2016)	No ERQ collected.
ECAT: examining attention mechanisms causally involved in reappraisal and rumination	Sanchez-Lopez et al. (2019)	Data requested but unavailable.
Effect of negative valence on assessment of self-relevance in female patients with borderline personality disorder	Sarkheil et al. (2019)	Bias measure is not dual valence.
The dynamic process of ambiguous emotion perception	Neta et al. (2021)	No ERQ collected.
Through the eyes of the beholder: SEE modulates valence bias in response to emotional ambiguity.	Neta and Dodd (2018)	No ERQ collected.
The primacy of negative interpretations when resolving the valence of ambiguous facial expressions	Neta and Whalen (2010)	No ERQ collected.
Negative interpretation bias connects to real-world daily affect: a multistudy approach.	Puccetti et al. (2023)	No ERQ collected.
Evaluating the effect of metacognitive beliefs about angry rumination on anger with cognitive bias modification	Krans et al. (2014)	Bias assessed following cognitive-bias modification training, that is, not baseline bias.

Note. DACOBS = Davos Assessment of Cognitive Biases Scale; BOLD = blood oxygen level dependent; ERQ = Emotion Regulation Questionnaire; fMRI =functional magnetic resonance imaging; ECAT = eye-gaze contingent attention training; SEE = simulated eye-movement experience.

or cognitive bias modification training). If authors did not report appropriate statistical analyses, we emailed corresponding authors to request the data and/or effect size estimates (two of three responded, but one of the responding authors was unable to provide the requested data/effect sizes). The PRISMA flowchart illustrates the search and selection process (see Figure 1).

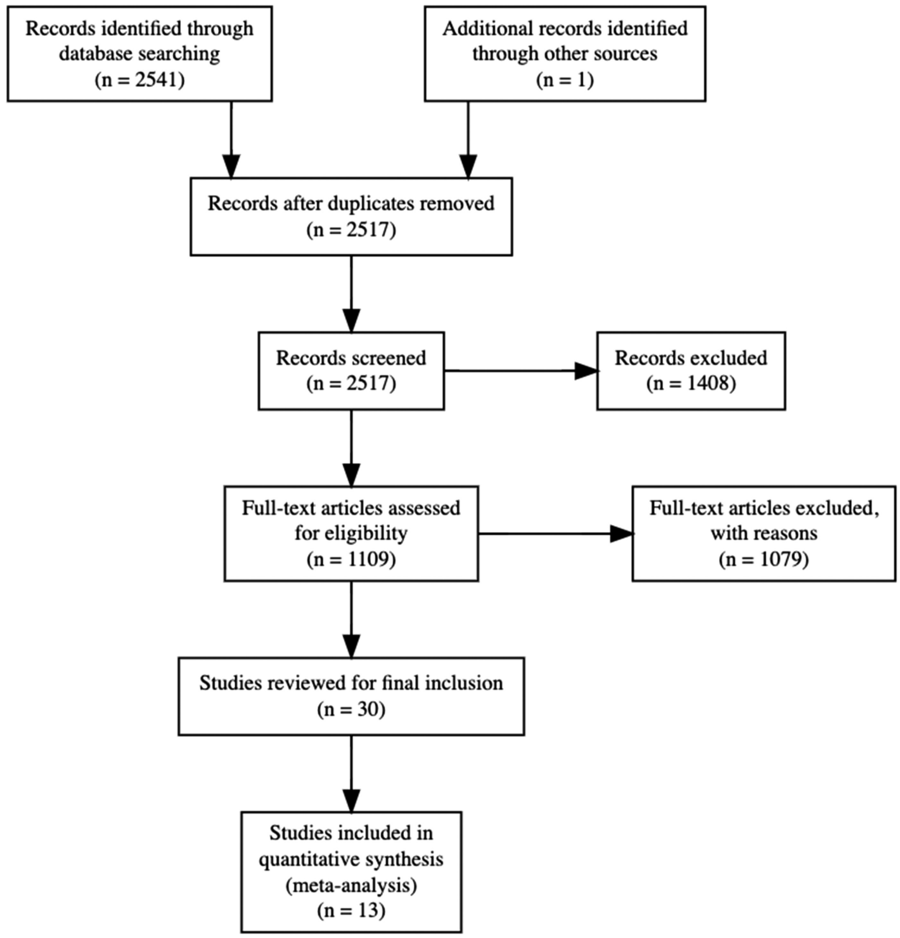
Tasks

Valence Bias

Most studies (i.e., 10/13 studies, 10/14 effect sizes) assessed valence bias using at least one of three categories of stimuli: faces, scenes, and words. Within each category were clearly positive (e.g., happy expressions), clearly negative (e.g., angry expressions), and ambiguous (e.g., surprised expressions) stimuli. In the task, participants viewed and categorized (via button-press or mouse click) each image as either positive or negative. Response assignments were counterbalanced across participants.

For the face stimuli, participants saw a subset of 72 distinct identities (37 female, 35 male) selected from the NimStim standardized facial expression stimulus set (Tottenham et al., 2009), Karolinska Directed Emotional Faces database (Lundqvist et al., 1998), and Umeå University Database of Facial Expressions (Samuelsson et al., 2012). Genders were represented equally, though each identity was not represented in all three expressions as in previous studies

Figure 1
PRISMA Flowchart



Note. PRISMA = Preferred Reporting Items for Systematic review and Meta-Analysis.

(e.g., Neta et al., 2009). The scene stimuli were selected from the International Affective Pictures System (Bradley & Lang, 2007) and the word stimuli are publicly available as online supplemental materials in earlier work (Clinchard et al., in revision; Harp et al., 2021).

In total, there were 48 faces (24 surprised and 24 unambiguous: 12 angry, 12 happy), 48 scenes (24 ambiguous and 24 unambiguous: 12 negative, 12 positive), and/or 44 words (22 ambiguous and 22 unambiguous: 11 negative, 11 positive) presented in a pseudorandom order, and split into two blocks each, where blocks were counterbalanced between participants. Participants were instructed to categorize each stimulus as fast and accurately as possible. Task data were collected using MouseTracker (Freeman & Ambady, 2010), E-Prime, Qualtrics, or Gorilla Experiment Builder (Anwyl-Irvine et al., 2020). Valence bias is calculated as the percentage of trials in which a participant categorized ambiguous stimuli as negative; for example, categorizing 18 of 24 ambiguous stimuli as negative would result in a 75% negative valence bias. If a participant had missing data for one stimulus category in an experiment that had three stimulus categories, then valence bias is calculated as the average of bias for the two remaining categories.

SST

The remaining studies (i.e., three out of 13 studies, four out of 14 effect sizes) assessed interpretation bias using the SST (Hirsch et al., 2020; Wenzlaff & Bates, 1998). In the task, participants view a series—typically 15–20 sets—of scrambled words which must be sorted to form a grammatically correct sentence. Often, the sentences must be unscrambled while participants maintain some item (e.g., a six-digit number) in working memory to reduce the likelihood of influence from explicit biases or demand characteristics (Würtz et al., 2022). Participants must resolve the sentences quickly (i.e., 10–15 s/sentence; Blanco et al., 2021; Kaleta et al., 2023; Wilson et al., 2022). Each sentence may be validly sorted in either an emotionally positive or negative manner, and interpretation bias is calculated as the proportion of unscrambled sentences with positive meaning (i.e., positive interpretation bias; see Table 2 for characteristics of each study).

Statistical Analysis

Correlations were either extracted or computed (e.g., from articles reporting multiple studies or "mega-analysis") between each study's

Table 2
Demographic and Experimental Characteristics of Studies

Publication	*n* ($N = 2{,}086$)	Age *M*(*SD*); range	Sex	Race and/or ethnicity	Sample	Internal versus external publication	Task	Stimuli
Brown et al. (2017), Raio et al. (2021)	47	20.64 (3.81); 18–37	23 female, 24 male	47 unknown	Undergraduate/local community	Internal	Valence bias	Faces
Neta et al. (2019)	469	31.26 (6.75); 18–53	201 female, 268 male	One AmInd, 99 Asian, 43 Black–Not Hisp, 293 White–Not Hisp, six Other, 26 Hisp, one NatHaw	Mturk	Internal	Valence bias	Faces and scenes
Petro et al. (2018)	41	23.68 (6.55); 17–51	28 female, 13 male	Six Asian, 10 Black–Not Hisp, 21 White–Not Hisp, one Other, three Hisp	Undergraduate/local community	Internal	Valence bias	Faces and scenes
Neta and Brock (2021), Brock et al. (2022)–Study 1	61	18.40 (0.80); 18–21	37 female, 15 male, nine unknown	Three Asian, three Black–Not Hisp, 42 White–Not Hisp, one Other, three Hisp, nine unknown	Undergraduate/local community	Internal	Valence bias	Faces and scenes
Neta and Brock (2021); Brock et al. (2022)–Study 2	78	19.43 (0.90); 18–22	32 female, eight male, 38 unknown	one Asian, 38 White–Not Hisp, one Hisp, 38 unknown	Undergraduate/local community	Internal	Valence bias	Faces and scenes
Clinchard et al. (revision) (resubmitted)	121	20.13 (1.49); 17–23	99 female, 22 male	Eight Asian, two Black–Not Hisp, five Other, 106 White–Not Hisp	Undergraduate/local community	Internal	Valence bias	Faces, scenes, and words
Harp and Neta (2023)	561	38.33 (13.34); 18–89	294 female, 265 male, two other	Eight AmInd, 33 Asian, 35 Black–Not Hisp, 45 Hisp, two NatHaw, nine Other, 429 White–Not Hisp	Mturk and social media advertisement	Internal	Valence bias	Faces, scenes, and words
Harp et al. (2022)	60	43.25 (13.97); 19–77	53 female, seven male	two Asian, four Other, 54 White–Not Hisp	U.S.-based MBSR Courses	Internal	Valence bias	Faces
Neta et al. (2023)—Study 1	120	19.81 (2.53); 18–35	100 female, 20 male	Two Asian, 118 White	Undergraduate/local community	Internal	Valence bias	Faces
Neta et al. (2023)—Study 2	34	20.32 (3.13); 18–35	27 female, seven male	Two Black, 33 White	Undergraduate/local community	Internal	Valence bias	Scenes
Blanco et al. (2021)	80	27.7 (11.3); No range reported	62 female, 18 male	80 unknown	Social media advertising	External	SST	Sentences
Kaleta et al. (2023)	112	41.84 (7.01); 70 and under	99 female, nine male, three unknown	One Chinese, 15 Indian, four mixed, four Other, six unknown, 84 White	Social media advertising; general practitioners	External	SST	Sentences
Wilson et al. (2022)—Study 1	182	56.36 (13.48); 18+	155 female, 26 male	One Bangladeshi; three Black British; one Chinese; three Indian; one Pakistani; one Other; one White and Asian; one White and Black Caribbean; 159 White British; one White Gypsy or Irish Traveler; five White Irish	Social media advertising; care-givers	External	SST	Sentences
Wilson et al. (2022)–Study 2	120	53.76 (17.65); 18+	82 female, 37 male, one unknown	One Arab, one Chinese, one Indian, 22 other, one White and Asian, one White and Black Caribbean, 90 White British, three White Irish	Social media advertising; non-care-givers	External	SST	Sentences

Note. In-lab publications are affiliated with the senior author's research team. External publications are from authors unaffiliated with the senior author. We note that Kaleta et al. (2023) reported $n = 114$, but only $n = 112$ had ERQ data. AmInd = American Indian or Alaska Native; NatHaw = Native Hawaiian or Pacific Islander; Hisp = Hispanic or Latino/a; MBSR = mindfulness-based stress reduction; SST = scrambled sentences task; ERQ = Emotion Regulation Questionnaire.

measure of valence bias and ERQ scores for both cognitive reappraisal and expressive suppression. Correlational analyses used Spearman's method if tests of normality (Shapiro & Wilk, 1965) indicated that values were not normally distributed. Because studies of valence bias typically report the percentage of negative interpretations (i.e., higher scores on the valence bias task equate to greater negativity/less positivity), we reverse-scored any effect sizes derived from correlations with "positive interpretation bias" (i.e., higher scores equate to greater positivity/less negativity). Effect sizes were calculated using the escalc command in the metafor package and subsequently meta-analyzed to synthesize results of the literature search (Viechtbauer, 2023).

Because the true effect size may vary from study to study due to methodological differences in assessing valence or interpretation bias, we used random-effect models with the restricted maximum likelihood estimator. Cochran's Q is reported as a test of heterogeneity. We tested for moderations of task type (i.e., valence bias vs. SST). We report the moderation with sum-to-zero contrasts, such that the intercept represents the mean meta-analytic effect, and moderator estimates represent the effect's deviance from the mean effect. We sought to test additional moderating variables, though we could not do so across all studies given colinearities with task type (i.e., valence bias vs. SST) and the other moderators. That said, we did not find evidence of heterogeneity within studies examining the valence bias task specifically (see the online supplemental materials), limiting our ability to make inferences regarding the impact of potential study-level moderating variables. We report 95% confidence intervals of effect sizes as a measure of certainty of the meta-analytic effects. We follow suggestions by Funder and Ozer (2019) in interpreting effect sizes.

Results

Meta-Analysis

A random-effects model assessed the relationship between trait cognitive reappraisal and valence bias ($k = 14$, $I^2 = 74.20\%$, $H^2 = 3.88$). Cochran's test evidenced heterogeneity across studies, $Q(13) = 50.14$, $p < .001$. Overall, there was a small, but significant, effect ($r = -.18$, 95% confidence interval [CI] [−.27, −.09], $SE = .05$, $z = -4.04$, $p < .001$), such that greater trait reappraisal was associated with a more positive bias (see Figure 2A).

Next, we fit a random-effects model to assess the relationship between expressive suppression tendencies and valence bias ($k = 13$, $I^2 = 73.36\%$, $H^2 = 3.75$; note that one study did not include the expressive suppression items from the ERQ; Blanco et al., 2021). Cochran's test evidenced heterogeneity across studies, $Q(12) = 51.81$, $p < .001$. Overall, there was a small, but significant, positive effect ($r = .10$, 95% CI [.01, .19], $SE = .05$, $z = 2.14$, $p = .03$; see Figure 2B), meaning that greater trait suppression was associated with a more negative bias.

Moderator Analysis

We next tested whether task type moderated the effects, given the evidence of heterogeneity across studies for both cognitive reappraisal and expressive suppression. In the cognitive reappraisal model, the omnibus test of moderation was significant, $Q_M(1) = 37.13$, $p < .001$. The mean relationship between bias and cognitive reappraisal remained significant ($b = -.23$, 95% CI [−.28, −.19], $SE = .02$, $z = -10.20$, $p < .001$). The relationship between bias and cognitive reappraisal was stronger for SST than valence bias tasks ($b = -.14$, 95% CI [−.19, −.10], $SE = .02$, $z = -6.09$, $p < .001$). The model was refit with treatment contrasts for the effect of task to determine the mean effect for valence bias ($r = -.09$, 95% CI [−.14, −.05], $SE = .02$, $z = -3.81$, $p = .001$) and SST tasks ($r = -.37$, 95% CI [−.45, −.30], $SE = .04$, $z = -9.67$, $p < .001$). The test for residual heterogeneity was not significant, $Q_E(12) = 12.99$, $p = .37$.

Likewise, there was evidence of moderation in the expressive suppression model, $Q_M(1) = 22.70$, $p < .001$. As before, the mean relationship between bias and expressive suppression was statistically significant ($b = .15$, 95% CI [.09, .21], $SE = .03$, $z = 4.84$, $p < .001$) when accounting for the effect of task type. The relationship between bias and expressive suppression was stronger for SST than valence bias tasks ($b = .15$, 95% CI [.09, .21], $SE = .03$, $z = 4.76$, $p < .001$). In fact, when the model was refit with treatment contrasts, it revealed that the effect was not significant for valence bias tasks ($r = .00$, 95% CI [−.06, .07], $SE = .03$, $z = 0.08$, $p = .94$) and that the omnibus effect was driven by the association among studies using SST tasks ($r = .30$, 95% CI [.19, .40], $SE = .05$, $z = 5.60$, $p < .001$). The test for residual heterogeneity was not significant, $Q_E(11) = 12.95$, $p = .30$.

Bias Assessment

Last, we examined evidence of publication bias with funnel plots (Figure 3). There was no relationship between effect size and sample size for either the trait cognitive reappraisal ($\rho = -.09$, $p = .77$) or expression suppression ($\rho = .00$, $p = .99$) effects.

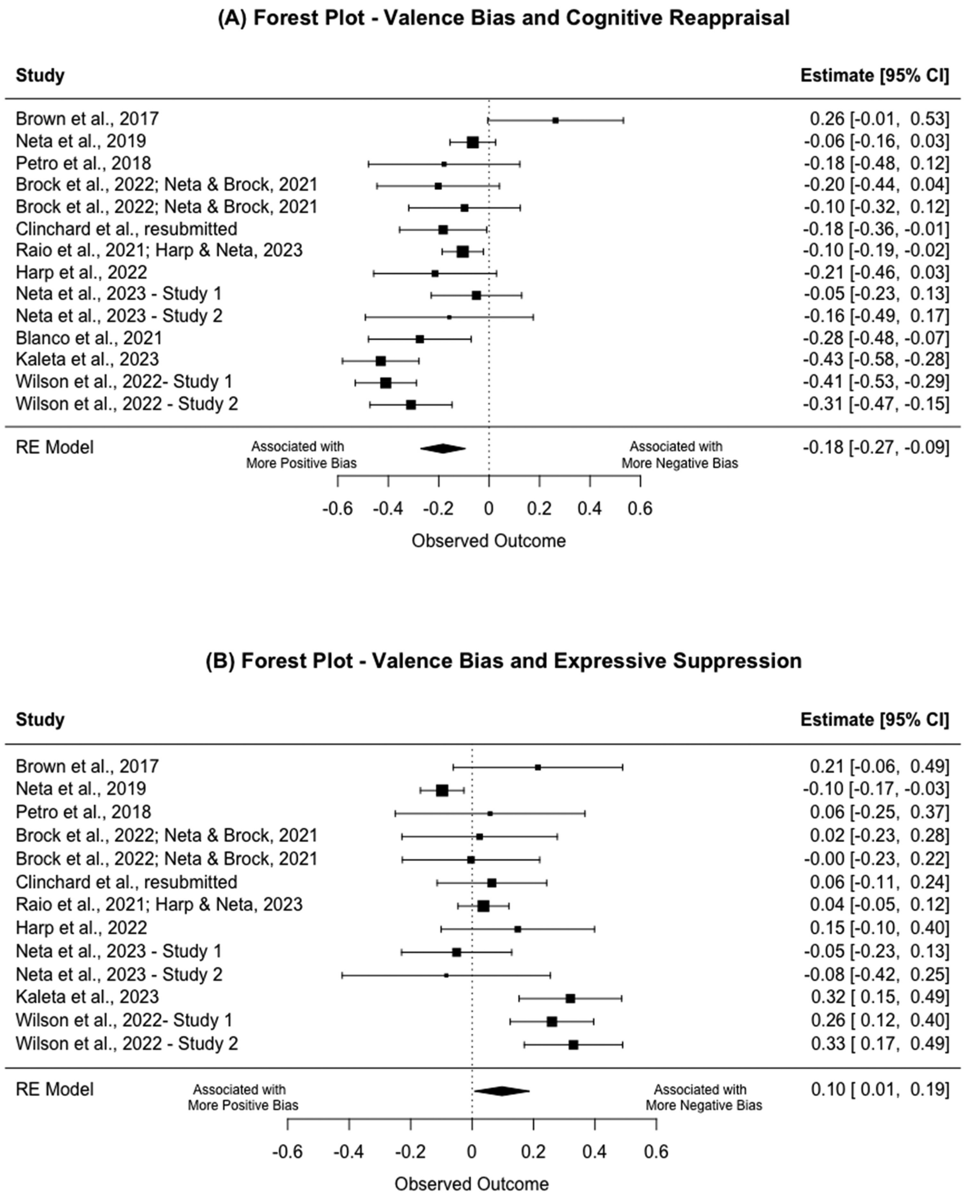
Discussion

In line with our first hypothesis (H1), the results showed that individuals with higher trait reappraisal show less negative affective responses to dual-valence emotionally ambiguous stimuli (i.e., a less negative valence/interpretation bias). This effect was significant for both tasks, although it was much larger for the SST than for the valence bias task. However, in contrast with our second hypothesis that bias would be unrelated to the emotion regulation strategy of expressive suppression (H2), individuals with higher trait suppression tended to show a more negative affective response to dual-valence ambiguity. This relationship was small and in the opposite direction to the relationship between bias and reappraisal. The effect was also driven by studies using the SST rather than valence bias task, which showed no association between bias and expressive suppression tendencies, providing conditional, partial support for the hypothesis.

Although the meta-analytic relationship between valence bias and trait reappraisal was small in terms of effect size, the findings suggest that reappraisal represents at least one source of variability that helps to explain variance of individual differences in response to emotional ambiguity. This effect is consistent with previous findings linking reappraisal use with high positive affect, low negative affect, and higher psychological well-being (Gross & John, 2003) and general health (Lopez & Denny, 2019). Given the effect sizes observed here, it is likely that other mechanisms are also at play in differentiating individuals with a positive versus negative valence bias. Nonetheless, the role of reappraisal merits further attention.

Figure 2

Forest Plot of Fixed-Effects Model for Relationship Between Valence Bias and Self-Reported Frequency of (A) Cognitive Reappraisal and (B) Expressive Suppression



Note. CI = confidence interval; RE = random effect.

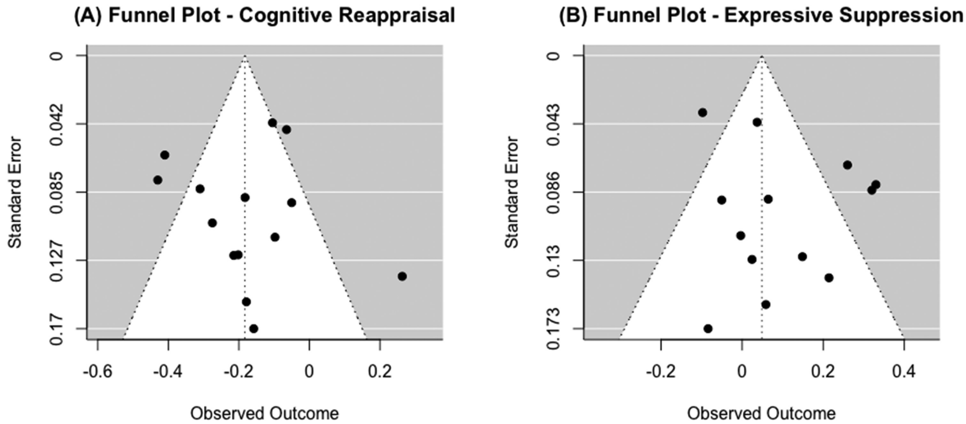
Below, we discuss our findings in the context of a mechanistic account of individual differences in valence bias and the initial negativity hypothesis. We note that the initial negativity hypothesis is grounded in research on valence bias, specifically, rather than interpretation bias, more broadly, and thus may not fully account for the pattern of findings with the SST compared to the valence bias task itself.

Toward a Mechanistic Account of Valence Bias

The present findings support our hypothesis that individual differences in valence bias are linked to individual differences in reappraisal. Mechanistically, greater use of cognitive reappraisal would support the overriding of an initially negative appraisal of ambiguity. Indeed, the initial or default appraisal of ambiguity has been found to be negative, even in individuals who ultimately show a positive appraisal (Kim et al., 2003; Neta et al., 2009, 2011, 2021; Neta & Tong, 2016; Neta & Whalen, 2010; Petro, Basyouni, & Neta, 2021; Petro et al., 2018). Individuals with a more positive valence bias seem to recruit—within the timescale of a single trial—a regulatory process that subsequently updates the default negativity in favor of positivity (Neta et al., 2011; Neta & Tong, 2016; Neta & Whalen, 2010; Petro et al., 2018). Recent evidence supports this notion, as a brief training in cognitive reappraisal

Figure 3

Funnel Plots for Meta-Analytic Effects for (A) Cognitive Reappraisal and (B) Expressive Suppression



seemingly cues use of the strategy in the valence bias task, resulting in a more positive valence bias (Neta et al., 2023). This explanation is consistent with our findings that individual differences in trait reappraisal are associated with valence bias. Furthermore, the present findings show some specificity to cognitive reappraisal in that trait expressive suppression was not related to individual differences in bias among the studies using the valence bias task.

That said, the effects differed for the other interpretation bias task (i.e., the SST; see more details in the next section). Specifically, rather than a null effect with expressive suppression, as in the valence bias task, there was a small, positive association between trait expressive suppression and a more negative bias in studies using the SST. Notably, the direction of this effect does not refute the broader initial negativity account of valence bias, which posits that regulation strategies that do not elicit appraisal change, such as expressive suppression, should not lead to a reduction in initial negativity (i.e., suppression should not be associated with a more positive bias).

Previously, the idea that the characteristic valence bias may arise from reappraisal of initially negative appraisals has been supported, albeit indirectly, by both behavioral and neuroimaging evidence. Specifically, individuals with a more positive valence bias are slower to respond (Neta et al., 2009), deliberate more (Neta & Tong, 2016), and evidence tends to accumulate more slowly for such positive appraisals (Harp et al., 2023). Furthermore, individuals with a more positive bias show greater activity in brain regions associated with reappraisal (Kim et al., 2003; Petro et al., 2018). The present findings complement these earlier studies with correlational support for the idea that individual differences in trait reappraisal might contribute to these previous observations.

Task-Dependent Differences in Findings

The differences between the SST and valence bias tasks revealed in our analyses are interesting in their own right. No study to date has directly examined the relationship between valence bias and the interpretation bias measured by the SST. It is thus unclear to what extent the two tasks assess shared versus unique variance in interpretation biases. However, the present findings suggest that the SST may reveal larger individual differences, possibly owing to more opportunities for regulatory processes to unfold. Responses in the valence bias task occur on the order of milliseconds (Harp et al., 2023; Neta et al., 2009), whereas the SST provides longer durations (i.e., 10–15 s; Blanco et al., 2021; Kaleta et al., 2023; Wilson et al., 2022). Additionally, the SST may provide greater reappraisal affordances by presenting both the positive and negative words in the scrambled sentences, whereas the valence bias task presents a single stimulus which may be interpreted as either positive or negative (Suri et al., 2018). In other words, whereas the speed of the valence bias task likely constrains opportunities to choose and implement different interpretations, the longer timeframes and more extensive stimulation of the SST may allow the processes underlying trait reappraisal to have a cumulatively larger impact on behavior. This may explain why the correlation with trait reappraisal was much larger in the SST than the valence bias task. Likewise, the longer timeframe may also leave room for processes underlying trait suppression to impact behavior in the SST task in the opposite direction. Future studies are needed to test and extend these ideas, especially given the small number SST studies in the current analysis.

Limitations and Future Directions

There are several limitations worth mentioning. First, the meta-analytic effects seen here are relatively small and associative in nature. The relatively small effect size is likely attributable to additional sources of variability beyond trait reappraisal and expressive suppression use that help to explain one's valence bias. One possibility is that additional components of the affective process, including subjective feelings and physiological reactions, might also contribute to the valence bias. That said, another possibility is that the present findings represent a rather conservative estimate of the true effects, given that there might be considerable differences between the strategies used to regulate one's emotions generally in daily life (i.e., what the ERQ measures) and which strategy is used in the particular context of resolving emotional ambiguity.

Relatedly, the directionality of the effect cannot be inferred from any of the studies, given that all studies only assessed an association between the measures. Thus, individual differences in valence bias could arise, at least in part, from individual differences in trait reappraisal, although it is also possible that a more negative valence bias, for example, constrains reappraisal affordances and results in lower use of reappraisal. There exists some evidence that cueing individuals to use cognitive reappraisal results in a more positive bias (Neta et al., 2023). Future research with experimental designs that permit causal inferences—specifically, randomized controlled trials—will be required to understand the directionality of the effect. Furthermore, researchers could explore additional measures of reappraisal (e.g., reappraisal success) as well as sources beyond, and perhaps interacting with, cognitive reappraisal that further explain variability in valence bias. As research in this area continues to accumulate, the meta-analytic data set should be revisited.

Constraints on Generality

The present findings offer some evidence of generalizability, although more research is needed. The nature of meta-analyses (i.e., pooling data across studies) provides some protection against constrained sampling in a single study, although biases present throughout all included studies would certainly also bias the meta-analytic result. One constraint, for example, is that none of these studies recruited samples of participants with neurological and psychiatric diagnoses, meaning that these findings might not generalize to clinical samples. Additionally, a large majority of participants were white and from the United States, and the operationalization of sex and gender used in these studies is mostly limited to a binary measure, which fails to capture important variation in gender identity across the sample. Furthermore, much of the data was collected by a single research team.

All of that said, there is notable representation of individuals across the adult lifespan (17–89 years of age), including comparable numbers of men and women, and the participants were recruited from various sources, including college students, community members, and online workers. Indeed, collapsing across the included studies, we report on a relatively racially diverse—although predominately white—sample. As such, we expect that these findings largely generalize, although future work assessing racial/ethnic differences in valence bias (e.g., Clinchard et al., in revision), as well as nonbinary or more diverse gender identities, could further uncover boundary conditions on the present effects (i.e., moderating variables).

Regarding methodological generality, it seems that the effects are somewhat sensitive to the method for assessing valence or interpretation bias, in that the effect is stronger for tasks like the SST than the valence bias task. Still, the relationship with cognitive reappraisal was observed across multiple types of emotionally ambiguous stimuli (i.e., faces, scenes, words, and scrambled sentences), underscoring the generalizability of this effect. In other words, these results show that the relationship between trait reappraisal and bias is not limited by the number of tools used to measure it (although the strength of the association may vary), and generally support the notion that the bias is a robust phenomenon that shapes responses to emotional ambiguity across tasks and stimulus types (Harp et al., 2021; Neta et al., 2013).

Conclusion

To summarize, we found support for the hypothesis that the stable and general tendency to respond more negatively or positively to emotional ambiguity is related to individual differences in trait reappraisal use. This work speaks to the importance of cognitive reappraisal as an emotion regulation strategy when faced with ambiguity. Although the meta-analytic effect found for trait reappraisal is relatively small for the valence bias task, we argue that it is nonetheless an important piece of the puzzle in uncovering why some individuals display a more positive valence bias in response to emotional ambiguity. Additionally, our moderation analysis supports the generalizability of our findings regarding trait reappraisal across different kinds of tasks and emotionally ambiguous stimuli (e.g., images vs. series of words) and task parameters (e.g., time constraints). Thus, this work represents an important contribution to our understanding of how characteristic responses to emotional ambiguity (i.e., valence bias) arise, and provides directions forward for further exploring a potential causal role of reappraisal in responses to ambiguity.

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