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Feeling Hangry? When Hunger Is Conceptualized as Emotion

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Many people feel emotional when hungry—or "hangry"—yet little research explores the psychological mechanisms underlying such states. Guided by psychological constructionist and affect misattribution theories, we propose that hunger alone is insufficient for feeling hangry. Rather, we hypothesize that people experience hunger as emotional when they conceptualize their affective state as negative, high arousal emotions specifically in a negative context. Studies 1 and 2 use a cognitive measure (the affect misattribution procedure; Payne, Hall, Cameron, & Bishara, 2010) to demonstrate that hunger shifts affective perceptions in negative but not neutral or positive contexts. Study 3 uses a laboratory-based experiment to demonstrate that hunger causes individuals to experience negative emotions and to negatively judge a researcher, but only when participants are not aware that they are conceptualizing their affective state as emotions. Implications for emotion theory, health, and embodied contributions to perception are discussed.

Keywords: hunger, emotion, embodiment, psychological construction, affect misattribution

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Empirical evidence demonstrates that emotions impact every aspect of our waking lives, from visual perception to decision-making and interpersonal processes (e.g., Balcetis & Dunning, 2006; Barrett & Bar, 2009; Keltner, Ellsworth, & Edwards, 1993; Lerner, Small, & Loewenstein, 2004; Loewenstein, 2000; Van Kleef, 2009). Less research, however, examines the impact of states such as hunger on perceptions, decisions, and interpersonal processes. Yet people appear to be at least implicitly aware of the fact that hunger impacts their emotions—the idea that hunger can impact emotional experiences and behaviors is captured in the colloquial expression *hangry,* defined by the Oxford Dictionary as feeling "bad tempered or irritable as a result of hunger" (Hangry, 2015).

A small body of scientific research affirms that hunger-induced emotionality or feeling "hangry" is more than mere colloquialism. For example, individuals who have not eaten (i.e., in a glucose-depleted state) tend to be more impulsive, punitive, and aggressive (e.g., Anderberg et al., 2016; Benton, 2002; Bushman, Dewall, Pond, & Hanus, 2014; Denson, Pedersen, Friese, Hahm, & Roberts, 2011; Symmonds, Emmanuel, Drew, Batterham, & Dolan, 2010; Williams, Pizarro, Ariely, & Weinberg, 2016). Other literature links hunger to negative mood (e.g., Hepburn, Deary, & Frier, 1992, 1994; Hermanns, Kubiak, Kulzer, & Haak, 2003, Hermanns et al., 2007; Taylor & Rachman, 1988). Yet the psychological mechanisms by which people become emotional when hungry, or "hangry," remain little understood. The purpose of the present studies is to begin to identify the psychological mechanisms of hunger-induced emotional states.

Potential Mechanisms of Hunger's Impact on Emotions, Judgments, and Behavior

One common assumption, both in folk and experimental psychology, is that hunger impacts emotions, judgments, and behaviors because it impairs self-regulation. In this view, hunger releases the constraints that typically keep people from feeling unbridled emotions, making impulsive judgments, or aggressing against others (e.g., Bushman et al., 2014; DeWall, Deckman, Gailliot, & Bushman, 2011; DeWall, Pond, & Bushman, 2010). Until recently, much research on self-regulation was guided by the "regulation as muscle" analogy, which hypothesizes that self-control fails when biological resources such as glucose are depleted (Baumeister, 2003, 2014; Gailliot & Baumeister, 2007; Gailliot et al., 2007; Muraven & Baumeister, 2000; Vohs et al., 2014).

This *regulatory depletion hypothesis* was first inspired by work demonstrating that mental effort can deplete blood glucose (Fairclough & Houston, 2004; Hall & Brown, 1979). Thus, it is assumed that negative, high arousal emotions or outbursts of aggression when hungry occur because individuals cannot regulate their feelings without sufficient blood glucose (e.g., DeWall et al., 2011). However, the regulatory depletion hypothesis has been critiqued in recent years following failed replications and mixed findings (e.g., Carter, Kofler, Forster, & McCullough, 2015; Job, Walton, Bernecker, & Dweck, 2013; Kurzban, 2010; Miles et al., 2016; Vadillo, Gold, & Osman, 2016; see review in Inzlicht, Schmeichel, & Macrae, 2014). Moreover, the underlying biological premise may be unfounded, as it is unlikely that short-term shifts in cognitive exertion alter blood glucose levels substantially

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in the central nervous system (e.g., Coker & Kjaer, 2005; Peters et al., 2004).

An alternate hypothesis is that feeling "hangry" is *psychologically constructed* (Lindquist & Barrett, 2008). Psychological constructionist theories propose that all mental events, including emotions, arise from the dynamic co-action of domain-general psychological processes. Specifically, instances of emotion and other mental events occur when the brain uses prior experiences and category knowledge to conceptualize or predict the meaning of affective representations from the body (i.e., "core affect" ranging from pleasantness-unpleasantness and activated-deactivated sensations, e.g., Barrett, 2017; Clore & Ortony, 2013; Cunningham, Dunfeld, & Stillman, 2013; Lindquist, 2013; Russell, 2003; Shaked & Clore, 2017). Research testing a psychological constructionist hypothesis tends to focus on shifts in affect caused by external factors (e.g., a situational event), yet ongoing changes in the body related to maintaining allostasis (i.e., homeostatic processes such as blood sugar, inflammation, etc.) also shift affect and have consequences for downstream experiences, judgments, and behaviors (MacCormack & Lindquist, 2017).

Indeed, the physiology underlying hunger is consistent with the idea that hunger impacts core affect. For instance, when blood sugar drops, *ghrelin,* the metabolic hormone that signals hunger, triggers a cascade of hormones, such as cortisol, that act on the sympathetic nervous system, in turn inducing unpleasant, highly arousing affective bodily changes (Christensen, Alberti, & Brandsborg, 1975; Corrall, Frier, Davidson, Hopkins, & French, 1983; Cryer, 1999; Heller, Macdonald, Herbert, & Tattersall, 1987; Marks & Rose, 1981). Moreover, brain regions such as the anterior cingulate cortex, insula, and amygdala show increased activation during hunger (Chen, Papies, & Barsalou, 2016; Dagher, 2009; Porubská et al., 2006; Tataranni et al., 1999) but also are more generally activated during affect and emotion (e.g., Lindquist, Satpute, Wager, Weber, & Barrett, 2016; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012). These findings suggest that there may be similar neural processes involved in these two seemingly distinct states, at least at the level of gross anatomical brain activity.

Building on psychological constructionist theory and the aforementioned physiological findings, we hypothesize that people experience instances of greater emotionality when hunger-induced affect is conceptualized as emotions in a given context (e.g., a negative situation). In this case, hungry people would be more likely to experience negative, high arousal emotions and engage in more antisocial interpersonal behaviors than they otherwise might when satiated in the same context. Notably, despite the colloquial implication that "hanger" is about anger specifically, we do not expect these effects to be unique to anger; rather we expect that hungry individuals can construct any negative, high arousal emotional state, such as feeling irritable, stressed, and so forth, depending on how the context guides such conceptualizations for that individual.

The Construction of Hunger Into Emotion

A rich theoretical history in psychology supports the psychological constructionist hypothesis that people experience emotions when they make bodily changes meaningful in the present context. Schachter and Singer (1962) classically demonstrated that individuals are more likely to engage in affiliative behavior when given a shot of epinephrine in the presence of a jovial as opposed to angry stranger. Zillmann (1971) demonstrated that experimentally inducing higher levels of physiological arousal through exposure to sexual stimuli or exercise increased aggressive behavior. Dutton and Aron (1974) found that male participants were more likely to experience physical attraction when they encountered an attractive female as opposed to male research assistant after crossing a rickety, arousal-inducing suspension bridge versus a low, stable bridge. Schwarz and Clore (1983) found that transient external conditions (such as bad weather) shifted individuals' affective states and influenced subsequent judgments of life satisfaction—but only when individuals were unaware of the source of their affective feelings.

The above literature highlights the power of context, but also awareness of one's state (or lack thereof) in the construction of emotions from bodily states such as physiological arousal. Psychological constructionist approaches do not presume that individuals have conscious access to the brain's construction of mental experience (e.g., Barrett, 2017; Barrett, Ochsner, & Gross, 2007). However, what an individual attends to in a given context could play a powerful role in shifting and updating the brain's current predictions about the meaning of incoming stimuli. As such, we hypothesized that instances in which people "misattribute" the meaning of their affective state to a different source is a subset of psychologically constructed phenomena and that in the case of feeling "hangry," people draw on the external situation to make meaning of their hunger-induced affect to construct a variety of negative emotion instances. We reasoned that as in misattribution theory, hunger-induced negative, high arousal emotions might be all the more likely to occur when people's attention is directed *away* from emotions and focused instead on the external circumstance (e.g., the person who just insulted me; the traffic jam, etc.). Across three studies, we test the hypothesis that "hanger," in the form of negative, highly aroused emotions, is constructed when people make meaning of their hunger-induced affect as the experience of negative emotions.

The Present Studies[1]

Studies 1 and 2 used a cognitive tool called the affect misattribution procedure (AMP; Payne, Cheng, Govorun, & Stewart, 2005; Payne et al., 2010) to establish whether hunger increases individuals' tendency to judge an ambiguous stimulus as negative when that stimulus was experienced in a negative context. Study 1 tested this hypothesis by manipulating negative versus neutral contexts before participants judged the meaning of ambiguous stimuli, whereas Study 2 further manipulated positive versus negative versus neutral contexts to demonstrate that hunger's impact on judgments of ambiguous stimuli is specific to negative contexts, but not positive or neutral contexts.

Study 3 extended Studies 1–2 in several ways. First, it was a laboratory-based experiment that directly assessed how hunger influences self-reported emotions and interpersonal judgments.

[1] All studies were approved by the University of North Carolina at Chapel Hill Institutional Review Board and were conducted in accordance with APA ethical conduct of research with human subjects (IRB#s 13–3050 and 15–3169).

Study 3 also manipulated hunger versus satiation to better assess the causal effect of hunger. Drawing from the affect misattribution literature, Study 3 further manipulated emotional awareness. We hypothesized that hungry individuals who were unaware of making meaning of their affective state as emotional would be more likely to experience "hanger" than individuals who were hungry and aware of making meaning of their affective state as emotional or any individuals who were satiated. In particular, we predicted that individuals who were hungry and *unaware* of making meaning of their state as emotional would be the most likely to report unpleasant, highly aroused emotions and harsher interpersonal judgments in a negative context.

Importantly, we did not expect participants to exclusively endorse feeling "anger" because negative situations can cause all manner of unpleasant emotions depending on how individuals make meaning of the context (Ellsworth & Scherer, 2003; Kirkland & Cunningham, 2012; Lindquist & Barrett, 2008). Furthermore, from a psychometric standpoint, people rarely report experiencing just one negative emotion when given multiple options. Instead many individuals endorse multiple negative emotion adjectives, thus communicating what those adjectives share in common (i.e., that they feel generally negative; Barrett & Fossum, 2001; Feldman, 1995). Thus, although the colloquial word "hanger" implies that people feel specifically angry when hungry, we expected people to report multiple negative, high arousal emotions as a result of hunger. No previous literature has examined hunger's relation to discrete emotions above and beyond general unpleasantness, so this provided a first study to identify which emotions people are more likely to report when experiencing hunger in a negative social context.

Finally, Study 3 supported a psychological constructionist theory of hunger's impact on emotions and interpersonal behaviors by ruling out the alternate hypothesis that hunger leads to emotion merely via depleted self-control (e.g., Bushman et al., 2014; DeWall et al., 2011).

Study 1

In Study 1, we first sought to establish that hungrier people would perceive ambiguous stimuli as more negative, but only when those stimuli were perceived in a negative context. Hunger induces negative, high arousal affect (e.g., Cryer, 1999), but we hypothesized that people's degree of hunger would only influence their perceptions of ambiguous stimuli when their negative, high arousal affect could be made meaningful in the presence of an affect-congruent (i.e., negative) context.

To test these hypotheses, we used the AMP (Payne et al., 2005, 2010). The AMP is a cognitive tool that is commonly used to measure implicit attitudes (e.g., pleasant and unpleasant reactions to stimuli; see Payne & Lundberg, 2014). The AMP achieves this goal by assessing the extent to which a person misattributes the meaning of an initial stimulus (e.g., an unpleasant picture; a picture of an opposite-race face) to an ambiguous Chinese pictograph that does not itself have meaning to the participant. In this context, the AMP is useful for examining the psychological processes underlying "hanger" because it measures the implicit process whereby an individual perceives the affect induced by one source (hunger interacting with the context of the affective picture) as caused by another (an ambiguous Chinese pictograph). The extent to which participants rate the ambiguous Chinese pictographs as more negative or positive following a negative or positive image is thus an index of their degree of affect misattribution. In Study 1, we hypothesized that hunger would interact with negative images, such that participants who were hungrier would experience the ambiguous pictographs as even more negative when preceded by a negative, but not neutral context.

Method

Participants. Two-hundred and 50 Mechanical Turk workers from the United States participated in the study for monetary compensation. As the AMP uses Chinese pictographs for ambiguous stimuli, four participants were excluded from analyses because they reported either a familiarity or fluency with Mandarin Chinese. Twenty-five participants failed attention checks and were excluded from subsequent analyses; another three participants had computer issues (e.g., the task froze) and were unable to complete the study, leading to a final sample of 218 participants (46% female; $M_{age} = 35$, $SD_{\mathrm{age}} = 10.41$, 18- to 71-years-old). The sample size was determined ahead of time based on an a priori power analysis and data were not analyzed until data collection was complete.

Although no prior work has examined the interaction of hunger with context using implicit cognitive tasks such as the AMP, we estimated that there would be moderate-to-small effect sizes for our main effects (e.g., $\beta = .3$) and interactions (e.g., $\beta = .15$), as observed in Payne et al. (2010) and Lee, Lindquist, and Payne (2017). Given the hierarchical, partially within-subjects nature of the study design, we planned a priori to use multilevel modeling. Power analyses for multilevel modeling are based on power simulations, which suggest that with a Level 1 sample (trials) greater than 30 nested within a Level 2 sample (participants) greater than 40, we would have 90% power to observe an effect ($p < .05$–.01; see simulations in Scherbaum & Ferreter, 2009). As we were not manipulating hunger, and we expected data loss due to the online sample we used (Thomas & Clifford, 2017), we aimed for well above this sample size including Level 1 $n = 40$ trials, Level 2 $n = 250$ participants.

Procedure. After consent, participants were oriented to the AMP in Qualtrics. Study 1 used a mixed model design, with the negative or neutral affective context preceding a Chinese pictograph as the within-subjects factor and self-reported hunger as the continuous between-subjects factor. On all trials, participants first saw a "context" image followed by an ambiguous Chinese pictograph. As is typical of the AMP, participants were instructed that they would see affective images before each Chinese pictograph, and that they should try their best to ignore the affective image, instead focusing on their judgment of the pictograph. The manipulated context in Study 1 was a negative, highly arousing versus neutral context.

The AMP was implemented in Qualtrics using the QRTEngine (Barnhoorn, Haasnoot, Bocanegra, & van Steenbergen, 2015). All participants first completed a practice block of eight trials before proceeding to the 40 experimental trials. Trials were presented in counterbalanced blocks based on image type. For each AMP trial (see Figure 1), participants saw a fixation cross on the center of the screen for 125 ms, then the negative versus neutral image for 75 ms, followed by a gray visual noise mask for 125 ms and the

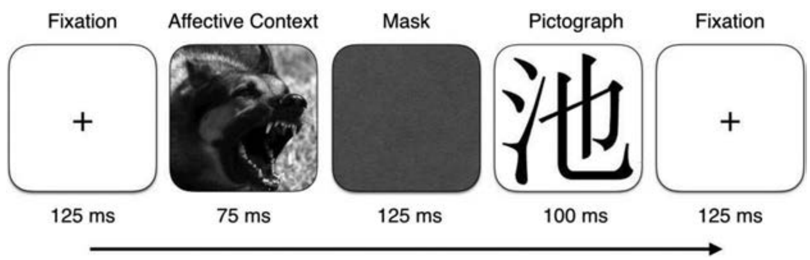

Figure 1. The affect misattribution procedure. An example trial from the affect misattribution procedure, adapted from Payne et al. (2005, 2010). After each trial, participants rated the Chinese pictograph on a bipolar scale (1 = *extremely pleasant,* 4 = *neither pleasant nor unpleasant,* 7 = *extremely pleasant*). Pictograph presented here is from the AMP task as validated in Payne et al. (2005).

randomly assigned pictograph for 100 ms. Participants then saw another fixation cross prior to rating how pleasant versus unpleasant they found the pictograph to be. Immediately after the AMP procedure, participants rated their engagement and attention during the AMP. Participants then reported how hungry they felt *during* the task. The study ended with demographics and debriefing.

Materials.

Affective images. Participants saw a total of 24 neutral and 24 negative images selected from the International Affective Picture System to serve as the affective context (IAPS; Lang, Bradley, & Cuthbert, 2008). In the IAPS valence scale, negative images range from 1–4, neutral images from 4–6, and positive images from 6–9. Based on IAPS norms, we selected images that fell in the middle of each range for the negative and neutral images. These excluded highly graphic negative images, which tend to be extreme in valence and likely to elicit ceiling effects. The negative images we chose ranged from 2.5–3.5, $M_{valence} = 3.17$ ($SD = .50$); $M_{arousal} = 5.37$ ($SD = .50$), and neutral images ranged from 4.5–5.5, $M_{valence} = 4.78$ ($SD = .17$); $M_{arousal} = 2.99$ ($SD = .70$).

Chinese pictographs. Pictographs were randomly chosen from the standard, previously validated AMP pictograph set (Payne et al., 2010) and randomly assigned for pairing with the affective contexts. Participants rated each pictograph on a bipolar Likert scale from 1 = *extremely pleasant* to 4 = *neither pleasant nor unpleasant* to 7 = *extremely unpleasant* ($M = 4.05$, $SD = 1.37$). Participants' trial-by-trial ratings of the ambiguous pictograph targets were our dependent measures.

Self-reported engagement. All participants responded to six questions assessing how engaged they were in the task, how easy it was to focus and stay on task, and how successful they thought they were at ignoring the affective primes using a Likert scale from 1 to 5 (1 = *strongly disagree*, 5 = *strongly agree*). A mean score was created from these six items ($M = 4.42$, $SD = .53$, range 2.83–5.00, $\alpha = .75$).

Self-reported hunger. Participants reported their degree of hunger by responding to "How hungry were you *during the rating task?*" on a Likert scale from 1 to 6 (1 = *not at all hungry*, 4 = *somewhat hungry*, 6 = *extremely hungry*; range 1–5; $M = 2.15$; $SD = 1.32$).

Analyses. Inspection of all variable histograms and scatterplots revealed no statistical outliers (greater than two standard deviations from the mean). As per Bulmer (1979), where skewness between −1 to −.50 and .50 to 1 indicates moderate skew, ratings for self-reported hunger exhibited moderate skew (.71, $SE = .17$) such that a greater proportion of participants in our sample reported that they were not hungry to moderately hungry as compared with highly hungry. However, reports did not demonstrate extreme skew and so we did not transform the distribution.

Due to the nested nature of the data, multilevel modeling with a random intercept (Raudenbush & Bryk, 2001) was used to analyze the data in SPSS. Context type (negative vs. neutral) was dummy-coded and served as the predictor of participants' pictograph ratings at Level 1. Participants' self-reported hunger ratings were the predictor at Level 2, and we examined the cross-level interaction between context and hunger. For each analysis in the study, we ran two models as part of standard model-building practices where Model 1 is a random effects ANOVA with no predictors to demonstrate the degree of dependence in the data. Model 1 for Study 1 is presented in Table 1, but is not discussed further. After examining the degree of dependency between and within participants' pictograph ratings, we used a random intercepts model to examine the cross-level interaction between context at Level 1 and hunger at Level 2. Standardized betas (β) are presented throughout (calculated as per Cohen, Cohen, West, & Aiken, 2003) as these allow for effect size comparison, but see Table 1 for unstandardized betas.

Results

As predicted, there was a significant effect of *context,* $\beta = .26$, $p < .0001$, 95% CIs [.23, .49], such that there was an estimated .26 unit increase in participants' pictograph ratings on negative context trials compared to neutral context trials (see Table 1). However, hunger alone did not increase participants' negative ratings of the pictographs. There was no significant main effect of *hunger*, $\beta = -.02$, $p = .403$, 95% CIs [−.10, .04]. Instead, as predicted, a Context × Hunger interaction, $\beta = .06$, $p = .014$, 95% CIs [.01, .11] revealed that hungrier individuals only experienced ambiguous pictographs as more negative in the context of a preceding negative image (see Figure 2). A follow-up probe of the interaction (see Table 2) indicated that hunger's effect in negative trials was significantly different than neutral trials.

Self-reported *mean engagement* was negatively correlated with *hunger*, $r = -.211$, $p = .002$ such that the hungrier individuals were, the more likely they were to report feeling like they struggled to concentrate on the task. This finding may reflect hunger's impact on perceptions of subjective negative affect (i.e., feelings of

Table 1
Study 1 Models for Hunger × Context Effects on Pictograph Ratings

Effects	*b*	β	*SE*	*t*	95% CI Lower	95% CI Upper
Model 1						
Fixed effects						
Intercept	4.051	—	.044	91.945***	3.964	4.138
Random effects						
Residual variance (σ^2)	2.663	—	.040	—	2.584	2.744
Random intercept variance (τ^{00})	.356	—	.040	—	.285	.445
Model 2						
Fixed effects						
Intercept	3.866	—	.090	42.639***	3.687	4.044
Context	.362	.264	.066	5.462***	.232	.492
Hunger	−.030	−.028	.036	−.838	−.101	.040
Context × Hunger	.064	.061	.026	2.463*	.013	.116
Random effects						
Residual variance (σ^2)	2.597	—	.039	—	2.520	2.676
Random intercept variance (τ^{00})	.358	—	.040	—	.286	.447
Model 3						
Fixed effects						
Intercept	4.300	—	.400	10.737***	3.511	5.090
Context	.362	.264	.066	5.459***	.232	.492
Hunger	−.038	−.036	.036	−1.042	−.110	.034
Engagement	−.094	−.036	.084	−1.113	−.261	.072
Context × Hunger	.064	.061	.026	2.465*	.013	.116
Random effects						
Residual variance (σ^2)	2.597	—	.039	—	2.520	2.676
Random intercept variance (τ^{00})	.357	—	.040	—	.286	.447

* $p < .05$. *** $p < .001$.

struggle). Nonetheless, when adding in *mean engagement* as a covariate (Model 3 in Table 1), the results from Model 2 still hold and there is no significant effect of *mean engagement* on pictograph ratings.

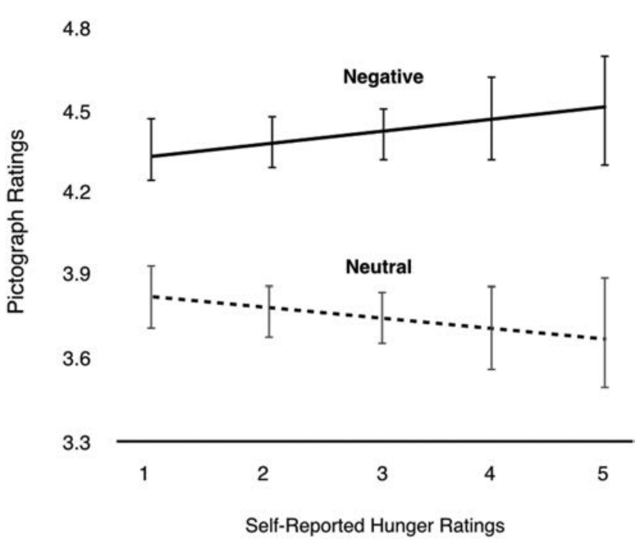

Figure 2. Study 1 Hunger × Context interaction. Participants who self-reported as being hungrier were more likely to rate an ambiguous pictograph as unpleasant in negative versus neutral contexts. Although the Likert scale anchors ranged from 1 = *not at all hungry* to 6 = *extremely hungry*, actual responses ranged from 1–5, as represented in this graph. Error bars computed +/− 1 *SE*.

Discussion

In Study 1, we found that the hungrier an individual reported feeling, the more likely they were to rate ambiguous pictographs as negative in the presence of a negative, but not a neutral context. These findings suggest that people may use the affect engendered by hunger (vs. satiation) as evidence that stimuli are negative when the context elicits such conceptualizations. According to some psychological models, judging a stimulus as negative (i.e., a "perception" or an "attitude") is a different psychological state from feeling unpleasant. However, a constructionist approach assumes that affect and conceptualization are ingredients in many different mental states (Cunningham et al., 2013; Lindquist, 2013; Lindquist & Barrett, 2012); whether affect is attributed to an external stimulus (e.g., an attitude about a pictograph) or one's own body (e.g.,

Table 2
Studies 1 and 2 Simple Slopes Tests for Model 2 With Neutral Context as the Reference Category

Effects	Estimate (*SE*)	*t*	*p*
Study 1			
Intercept	4.23 (.091)	46.54	<.0001
Slope	.03 (.036)	.96	.337
Study 2			
Negative context			
Intercept	4.23 (.099)	42.63	<.0001
Slope	.11 (.036)	3.09	.002
Positive context			
Intercept	3.27 (.099)	32.93	<.0001
Slope	.01 (.036)	.23	.821

a feeling of unpleasantness) depends on the focus of attention in that context (Lee, Lindquist, & Payne, 2017; Lindquist & Barrett, 2008). As we predicted, hunger does not automatically create more negative affect in *any* context because hungry individuals did not rate Chinese pictographs preceded by neutral images as more negative.

As Study 1 is the first to demonstrate that hungry individuals conceptualize their affect as negative feelings (i.e., negative judgments of ambiguous stimuli) in the presence of a negative context, we sought to replicate and extend this effect. Study 1 cannot rule out the role of arousal in driving the findings, as the negative images significantly differed from the neutral images in both valence and arousal dimensions. Thus, it remains unclear whether hunger would also interact with highly arousing positive contexts, such that individuals would rate ambiguous pictographs as more pleasant when feeling hungry following a pleasant context. However, given the literature suggesting that hunger results in unpleasant, high arousal affect (e.g., Cryer, 1999), we did not predict positive contexts to interact with hunger to shift affective perceptions; a positive context would be incongruent with participants' hunger-induced affective state and they would thus be less likely to make meaning of their state as being emotional in these contexts. We thus conducted Study 2 to clarify the specificity of our hunger effect.

Study 2

Although Study 1 provides initial evidence that hunger can be conceptualized as negative judgments of ambiguous stimuli when made meaningful in negative contexts, it could not rule out that hunger is conceptualized as "hanger" in *any* high arousal context. Study 2 thus built upon and extended Study 1 to rule out the possibility that any high arousal context (negative or positive) would allow participants to make meaning of their hunger as affective feelings. Like Study 1, Study 2 employed the AMP but this time included negative, positive, and neutral images as context. Based on evidence that hunger is associated with self-reported unpleasant affect (e.g., Cryer, 1999), we predicted that hunger would impact affective judgments of ambiguous Chinese pictographs in the presence of negative, but not positive or neutral contexts.

Method

Participants. One-hundred and 92 Mechanical Turk workers from the United States participated for monetary compensation. As in Study 1, five participants were excluded from analyses because they reported familiarity or fluency with Mandarin Chinese. Additionally, 18 participants were excluded from final analyses because they were not blind to the purpose of the AMP (e.g., one participant reported that it "tests my automatic affective biases") and 29 participants were excluded due to failed attention checks. Thus, the final sample was 140 participants (46.4% female; M_{age} = 35 years, SD_{age} = 10.54 years, 20- to 62-years-old). As in Study 1, the sample size was determined ahead of time based on an a priori power analysis and data were not analyzed until data collection was complete.

Using Study 1 as a guide, we estimated that there would be moderate-to-small effect sizes for our main effects (e.g., context was $\beta = .26$; hunger was $\beta = .04$) and small effect size for interactions (e.g., Context $\times$ Hunger $\beta = .06$). Additionally, prior simulation studies (Scherbaum & Ferreter, 2009) suggest that with a Level 1 sample (trials) greater than 30 nested within a Level 2 sample (participants) greater than 40, we would have 90% power to observe an effect ($p < .05$–.01). However, as we were not manipulating hunger, and anticipating data loss due to our MTurk sample, we aimed well above this sample size including Level 1 n = 60 trials, Level 2 n = 192 participants. We arrived at this number of participants because we had allotted a set amount of funds to the study, which resulted in 192 participants. Given that this sample size would give us ample power, we collected data until it was met.

Procedure. Study 2 exactly replicated Study 1 in using the Qualtrics QRTEngine except for the addition of positive trials. All participants first completed a practice block of 12 trials before completing 60 experimental trials. Trials were presented in counterbalanced blocks based on image type. After completing the AMP, just as in Study 1, participants rated their engagement and attention during the AMP. Participants then reported how hungry they felt *during* the task. The study ended with demographics and debriefing.

Materials.

Affective images. Participants saw a total of 24 neutral, 24 negative, and 24 positive images selected from the International Affective Picture System to serve as the affective context (IAPS; Lang et al., 2008). We used the same negative and neutral images from Study 1, but chose additional positive images that ranged from 6.5–7.5, $M_{valence}$ = 6.93 (SD = .33); $M_{arousal}$ = 5.28 (SD = .48). It was impossible to match neutral images on arousal with negative images, $t(38) = 12.24$, $p < .0001$, 95% CIs [1.98, 2.77] or positive images, $t(38) = 11.98$, $p < .0001$, 95% CIs [1.90, 2.68], but negative and positive images were chosen so they did not significantly differ in terms of arousal, $t(38) = .52$, $p > .250$, 95% CIs [−.23, .39].

Chinese pictographs. Pictographs were randomly chosen from the standard, previously validated AMP pictograph set (Payne et al., 2010) and randomly assigned for pairing with the affective contexts. As in Study 1, participants rated each pictograph on a bipolar Likert scale from 1 = *extremely pleasant* to 4 = *neither pleasant nor unpleasant* to 7 = *extremely unpleasant* (M = 3.80, SD = 1.83). Participants' trial-by-trial ratings of the ambiguous pictograph targets were our dependent measures.

Self-reported engagement. All participants responded to six questions assessing how engaged they were in the task, how easy it was to focus and stay on task, and how successful they thought they were at ignoring the affective primes using a Likert scale from 1 to 5 (1 = *strongly disagree*, 5 = *strongly agree*). A mean score was created from these six items (M = 4.49, SD = .50, range 2.80–5.00, $\alpha = .70$).

Self-reported hunger. Participants reported their degree of hunger by responding to "How hungry were you *during the rating task?*" on a Likert scale from 1 to 6 (1 = *not at all hungry*, 4 = *somewhat hungry*, 6 = *extremely hungry*; range 1–5; M = 2.34; SD = 1.40).

Analyses. Again, as in Study 1, inspection of all variable histograms and scatterplots revealed no statistical outliers (greater than two standard deviations from the mean). As per Bulmer (1979), where skew between −.50 and .50 is slightly or approximately skewed, ratings for self-reported hunger exhibited slight skew (.45, SE = .21). Again, a greater proportion of participants in our sample reported that they were not hungry to moderately hungry as compared with highly hungry. We used multilevel modeling with a random intercept, with dummy-coded context (negative vs. neutral; positive vs. neutral) variables as predictors at Level 1 and participants' self-reported hunger as a predictor at Level 2. We also examined the predicted cross-level interaction between context and hunger. As part of model-building, Model 1 was a random effects ANOVA with no predictors to examine dependence in the data. Model 1 for Study 2 is presented in Table 3 but not discussed further. In Model 2, we used a random intercepts model to examine the cross-level interaction between context and hunger. Standardized betas are presented throughout as these allow for effect size comparison, but see Table 3 for unstandardized betas.

Results

Replicating Study 1, the context influenced participants' ratings of ambiguous pictographs. Similar to Study 1, there was an estimated .36 unit increase in participants' pictograph ratings in *negative contexts* as compared to neutral contexts $\beta = .36$, $p < .0001$, 95% CIs [.51, .83] (see Table 3). Consistent with the broader AMP literature, there was also an estimated .16 unit decrease in participants' pictograph ratings following *positive contexts*, indicating that pictographs were rated more pleasantly on positive compared to neutral contexts, $\beta = -.16$, $p < .0001$, 95% CIs [−.45, −.13]. Critically, as in Study 1 there was no significant main effect for *hunger*, $\beta = .03$, $p = .165$, 95% CIs [−.01, .115], suggesting once again that hunger on its own does not appear to drive affective perceptions of the pictographs. Critical to our hypothesis and replicating Study 1, there was only a significant Negative Context × Hunger interaction, $\beta = .04$, $p = .031$, 95% CIs [.01, .12] (see Figure 3). A follow-up probe of the interaction found that negative pictograph ratings were greater for hungry individuals in the context of negative images, but not positive or neutral images (see Table 2). Additionally, there was no significant interaction for Positive Context × Hunger, $\beta = -.02$, $p = .186$, 95% CIs [−.09, .01].

As in Study 1, individuals' self-reported *Mean Engagement* was again negatively correlated with *hunger*, $r = -.211$, $p = .002$. However, when adding in *mean engagement* as a covariate (Model 3 in Table 3), the results from Model 2 still held with no significant effect of *mean engagement* on pictograph ratings.

Discussion

Study 2 not only replicated the findings from Study 1, but also ruled out that the effects of Study 1 were general to *any* highly arousing context. Instead, our findings suggest that a negative context may be key for transforming hunger into feeling negative, high arousal emotions or colloquially, "hanger." The unpleasant, highly aroused affective feelings engendered by hunger appear to be attributed to ambiguous Chinese pictographs only when the context is congruent with the hedonic tone of those feelings. These

Table 3
Study 2 Models for Hunger × Context Effects on Pictograph Ratings

Effects	b	β	SE	t	95% CI Lower	95% CI Upper
Model 1						
Fixed effects						
Intercept	3.805	—	.044	86.841***	3.718	3.891
Random effects						
Residual variance (σ^2)	3.139	—	.046	—	3.050	3.229
Random intercept variance (τ^{00})	.225	—	.032	—	.169	.298
Model 2						
Fixed effects						
Intercept	3.565	—	.094	38.094***	3.380	3.749
Negative context	.670	.366	.082	8.210***	.510	.830
Positive context	−.293	−.160	.082	−3.595***	−.453	−.133
Hunger	.048	.036	.034	1.395	−.019	.115
Negative Context × Hunger	.064	.048	.030	2.158*	.006	.122
Positive Context × Hunger	−.039	−.029	.030	−1.323	−.097	.019
Random effects						
Residual variance (σ^2)	2.907	—	.042	—	2.826	2.992
Random intercept variance (τ^{00})	.224	—	.032	—	.169	.296
Model 3						
Fixed effects						
Intercept	3.582	—	.477	7.504***	2.638	4.526
Negative context	.670	.366	.082	8.210***	.510	.830
Positive context	−.293	−.160	.082	−3.595	−.453	−.133
Hunger	.047	.035	.035	1.360	−.021	.116
Engagement	−.004	−.001	.099	−.036	−.199	.192
Negative Context × Hunger	.064	.048	.030	2.158*	.006	.122
Positive Context × Hunger	−.039	−.029	.030	−1.323	−.097	.019
Random effects						
Residual variance (σ^2)	2.907	—	.042	—	2.826	2.992
Random intercept variance (τ^{00})	.226	—	.032	—	.170	.299

* $p < .05$. *** $p < .001$.

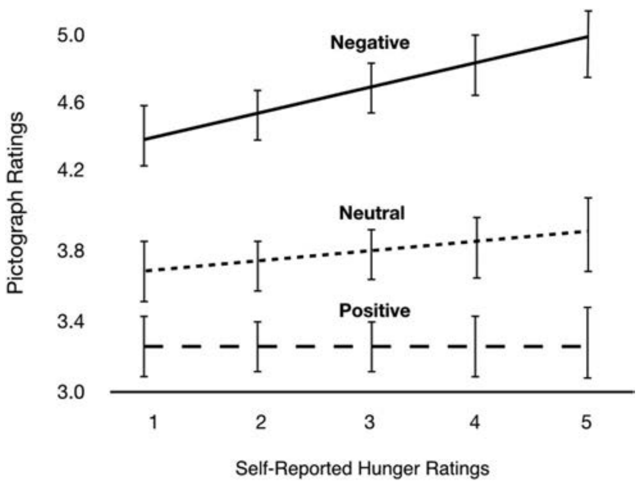

Figure 3. Study 2 Hunger × Context interactions. Participants who self-reported as being hungrier were more likely to rate an ambiguous pictograph as unpleasant in negative versus positive and neutral contexts. Although the Likert scale anchors ranged from 1 = *not at all hungry* to 6 = *extremely hungry,* actual responses ranged from 1–5, as represented in this graph. Error bars computed +/− 1 *SE*.

findings thus provide important boundary conditions for the experience of "hanger."

Despite providing preliminary evidence that hunger can become conceptualized as emotional in nature, Studies 1 and 2 had several limitations. First, both studies measured rather than manipulated hunger. Second, they used a cognitive paradigm that may lack ecological validity. Third, we took for granted the fact that individuals would misattribute their hunger-induced affect based on the design of the AMP, but we did not explicitly manipulate the likelihood of such misattributions. Fourth, Studies 1 and 2 examined how conceptualizations of hunger as emotion might result in negative judgments of stimuli, but did not examine how conceptualizations of hunger as emotion resulted in emotional experiences (e.g., the self-reported experience of specific unpleasant emotions). Finally, an alternate hypothesis is that hungry participants in Studies 1–2 merely lacked the self-regulation to inhibit more negative ratings of the Chinese pictographs. This interpretation is less likely given that we did not observe a main effect of hunger on pictograph ratings, but given the literature linking glucose to self-control failures (e.g., Gailliot et al., 2007) and hypothesizing the effect of hunger on self-control in aggression (Bushman et al., 2014), we sought to rule out this alternate hypothesis in Study 3.

Study 3

Study 3 was a laboratory experiment designed to address the additional questions raised by the findings of Studies 1–2. Study 3 builds upon Studies 1–2 in four ways. First, we experimentally manipulated hunger versus satiation. Second, our paradigm involved social interactions and a real negative context to increase the ecological validity of our findings. Third, we manipulated the likelihood that participants would misattribute their hunger-induced affect to the situation. Following research on affect misattribution (Schwarz & Clore, 1983), we hypothesized that making participants relatively more aware of their emotional conceptualizations would reduce their tendency to conceptualize hunger as "hanger." Drawing on the affect-labeling literature (e.g., Kassam & Mendes, 2013; Lieberman et al., 2007; Niles, Craske, Lieberman, & Hur, 2015), we did so by asking participants to write about emotion concepts ("anger," "sadness") in some conditions, or asking them to write about neutral, nonemotional information in another condition. Fourth, Study 3 measured the impact of hunger on self-reported emotional experiences and interpersonal judgments. Finally, to rule out other mechanisms for our findings, Study 3 addressed the alternate hypothesis that regulatory depletion primarily drives "hanger" by assessing whether hungry people exhibited less self-regulation than satiated people. Self-regulation was assessed as the length of time participants persevered on a tedious mental rotation task (Shepard & Metzler, 1971; Williams & DeSteno, 2008).

Method

Participants. Two-hundred and 36 PSYC101 students (58% female; M_{Age} = 19 years old, SD_{Age} = 2.48, 17- to 45-years-old) were recruited from the University of North Carolina at Chapel Hill study pool and participated in the laboratory experiment for research credit. Based on the small to medium effect size for main effects and interactions observed in Lindquist and Barrett (2008) which similarly manipulated affect and attention to emotion, power analyses in GPower (Faul, Erdfelder, Lang, & Buchner, 2007) suggested that we would have 80% power to observe a significant interaction effect ($p < .05$–.01) with 180 participants and 90% power with 230 participants. We aimed to collect 240 participants ($n = 40$ per condition) but stopped short by four participants due to the end of the semester. No data were analyzed until after data collection finished.

Procedure. Upon signing up for the experiment, participants were prescreened so that any individuals who were unable or unwilling to change their normal eating schedule prior to lab arrival were excluded. We also explicitly excluded participants who might be adversely impacted by our manipulations (i.e., with diabetes, eating disorders, or mood disorders). After prescreening, participants were randomly assigned to a condition in a 2 (Body State: Hungry vs. Satiated) × 3 (Attentional Focus: Anger-Focused vs. Sadness-Focused vs. No Emotion-Focused) between-subjects design. Participants in the hunger condition fasted for 5 or more hours prior to the lab visit and participants in the satiated condition ate a full meal or large snack less than one hour prior to lab visit. As a cover story, participants were told that the study was about "visual performance" and that they needed to fast versus eat prior to arrival so that we could control for the impact of glucose on visual performance. Refer to Figure 4 for study timeline.

Fasting manipulation check. Upon arrival, participants completed informed consent and a "Food Questionnaire" which ensured that they had actually fasted or eaten as instructed. The questionnaire consisted of three items indexing when the participant last ate or drank something other than water (Likert scale ranging from 1 = *less than 1 hr ago*, 7 = *more than 6 hr ago*), how hungry the participant felt (Likert scale ranging from 1 = *not at all hungry*, 7 = *extremely hungry*), and what type of meal they had last eaten (a full meal, moderate snack, small snack, or caloric beverage such as a protein shake, coffee, juice, soda, etc.). After

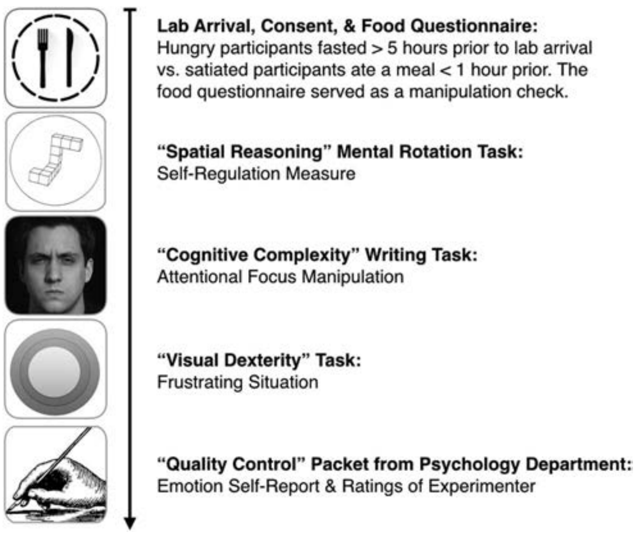

Figure 4. Study 3 procedural order across participants. Names of tasks as told to participants are in quotes, as part of our cover story that this was a visual perception study. Geometric shape presented here is from Shepard and Metzler's (1971) mental rotation task. Facial image presented is from the IASLab Set (Gendron, Lindquist, & Barrett, 2011).

completing the questionnaire, the experimenter checked that the assigned hungry versus satiated condition had been met. Participants in the hunger condition who had eaten less than 5 hr prior to arrival or participants in the satiation condition who had eaten more than 1 hr prior to arrival and had not eaten a full meal or moderate snack were rescheduled and reinstructed according to their assigned condition.

Measure of self-regulation. All participants next completed a "spatial reasoning" task, which was our measure of self-regulation. This was a mental rotation task that consisted of geometric shapes taken from Shepard and Metzler (1971, see example in Figure 4). As per Williams and DeSteno (2008), this task was used to assess perseverance and thus served as a measure of self-regulation. Specifically, we examined whether hungry individuals were less able to persevere at the tedious task than satiated individuals. On each trial, participants compared the images of two geometrical figures on a computer screen and determined if these figures were able to be rotated in space to match one another or not. Participants were told that the figure combinations were infinite and that the task would take longer than the experiment allowed. Participants were shown how to press a key to exit out of the task when they felt they had completed as many trials as they could. The number of minutes that participants spent on this task served as our measure of self-regulation.

Attentional focus manipulation. Next, all participants completed a writing task meant to direct their explicit focus on specific emotion concepts or neutral information (adapted from Lindquist & Barrett, 2008). For this task, participants were randomly assigned to view a male face posed to display a prototypically angry, sad, or neutral facial expression (Figure 4 shows the "anger" face). It was reasoned that the facial expression would serve as a visual, symbolic representation for that emotion concept (Barrett, 2011; Doyle & Lindquist, 2017; Fridlund, 1994; Lindquist & Gendron, 2013) and thus a good cue for accessing concept-relevant associations. Participants were told that the individual was named Jon and that "Jon feels angry (sad/neutral)." They were then instructed to write a vignette detailing: (a) "How does Jon feel? Describe his thoughts and bodily sensations in as much detail as possible;" (b) "What actions might Jon take?;" and (c) "Why does Jon feel angry (sad/neutral)—what happened to make him feel this way?" Participants were told they could write as little or as much as they wished, as long as they were detailed under the cover story that this was a measure of "cognitive complexity." As a manipulation check, participants' vignettes were later transcribed and coded using the Linguistic Inquiry and Word Count program (Pennebaker, Booth, & Francis, 2015).

Context manipulation. Next, all participants underwent the same negative interpersonal situation to create an ecologically valid context in which they could conceptualize their hunger as "hanger." We used a displaced aggression paradigm in which participants completed a tedious computerized "visual dexterity" task that crashed part way through. In the task, participants saw a series of concentric colored circles on the computer screen (see Figure 4 for an example) and were asked to decide as quickly and accurately as possible whether the number of circles present was odd or even. Participants were told the cover story that this task measured the speed and accuracy of their visual perception. After 100 trials, participants received an error message that simulated a Windows computer crash. This prompted the participant to find the experimenter outside the testing room and inform him/her of the crash. All experimenters were trained to deliver the same negative reaction. The experimenter entered the testing room, looking confused and upset. The experimenter attempted to fix the crash by typing on the keyboard and clicking the mouse. The experimenter then said "This has never happened before," then asked the participant: "What did you do? What keys did you press?" Finally, the experimenter said "I don't know how to fix this, but I'm going to go contact my supervisor to find out. Once I get the task fixed, you're going to have to do the whole task over again if you want your study credit." After this, the experimenter left the room for a brief period (2 min), allowing the participant to consider the situation alone.

Dependent measures. After the brief period was over, the experimenter reentered the testing room with a manila envelope filled with questionnaires, and asked the participant to fill out the questionnaires while s/he contacted the study supervisor in another room. Inside the envelope were the two dependent measures: one questionnaire was called a "Participant Satisfaction" questionnaire and inquired about the participants' emotions. The other was called the "Rate Your Experience" questionnaire and inquired about the participants' perceptions of the quality of the experimenter and the study. The cover story was that the lab had been randomly selected by the Psychology and Neuroscience Department for a routine quality control study on research within the department. Participants were informed that the questionnaires would be used to evaluate whether the experimenters were performing their jobs well. Participants were ensured that questionnaires were completely anonymous and that s/he should seal the envelope after finishing the questionnaires to ensure confidentiality.

For the "Participant Satisfaction" questionnaire, we used the modified Differential Emotion Scale (mDES; Fredrickson, Tugade, Waugh, & Larkin, 2003) for participants' self-reported emotion experiences. Participants rated how many times they had experienced that emotion *during the lab visit today* using a 5-point Likert scale (0 = *not at all* to 4 = *extremely*). The mDES covers 20 questions, with each question containing three synonymous emotion terms. In total, there were 10 positive emotion questions (e.g., "What is the most grateful, appreciative, or thankful you felt?") and 10 negative emotion questions (e.g., "What is the most angry, irritated, or annoyed you felt?"). For the "Rate Your Experience" questionnaire, participants rated their personal impressions of how aggressive, helpful, lacking in empathy, professional, and judgmental the experimenter was. All items were rated for agreement using a 7-point Likert scale (0 = *not at all* to 6 = *extremely*).

Demographics and debriefing. After the participant completed the dependent measures, the experimenter reentered the testing room and told the participant that the study supervisor had decided the participant did not need to redo the "Visual Dexterity" task after all. Participants then completed a standard demographics questionnaire before completing a funneled debriefing. During debriefing, participants were first interviewed about their general thoughts and reactions to the experiment and also their impressions about what the experiment assessed. No participants reported that they thought the study was about hunger's influence on their emotions and interpersonal judgments, nor did any participants report suspicions about the authenticity of the computer crash. After participants provided their hypotheses about the study's purpose, they were debriefed as to the true nature of the experiment and offered snacks.

Analyses. To compute our dependent variables, we used the items on the mDES (i.e., the "Participant Satisfaction" questionnaire), to first create a mean score for participants' self-reported negative, high arousal emotions (mean score included ratings for the anger, contempt, disgust, embarrassment, fear, guilt, hate, shame, and stress items; $\alpha = .83$). We considered these emotions to be negative and high arousal based on multidimensional scaling and factor loadings from prior literature (e.g., Alvarado & Jameson, 2011; Feldman, 1995; Russell, 1980; Russell & Bullock, 1986). We did not include sadness as this is prototypically considered a low arousal emotion (Shaver, Schwartz, Kirson, & O'Connor, 1987), although we recognize that the valence and arousal associated with each emotion category can vary by instance (e.g., Wilson-Mendenhall, Barrett, & Barsalou, 2013). We chose to look specifically at negative, high arousal items because, as mentioned, the literature consistently shows that hunger induces unpleasant, highly aroused affect (e.g., Cryer, 1999; Heller et al., 1987). Notably, our findings hold regardless of whether we assess negative, high arousal emotions specifically or focus on all negative emotions (see online supplemental materials), likely because there are relatively few negative low arousal emotions in the mDES. In future research, it would be interesting to systematically assess the extent to which hunger impacts high versus low arousal negative emotions. Notably, as follow-up exploratory analyses, we chose to specifically examine the emotion categories of anger and hate, as these would most approximate the colloquial experience of feeling "hangry."

As we were interested in participants' interpersonal judgments of the experimenter, we also used the items on the "Rate Your Experience" questionnaire to create a mean score for participants' ratings of the experimenter consisting of ratings on how helpful, professional, empathetic, difficult, aggressive, and judgmental the experimenter was. Positive items were reverse scored resulting in an index of unpleasant interpersonal judgments ($\alpha = .72$). Notably, as follow-up exploratory analyses, we examined a subset of the items that we deemed a priori to be most likely to relate to the negative interpersonal situation participants had experienced (how aggressive, lacking empathy, and judgmental the experimenter was).

Prior to analyzing our data, we performed a manipulation check (Blood Glucose Questionnaire) to ensure that fasting versus satiated participants were indeed hungry versus not hungry. In our sample, 119 participants were assigned to the hunger condition versus 117 participants were assigned to the satiation condition. However, 54 participants in the hunger condition who fasted for 5 or more hours still reported being *somewhat full* (3) to *not at all hungry* (1) on the "How hungry are you right now?" scale (1 = *not at all hungry* to 7 = *extremely hungry*). similarly, seven participants in the satiated condition who just ate a full meal 1 hr or less still reported being *somewhat hungry* (4) to *extremely hungry* (7). These findings likely represent normal variation in satiety between meals, as individuals can vary in length of satiety depending on metabolism, recent meal content and physical activity, hormonal cycles such as menstruation, and even morphological factors such as the length of the small intestine (Blundell, Stubbs, Hughes, Whybrow, & King, 2003; Jeroen Maljaars, Peters, Kodde, & Geraedts, 2011; Lawton, Delargy, Brockman, Smith, & Blundell, 2000; Pohle-Krauza, Carey, & Pelkman, 2008). Indeed, there is evidence that even at longer intervals of short-term fasting (>24 hr) there is variance in subjective hunger intensity (e.g., as in Herbert et al., 2012).

To balance concerns about reliability and validity, we performed analyses in three ways (see online supplemental materials for additional analyses). First, we included all participants, regardless of whether they passed our manipulation check or not in an "intent-to-treat" analysis (see Bouwmeester et al., 2017). This type of analysis assesses the impact of the experimentally manipulated independent variable on the dependent variable, irrespective of individual differences in manipulation success. Second, we excluded any participant who explicitly failed our manipulation check (by reporting less than the Likert midpoint of 4 in the hunger condition and greater than 4 in the satiated condition), resulting in 65 hungry participants and 110 satiated participants, with a final $N = 175$ (≥ 20 participants per condition). Third, we performed follow-up analyses in which we preserved power by using the full sample but reassigned participants to the hungry versus satiated condition based on their self-reported hunger. Importantly, the pattern of findings for self-reported emotions replicated regardless of the analysis method used, bolstering the claim that manipulating participants' blood glucose levels via fasting had the predicted effect on emotion experience (see online supplementary materials).

We report the analyses in which we excluded participants who were not hungry because this analysis most closely addressed the effect of the psychological state of hunger on our outcomes. We recognize, however, that this choice leaves open the interpretation that the participants for whom the hunger manipulation was effective might have systematically differed from others in some manner (Bouwmeester et al., 2017). Our pattern of findings in the intent-to-treat analyses (see online supplemental materials) minimizes this concern, but do not fully mitigate it as it is clear from our manipulation check that fasting did not impact all participants equally. Future research should examine which factors moderate the effect of fasting on hunger, as addressing these moderators would give even more insight into the mechanisms of "hanger." One candidate may be individual differences in interoception, that is, the ability to perceive changes in the visceral body (Critchley & Garfinkel, 2017).

As a manipulation check for the attentional focus factor, we content-coded responses on the writing task using the LIWC (Pennebaker et al., 2015) to ensure that participants in the anger-focused condition were using more anger words than those in the sadness-focused and no emotion-focused conditions and vice versa in the sadness-focused condition. In the no emotion-focused condition we ensured that participants were not explicitly focusing on anything emotional by comparing the number of affective words they used, in general (i.e., any positive or negative affect words, e.g., good, bad), compared with the other two conditions. One-way ANOVAs confirmed that our manipulation was successful, such that anger-focused participants wrote about anger more than those in the sadness-focused and no emotion-focused conditions (ps $<$ .001), sadness-focused participants wrote about sadness more than those in the anger-focused and no emotion-focused conditions (ps $<$ .001), and no emotion-focused participants wrote about emotion and affect less than those in the anger-focused and Sadness-focused conditions (ps $<$ .001). See Table 4 for manipulation check results.

To test our primary hypotheses, we first established that no outliers bore undue leverage on our findings for any variables (i.e., establishing that no individual's means were greater than two standard deviations above the sample mean for any variable). To test the primary hypothesis that hunger is conceptualized as emotion when participants are not explicitly paying attention to their feelings, we then examined main effects and interactions using a series of 2 Body State (Hunger, Satiated) × 3 Attentional Focus (Anger-Focused, Sadness-Focused, No Emotion-Focused) between-subjects factorial ANOVAs. The dependent variables were participants' self-reported emotions and perceptions of the experimenter. Second, to rule out that hunger induces self-regulatory depletion, we used an independent-samples t test to compare how long hungry versus satiated participants persisted at the mental rotation task and also used our measure of self-regulation as a covariate in a series of 2 Body State (Hunger, Satiated) × 3 Attentional Focus (Anger-Focused, Sadness-Focused, No Emotion-Focused) between-subjects factorial ANCOVAs.

Results

Self-reported emotions. A 2 (Hunger vs. Satiation) × 3 (Anger-Focused, Sadness-Focused, No Emotion-Focused) ANOVA for mean negative, high arousal emotions revealed a significant main effect of body state, $F(1, 166) = 4.47$, $p = .036$, $\eta^2 = .02$ such that hungry individuals were more likely to report feeling high arousal, negative emotions compared with satiated individuals. We found no significant main effect of attentional focus, $F(2, 166) = 2.12$, $p = .112$, $\eta^2 = .02$. However, as predicted, there was a significant interaction between Body State × Attentional Focus, $F(2, 166) = 5.51$, $p = .005$, $\eta^2 = .06$. A doubly centered planned contrast (Abelson & Prentice, 1997) confirmed our a priori prediction that hungry participants whose attention was not directed toward emotional information ($M = .88$) were more likely to report negative, high arousal emotions as compared to other hungry participants who explicitly focused their attention on emotions such as anger ($M = .42$) or sadness ($M = .49$), or as compared with satiated participants who focused on anger ($M = .48$), sadness ($M = .47$), or no emotional information ($M = .37$), $F(1, 166) = 11.52$, $p < .001$ (see Figure 5).

As follow-up exploratory analyses, we focused on a two a priori emotion adjectives: anger and hate, given their link to the colloquial use of "hanger." Using a 2 (Hunger vs. Satiation) × 3 (Anger-Focused, Sadness-Focused, No Emotion-Focused) ANOVA, we again found significant effects for self-reports of hate, but not for anger (ps $>$ .250).

For self-reports of hate, there was a significant main effect for body state, $F(1, 165) = 4.90$, $p = .028$, $\eta^2 = .03$, such that individuals who were hungry were more likely to report feeling hate compared with individuals who were satiated. The main effect of attentional focus was not significant, $F(2, 165) = 1.44$, $p = .241$, $\eta^2 = .02$. Finally, we observed a significant interaction between Body State × Attentional Focus, $F(2, 165) = 5.77$, $p = .004$, $\eta^2 = .06$. A doubly centered planned contrast confirmed the previous pattern of findings: That hungry participants who did not focus on emotional information ($M = .65$) were more likely to report experiencing hate as compared with other hungry participants who focused on emotions such as anger ($M = .09$) or sadness ($M = .25$), or as compared with satiated participants who focused on anger ($M = .23$), sadness ($M = .14$), or no emotional information ($M = .03$), $F(1, 165) = 11.05$, $p = .001$ (see Figure 6).

Self-reported perceptions of the experimenter. Next, to examine participants' interpersonal judgments of the experimenter, we ran a 2 (Hunger vs. Satiation) × 3 (Anger-Focused, Sadness-Focused, No Emotion-Focused) ANOVA using the mean experimenter ratings score as the dependent variable (i.e., how helpful, professional, empathetic, difficult, aggressive, and judgmental the experimenter was). There were neither significant main effects of the body state nor attentional focus, nor a significant interaction (ps $>$ .20). As follow-up exploratory analyses, we examined a subset of the items that were a priori most likely to

Table 4
Mean Anger, Sadness, and Affective Words Written in the Attentional Focus Writing Task

	Attentional focus condition			Test of significance	
Outcome	Anger-focused	Sadness-focused	No emotion-focused	$F(2, 169)$	p
Anger words	5.39 (.234) [s,n]	.83 (.239)	.30 (.270)	133.55	<.0001
Sadness words	.77 (.200)	5.67 (.205) [a,n]	.54 (.231)	192.99	<.0001
Affective words	9.78 (.404)	10.53 (.412)	6.73 (.465) [a,s]	20.39	<.0001

Note. Post-hoc simple effect significant differences (ps $<$ .05) between the three conditions are denoted with a = anger-focused, s = sadness-focused, and n = no emotion-focused. Standard errors are provided in parentheses next to the word count means.

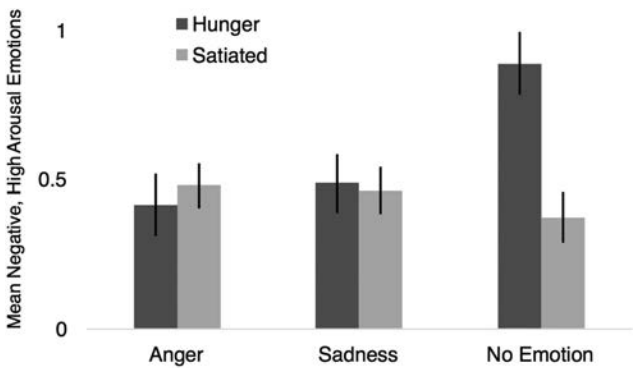

Figure 5. Study 3 mean differences for mean negative, high arousal emotions. Hungry individuals in the no emotion-focused condition reported significantly greater feelings of negative, high arousal emotions (anger, contempt, disgust, embarrassment, fear, guilt, hate, shame, and stress). Error bars computed +/− 1 *SE*.

relate to the negative interpersonal situation participants had experienced (how aggressive, lacking empathy, and judgmental the experimenter was) to ascertain whether hunger interacted with awareness to influence individuals' more specific interpersonal judgments. Again, we ran 2 (Hunger vs. Satiation) × 3 (Anger-Focused, Sadness-Focused, No Emotion-Focused) ANOVAs with experimenters' rated aggressiveness, lack of empathy, and judgmental behavior as the dependent variables. We did not find effects on participants' ratings of aggressiveness or lack of empathy (all ps $> .10$).

There were, however, significant effects for participants' ratings of the experimenter as judgmental. There was no significant main effect for body state, $F(1, 168) = 1.25$, $p = .265$, $\eta^2 < .01$, but there was a significant main effect for attentional focus, $F(2, 168) = 4.05$, $p = .019$, $\eta^2 = .05$. Simple effects revealed that within the attentional focus factor, participants in the no emotion-focused conditions were significantly more likely to rate the experimenter as judgmental compared with participants in the anger-focused ($p = .006$) and sadness-focused conditions ($p = .012$). Critical to our hypotheses, there was a marginally significant interaction between Body State × Attentional Focus, $F(2, 168) = 2.29$, $p = .105$, $\eta^2 = .03$. A doubly centered planned contrast confirmed the previous pattern of findings: that hungry participants who did not focus on emotional information ($M = .70$) were more likely to rate the experimenter as judgmental as compared with other hungry participants who focused on emotions such as anger ($M = .05$) or sadness ($M = .13$), or as compared with satiated participants who focused on anger ($M = .05$), sadness ($M = .22$), or no emotional information ($M = .21$), $F(1, 168) = 4.65$, $p = .032$ (see Figure 7).

Notably, this finding should be taken as preliminary and speculative, given that it did not replicate in the "intent-to-treat" analysis with the full sample, although it did replicate when we reassigned participants based on their hunger status (see online supplemental materials). This pattern of findings leaves open the alternative hypothesis that participants who were assigned to the hunger and satiation conditions and who passed the manipulation check differ from participants who failed the check in some meaningful way, at least with regards to the effects of hunger on interpersonal judgments. We address these ideas in the Limitations section below.

Regulatory depletion. Contrary to prior hypotheses (e.g., Bushman et al., 2014), hunger did not induce self-regulatory depletion: hungry participants persevered as long as satiated participants on the mental rotation task ($M_{\text{hunger}} = 8.16$ min vs. $M_{\text{satiated}} = 8.90$ min), $t(149) = -.75$, $p = .457$, 95% CIs [−2.72, 1.23], Cohen's $d = .13$ (see Figure 8). Finally, to determine if self-regulation interacted with body state or attentional focus to drive self-reported emotions or interpersonal judgments, we reran the ANOVA models above with time spent on the mental rotation task as a covariate representing how much regulatory reserve hungry versus satiated participants possessed. Self-regulation was not significant in any model, neither as a main effect nor interaction and the pattern of the previously reported ANOVAs remained the same (see online supplementary materials).

Discussion

In Study 3, we found evidence that hunger can become conceptualized as emotion in a negative interpersonal situation, but only when individuals are not explicitly focused on emotions. Consis-

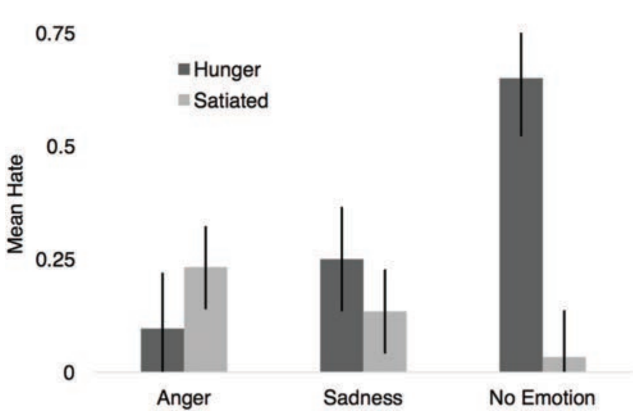

Figure 6. Study 3 mean differences for hate. Hungry individuals in the no emotion-focused condition reported significantly greater feelings of hate. Error bars computed +/− 1 *SE*.

Figure 7. Study 3 mean differences in ratings of the experimenter as judgmental. Hungry individuals in the no emotion-focused condition reported significantly greater perceptions of the experimenter as judgmental. Error bars computed +/− 1 *SE*.

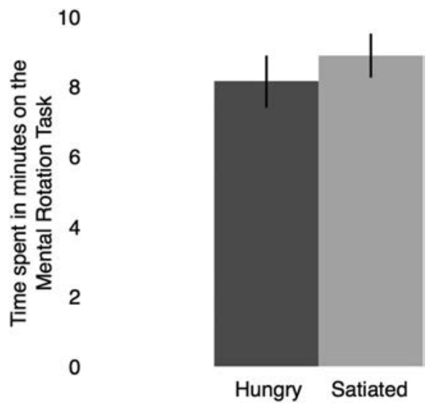

Figure 8. Study 3 mean differences in minutes spent on the self-regulation task. Hungry versus satiated individuals did not significantly differ in perseverance on the mental rotation task, $t(149) = -.75$, $p = .457$, 95% CIs [−2.72, 1.23]. Error bars computed +/− 1 *SE*.

tent with our predictions, hungry individuals reported greater unpleasant, high arousal emotions when their attention was not specifically drawn to emotion. In exploratory analyses, we found that individuals were also more likely to indicate that they were experiencing "hate" and to view the research assistant as judgmental if they were hungry but not directed to attend to emotion. Thus, although it is clear that hunger interacts with awareness to impact multiple unpleasant, high arousal emotions, we do have some preliminary evidence that if the context affords it, hunger and awareness can translate into unpleasant, antisocial interpersonal feelings and behaviors.

Critically, contrary to the *regulatory depletion hypothesis*, hungry versus satiated individuals did not differ in self-regulation, nor did self-regulation impact participants' self-reported emotions and interpersonal judgments when controlled for in analyses. This finding suggests that regulatory depletion, as measured in the present study, did not play a powerful role in shaping individuals' emotions and judgments. Of course, it remains a possibility that our measure of perseverance did not adequately measure participants' self-regulatory abilities. However, the fact that hunger interacted with participants' awareness about emotions and the fact that we did not consistently find a main effect of hunger further underscores our interpretation that negative emotion can be constructed out of hunger when people make meaning of hunger-induced negative affect in context.

Study 3 thus built on Studies 1–2 to demonstrate that specifically manipulating hunger and participants' attention toward emotional information altered "hanger." Furthermore, these hunger-induced emotions manifested as both experiences of negative emotions (i.e., greater ratings of negative, high arousal emotions) as well as perceptions that the researcher was judgmental.

General Discussion

Across three studies, we found evidence that hunger alters individuals' affective perceptions and experiences. Specifically, we demonstrated that hunger can be experienced as a negative, high arousal state—or "hanger"—when made meaningful as an instance of emotion in a negative context. Consistent with the classic misattribution literature, this effect occurred only when participants were *not* explicitly focused on emotions. In Studies 1–2, hungrier participants were more likely to judge an ambiguous stimulus as negative when it was preceded by a negative, but not neutral or positive, context. Hunger on its own did not automatically lead to negative affective judgments; instead, the negative context guided how individuals automatically made meaning of the hunger-induced affect.

Study 3 extended Studies 1–2 by explicitly manipulating hunger and focus on emotions and examining how hunger translates into emotions and judgments in a more ecologically valid interpersonal context. We found that participants experienced hunger as negative emotions, but only when *not* explicitly directed to focus attention on emotional information. We have preliminary evidence that individuals were also more likely to experience negative, antisocial states when hungry but not explicitly focusing on emotions; participants who were hungry but not focused on emotions were more likely to report feeling "hate" and that the researcher was "judgmental." Study 3 also provides preliminary evidence that regulatory depletion may not be the primary mechanism by which hunger impacts emotion. Hungry versus satiated individuals did not differ in self-regulation, nor did self-regulation impact the effects of hunger and attentional focus on emotions when included as a covariate in our models. Our findings are thus contrary to the hypothesis that hunger primarily impacts our social and affective lives by depleting self-control (e.g., Bushman et al., 2014; DeWall et al., 2011).

Study 3 instead suggests that feeling "hangry" stems from making meaning of hunger-induced affective sensations as feelings of negative, high arousal emotion in an unpleasant context. Although the colloquialism "hangry" implies that people who are hungry may feel specifically angry, we did not predict that people would exclusively experience anger for several reasons. First, following the literature on the affective states induced by hunger as well as previous psychological constructionist and affect misattribution theories, we hypothesized that hunger itself would give rise to a general feeling of unpleasant, highly aroused affect. Furthermore, following evidence that people can make meaning of their affect in multiple ways based on the context and their goals (Ellsworth & Scherer, 2003; Kirkland & Cunningham, 2012; Lindquist & Barrett, 2008), as well as evidence that people rarely endorse a single negative emotion category to describe their experience (Barrett et al., 2001; Feldman, 1995), we did not predict that conceptualizations of hunger would result in a single emotion (e.g., anger). This prediction was borne out in the data, where we found in Study 3 that participants who were hungry and not focused on their emotions reported more intense experiences of all unpleasant, highly aroused emotions. That said, we did find that participants reported feeling "hate" and that they found the researcher to be judgmental, which may reflect participants' negative, antisocial experiences toward the researcher in that interpersonal context, more specifically.

Limitations

As a first direct test of the psychological mechanisms underlying "hanger," our findings are not without limitations. For instance, hunger was measured, but not manipulated in Studies 1 and 2, leaving open alternate interpretations of our findings (i.e., people who report more intense responses on Likert scales for hunger are also more generally affectively reactive to negative contexts). Additionally, hunger was self-reported after the AMP task was completed in both Studies 1 and 2 and thus relied on retrospective ratings of hunger. However, we deemed this procedural choice necessary as measuring hunger prior to the AMP might have altered the effects, as demonstrated in Study 3, where attentional focus impacted the resulting emotions.

To overcome limitations inherent with measuring hunger, we manipulated hunger versus satiation in Study 3, but still found considerable between-subject variation in the subjective experience of hunger even amid our objective manipulations of fasting. To ensure the robustness of our findings and balance concerns about reliability and validity, we analyzed our data in several ways, all with similar results. In the "intent-to-treat" analyses reported in our online supplemental materials (Bouwmeester et al., 2017), we analyzed all participants who were assigned to fast versus eat, regardless of their self-reported hunger and found the predicted interaction between hunger and awareness on emotional self-reports. In a second set of analyses, we removed participants who did not pass our manipulation check for hunger and still found the predicted interaction. Finally, we reassigned participants to the hunger versus satiation condition with the logic that regardless of fasting status, those participants who reported being hungrier should be assigned to a hunger condition; here, we again replicated the same pattern of findings. Granted, the latter two sets of findings open up the possibility that participants who were excluded or who were reassigned differ systematically from ones that do not and this limits the interpretation that fasting and its interaction with awareness had a causal effect on our dependent variable.

To address the possibility that we did not causally manipulate hunger, future research should take two approaches. First, future research could replicate and extend our manipulations by inducing longer fasts and including more objective, markers of hunger such as blood glucose and circulating active ghrelin, in addition to self-reported hunger. However, it remains likely that there are significant individual differences in the subjective experience of hunger following fasting (e.g., Blundell et al., 2003; Jeroen Maljaars et al., 2011). Future research should also measure and model the individual differences that moderate the relationship between fasting and hunger, because our findings suggest that fasting status and subjective hunger are related, but can be uncoupled. One candidate moderator is interoception or the awareness of one's bodily changes (Critchley & Garfinkel, 2017; for a review on interoceptive contributions to eating and obesity, see Simmons & DeVille, 2017).

Another potential moderator is how frequently individuals fast or whether they have experience with fasting in the past. For example, longitudinal evidence suggests that dieting and restricted caloric intake increase appetite and may reduce how long an individual can go before feeling hungry, even after 1 year of dieting (Sumithran et al., 2011). However, individuals who undertake intermittent fasting or restricted-calorie but high-protein diets exhibit reduced appetite (e.g., Johnstone, Horgan, Murison, Bremner, & Lobley, 2008; Wadden, Stunkard, Day, Gould, & Rubin, 1987). Nonetheless, it remains a possibility that the subjective experience of hunger, rather than length of time since eating or objective blood glucose levels, is ultimately what dictates whether hunger will be conceptualized as emotion when the context prompts such conceptualizations. This interpretation would remain consistent with our constructionist predictions that subjective experiences of body states become experienced as emotions in certain contexts when they are made meaningful as emotions rather than body states.

These limitations notwithstanding, our findings held across three studies using two different methodologies: two cognitive–behavioral studies drawn from an online sample of adults ranging in age from 18- to 71-years-old and a social psychological laboratory experiment of college students. Although previous research examines hunger's impact on aggression, risky decisions, moral judgments, and mood or affect more generally, the present article provides the first evidence that hunger shifts self-reported experiences of emotions, posing several important implications for how our social and affective lives can be impacted by the homeostatic processes that are continuously operating within our bodies.

Implications

Perhaps one of the most interesting implications of the present findings is that hunger has the potential to adversely impact affective judgments and experiences. This could help explain why people dislike their spouses more when their blood sugar is low (Bushman et al., 2014) or why they are more morally punitive when hungry (Williams et al., 2016). However, our findings suggest that hunger does not automatically lead to more negative emotions and interpersonal judgments. Context plays a central role in whether hunger is conceptualized as emotions, as does the focus of a person's attention. Given that situated inferences about the meaning of affect tend to be relatively automatic and unconscious (Barrett, Ochsner, & Gross, 2007; Schwarz & Clore, 1983; Winkielman, Berridge, & Wilbarger, 2005), these studies suggest that individuals only conceptualize hunger as emotion when not explicitly focused on the emotional nature of their feelings.

Our findings also suggest that having an emotion label (e.g., "anger") accessible could lead to the implicit regulation of emotion, reducing the likelihood that hunger results in the experience of negative, high arousal emotions or judgments that people and objects in the world are unpleasant. Much research suggests that drawing attention to affective feelings by putting feelings into words ("affect labeling") can regulate or reduce the intensity of affect. For example, labeling one's affective state in the moment has been shown to reduce the intensity of physiological responses (Kassam & Mendes, 2013; Niles et al., 2015) and self-reported emotion (Lieberman, Inagaki, Tabibnia, & Crockett, 2011). Individuals who are better able to label their emotions in a discrete and specific manner (i.e., who are high in emotion differentiation) are better able to regulate their emotions (Barrett et al., 2001) and show more chronic activation of brain networks involved in executive control (Lee, Lindquist, & Nam, 2017). A recent meta-analysis of 356 neuroimaging studies found that the mere presence of emotion labels in experimental tasks reduced amygdala activation, which is associated with marshaling bodily changes to affectively evocative stimuli (Brooks et al., 2017).

It is sometimes assumed that this "muting" effect of affect labeling may be because engaging in conscious reflection (e.g., telling a story about why Jon is angry vs. sad) causes detachment, disrupting the more automatic, first-person flow of subjective experience (cf., Lieberman, 2011). Although this account is plausible in the present studies, it is also possible that drawing attention to one's affective state via emotion labels allowed participants to make meaning of hunger as emotions (e.g., anger or sadness; see Lindquist & Barrett, 2008), resulting in the subsequent regulation of their experiences and behavior (see Lindquist, Satpute, & Gendron, 2015 for a discussion). Whereas Studies 1 and 2 did not ask individuals to label their feelings, in Study 3, participants were randomly assigned to focus attention on and write about the categories *anger*, *sadness*, versus no emotion in particular. As only individuals in the Hunger × No Emotion-Focused condition reported significant differences in emotion experience, it may be that the presence of "anger" and "sadness" labels disrupted the impact of hunger on emotion because those labels made participants realize that they were conceptualizing their hungry affect as emotions and they were thus able to regulate their feelings and behaviors toward the situation and the researcher. Further research should more explicitly examine the impact of affect labeling on hunger and emotions. Future research might also examine how conceptualizing one's affective state as hunger or another body state, as opposed to an emotion, influences emotional outcomes. This may be one pathway for reducing hunger's impact on relationships moral behaviors, and impulsivity (e.g., Anderberg et al., 2016; Bushman et al., 2014; Williams et al., 2016).

The present findings also have important implications for emotion theory. First, they support the constructionist view that affect is made meaningful in context to generate instances of emotion. They also underscore that homeostatic processes in the body can be a source of that affect. Other emotion theories (basic emotion and causal appraisal theories) tend to view bodily changes such as hunger and emotions as emerging from two distinct biological systems (e.g., Ekman & Cordaro, 2011; Panksepp, 1998). It is thus assumed that hunger and emotions could only have interacting and reciprocal influences on one another, such that hunger activates discrete emotions. This interpretation would not readily explain the opposite effect however: that people sometimes confuse emotions for hunger. For instance, in cases of "emotional eating," individuals misinterpret emotions such as anxiety for hunger (Herman, Polivy, Lank, & Heatherton, 1987; McKenna, 1972). This finding is much more consistent with the constructionist hypothesis that hunger and emotion emerge from the same basic psychological "ingredient"—core affect.

Our findings can thus also refine the construct of core affect. It is often assumed that affective representations (whether something is good or bad, highly or lowly arousing) is only computed centrally in the brain, in turn altering body states (e.g., Scherer, 2001; Zelazo & Cunningham, 2007). However, there is growing acknowledgment for the opposite effect, such that affective representations in the brain incorporate ongoing bodily changes (Barrett & Simmons, 2015; Critchley & Nagai, 2012; MacCormack & Lindquist, 2017; Russell, 2003). In this sense, bodily phenomena that seem distally linked to the present context (e.g., hunger in the presence of an offense) may still ultimately influence behavior in that context. This idea has important implications for how we think of "accurate" and "inaccurate" affective perceptions of the world and what constitutes "attribution" and "misattribution."

For instance, it is often assumed that when affect related to a less proximal cause (e.g., due to hunger) influences judgments of the context (e.g., the presence of an offense) that it is an "inaccurate" perception of the world. Affect is thus said to be *misattributed* in such situations. However, the constructionist conception of affect breaks down the boundaries between attribution and *mis*attribution. Constructionist accounts do not assume conscious access to this meaning-making process, but rather that the brain is predicting and drawing on prior knowledge and features of the situation in the moment to construct meaning about what the body is feeling. The brain does make prediction errors (e.g., Clark, 2013; Iglesias et al., 2013), but assuming that all instances of "misattribution" (e.g., feeling "hangry") are prediction errors overlooks the relevance of core affect for maintaining homeostasis (i.e., allostasis). Even if the unpleasant, highly aroused affect induced by hunger seems irrelevant to the current situation (e.g., encountering a threatening person), it is ultimately relevant because the current context might have even more import for the well-being of your glucose-deprived body. In this sense, unpleasant feelings may be amplified when homeostasis is threatened by multiple sources (e.g., social threat while glucose-depleted).

More broadly, given that the third study provides preliminary evidence that hunger may interact with awareness to shift social judgments, future research should implement more targeted study designs to assess whether and how hunger shapes perceptions of social others and the world more generally. For example, in nonhuman animal models, fasting wood frog tadpoles (*Lithobates sylvaticus*) are more active and less risk-averse when they hear alarm calls from other frogs than are satiated wood frog tadpoles (Carlson, Newman, & Langkilde, 2015). Similarly, when compared with satiated fish, food-deprived fish will forage for food further from home, even when in predator-laden waters (Damsgird & Dill, 1998; Godin & Crossman, 1994). Schooling fish exhibit reduced group cohesion when hungry but maintain group cohesion when satiated, providing initial evidence that hunger impacts social behaviors in other species besides humans (Sogard & Olla, 1997). These animal studies suggest that hunger likely impacts approach-avoidance behaviors, risk-taking, and social behaviors such as group cohesion and synchrony more broadly. Future work might extend on these findings to humans, who can also be more or less aware of their body states. As hunger induces affective changes, it is possible that hunger could influence any social–cognitive process reliant on affect (e.g., attitudes toward out-group vs. in-group members, affective forecasts about the future, risk perceptions, and affect-based decisions).

Future work should also delve deeper into the biological pathways by which hunger changes affect. For example, the peptide hormone *ghrelin* is a primary hunger signal, and early evidence demonstrates that ghrelin administration increases sympathetic nervous system reactivity during a stressor relative to placebo administration (Lambert et al., 2011). If ghrelin increases sympathetic activation, then this may be one pathway by which hunger impacts momentary affect and in turn, emotional states. Other growing work in both nonhuman animals and humans demonstrate that resistance to *leptin*, a hormone produced by adipose cells throughout the body to signal satiety, is implicated in depression etiology (e.g., review in Lu, 2007).

The actual food that individuals ingest may be another mechanism by which metabolic processes impact mood. For example, *tryptophan*, an amino acid necessary to synthesize serotonin, can become depleted with fasting (Altman, Shankman, & Spring, 2010). Tryptophan-depleted individuals demonstrate greater negativity bias on the emotional Stroop task, exhibit enhanced memory for negative stimuli (relative to neutral), and are worse at evaluating intimacy and romance in pictures of couples, relative to individuals who are not tryptophan-depleted (Bilderbeck et al., 2011; Pringle, Cooper, Browning, & Harmer, 2012; Wang et al., 2009).

Finally, although the present studies focused on hunger, these results may extend to other body states that induce negative affect such as fatigue or inflammation (see MacCormack & Lindquist, 2017). Even more longstanding changes to peripheral body representations from illness, trauma, and normative development (i.e., puberty and old age) likely have an influence on how people construct emotions. For example, although diseases such as cancer certainly impact mood via appraisals (e.g., uncertainty, existential threat), the way that the disease itself alters homeostatic functioning and peripheral physiology may also contribute to changes in mood and emotion—such as systemic inflammation predicting depression (see review in MacCormack & Lindquist, 2017). Future research should pursue how shifts in putatively "nonemotional," homeostatic processes—be they in daily life, development, or disease—can drive emotions and interpersonal processes. Such a research program would help reveal the body's power to shape emotions and the mind more generally.

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