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ORIGINAL ARTICLE

Shift in Valence Bias Associated with Decrease in Trait Anxiety and Depression Symptoms

Nicholas R. Harp[1] · **R. James R. Blair**[2] · **Maital Neta**[3]

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Abstract

Purpose Mindfulness-Based Stress Reduction (MBSR) is a well-known method for reducing stress and negative affect. Recently, a small, open-label trial showed that MBSR training was associated with a shift toward more positive responses to emotionally ambiguous signals (e.g., surprised expressions that convey either positive or negative meaning).

Methods Here, we test whether the MBSR-induced shift in responses to emotional ambiguity reported previously is accompanied by a reduction in self-reported depression and anxiety symptoms ($n = 42$).

Results In support of our hypothesis, we found that the degree to which individuals' post-training responses to emotional ambiguity became more positive was associated with the degree of reduction in post-training depression and anxiety symptoms (i.e., post-training symptoms controlling for pre-training symptoms; $ps = 0.001$). Importantly, the effect remains significant even when accounting for increases in self-reported mindfulness.

Conclusions Altogether, the results suggest that shifts in valence bias and reductions in internalizing symptoms track one another following MBSR, warranting future randomized, mechanistic investigations.

Keywords Affective processing · Anxiety · Depression · Individual differences

Mindfulness-Based Interventions (MBIs) aim to cultivate mindfulness, conceptualized as an attention toward the present moment coupled with an attitude of acceptance (Bishop et al., 2004). The cultivation of mindfulness through MBIs is a well-known method for improving both physical (e.g., chronic pain, neurogenic inflammation; Khoo et al., 2019; Rosenkranz et al., 2013) and mental health outcomes (e.g., depression, anxiety; Querstret et al., 2020), as well as psychological well-being (Dawson et al., 2020). In fact, MBIs are as effective as other evidence-based approaches (e.g., escitalopram for anxiety disorders; Goldberg et al., 2018; Hoge et al., 2023). One particularly well-studied MBI is Mindfulness-Based Stress Reduction (MBSR), a standardized, typically eight-week program with daily individual homework practices (e.g., guided meditations, mindful yoga; Kabat-Zinn, 2013).

Given the efficacy of MBIs for ameliorating symptoms of mood disorders (e.g., depression; Dawson et al., 2020; Hoge et al., 2023; Querstret et al., 2020), it stands to reason that characteristic features of depression might be mitigated following MBIs. One such feature is an exacerbated negativity bias (Watters & Williams, 2011); that is, an enhanced attention toward and memory for negative emotional information (Ito et al., 1998; Norris et al., 2019). Indeed, both brief (i.e., a 15 min instructional period; Kiken & Shook, 2011) and longer-term (i.e., an eight-week MBSR program; Harp et al., 2022) mindfulness interventions are associated with mitigated negativity. More specifically, an open-label trial – in which both the participants and investigators were aware of the treatment condition – found that MBSR course participants were more likely to view surprised facial expressions in a positive (less negative) manner following the course compared to before the course (Harp et al., 2022).

Surprised facial expressions are a particularly useful measure for assessing negativity bias because they are

✉ Nicholas R. Harp
nicholas.harp@yale.edu

1 Department of Psychiatry, Yale University, Suite 701, 7th Floor, 1 Church St, New Haven, CT 06510, USA

2 Region Hovedstadens Psykiatri Børne og Ungdomspsykiatrisk Center, Genthofte, Hovedstaden, Denmark

3 Department of Psychology, University of Nebraska-Lincoln, Lincoln, NE, USA

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emotionally ambiguous. That is, surprised expressions can convey either positive (e.g., birthday party) or negative (e.g., car accident) meaning. In response to such emotionally ambiguous signals, individuals display a *valence bias* in that some individuals tend to interpret ambiguity more positively and others more negatively (Neta et al., 2009). This valence bias generalizes to a variety of ambiguous stimuli (e.g., scenes, words; Harp et al., 2021), and is relatively stable outside of intervention contexts (e.g., over periods of one week to one year; Harp et al., 2022; Neta et al., 2009). Importantly, negative valence bias tendencies are positively associated with affective symptomology, including trait anxiety (Park et al., 2016), depression, and negative affect more broadly (Neta & Brock, 2021). Moreover, treatments for depression/anxiety, such as MBSR, have been shown to decrease negative valence bias tendencies (AsPredicted Preregistered Study Number: #14,737, Harp et al., 2022).

However, an important, open question is whether a shift in valence bias tracks – or corresponds with – changes in affective symptomology (e.g., depression, anxiety symptoms) following MBIs. In other words, is the degree of change in valence bias throughout MBSR associated with post-treatment affective symptoms, after controlling for pre-treatment symptom levels? To answer this question, we tested whether changes in valence bias throughout an MBSR training explained variance in post-training anxiety and depression symptoms, while controlling for baseline (pre-training) symptom levels using data from participants in the previously reported open-label trial of MBSR courses across the United States (Harp et al., 2022). The findings provide evidence that the shift toward a more positive valence bias tracks with a simultaneous shift toward less severe affective symptoms following the intervention, providing directions forward for more targeted, mechanistic investigations.

Method

Participants. The present data included sixty-one participants from the United States, who were collected as part of a pre-registered study investigating the effects of MBSR training on valence bias (https://aspredicted.org/i9qy5.pdf; Harp et al., 2022). The present analyses should be considered exploratory extensions of the pre-registered study analyses. Two participants were removed due to disclosure of study hypotheses by the instructor, and one participant was removed for failing to stay awake throughout the study procedures. Of the remaining fifty-eight participants, fifteen dropped out of the study before the end of the MBSR course and one failed to respond to the mindfulness questionnaire after the MBSR course. Thus, the final sample included forty-two participants (M_{age}= 42.36; SD_{age} = 12.03, $Range_{age}$ = 23–69; 37 Female, 5 Male; 1 Asian, 4 more than one race, 37 White; 3 Hispanic or Latino/a, 38 Not Hispanic or Latino/a, 1 unreported). Participants were recruited via advertisements distributed by MBSR instructors. Eligibility criteria included being 18 years of age and lacking prior experience with mindfulness practice.

Though the present sample size was constrained due to the use of an existing dataset, we conducted a power analysis to determine the recommended sample size for a multiple regression with two predictors for a two-tailed test at alpha of 0.05 and 80% power in G*Power. Previous reports suggest that the relationship between valence bias and depression and anxiety tend to be small effects (i.e., approximately $r = .1–0.3$; Neta & Brock, 2021; Park et al., 2016). We used an estimated effect of $r = .30$ (partial $R^2 = 0.09$). The power analysis indicated a recommended sample size of 82 participants. Thus, the present study is somewhat underpowered, and results should be interpreted as preliminary.

Procedure. Participants completed a series of five online sessions. Four were completed during the MBSR course and an additional session at an eight-week follow-up. Here, we report analyses from the four sessions during the MBSR course. The first session occurred before the first MBSR class and the second session occurred after the second MBSR class. Both session one and session two occurred in the first week of the MBSR course (i.e., pre-training). The third session occurred before the final MBSR class, and the fourth session occurred after the final MBSR class. Both session three and four occurred in the final week of the MBSR course (i.e., post-training).

In each session, participants completed a valence bias task requiring two-alternative forced choice categorizations (i.e., "positive" or "negative") of positive (happy), negative (angry), and emotionally ambiguous (surprised) facial expressions. Specifically, participants categorized a subset of 24 faces (6 happy, 6 angry, 12 surprise) from 120 total facial expressions (30 happy, 30 angry, 60 surprise) from the Karolinska Directed Emotional Faces (Lundqvist et al., 1998), Umeå (Samuelsson et al., 2012), and NimStim sets (Tottenham et al., 2009) in each session. In more detail, participants completed 72 trials (18 angry, 18 happy, 36 surprise) per session using one of five sets of 24 faces (6 happy, 6 angry, 12 surprise). Thus, participants categorized each face three times per session, but did not see the same faces across sessions. Trials with the ambiguous surprised expressions were used to compute valence bias as the percentage of trials categorized as negative. Face sets were counterbalanced across sessions and response sides were counterbalanced across participants.

Measures. Participants completed the valence bias task (and a color bias task beyond the scope of the present report), the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006), the Beck Depression Inventory (BDI-II; Beck et al., 1996), and the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983), along with other measures assessing personality, emotion regulation tendencies, intolerance of uncertainty, optimism, empathy, and stress that are beyond the scope of the present report. Importantly, we did not test these additional measures as predictors in the present model given our focus on internalizing symptoms.

FFMQ. The 39-item FFMQ (Baer et al., 2006) measures five facets of mindfulness, though we focus here on the 7-item non-reactivity facet. The non-reactivity subscale showed adequate reliability for both pre-training ($a = 0.84$) and post-training responses ($a = 0.85$).

BDI. The 21-item BDI (Beck et al., 1996) measures severity of depression symptoms. The scale showed good reliability for both pre-training ($a = 0.90$) and post-training responses ($a = 0.92$).

STAI. The 40-item STAI (Spielberger et al., 1983) measures both state and trait anxiety levels, though we focus here on trait anxiety only. The scale showed good to excellent reliability for both pre-training ($a = 0.95$) and post-training responses ($a = 0.93$).

Analyses. All analyses were completed in R (Version 4.2.1; Core Team, 2022). Because previous reports indicate no effect of a single MBSR class on valence bias (Harp et al., 2022), which we confirmed in the present sample[1], we averaged valence bias from session one and two to create a single pre-training valence bias score and applied the same procedure to session three and four valence bias to create a single post-training valence bias score. Of note, seventeen valence bias values were missing out of a total of 168 values (four measurements per participant from a sample of 42 participants; i.e., 10.12% of the data were missing). If a participant had a missing valence bias value for one of the pre- or post-session measurements, the available (not missing) score was used as the average. Participants that were either missing both pre- and post-session measurements at a given time ($n = 15$; 25.86% of the sample) – e.g., missing both sessions 3 and 4 due to dropping out – or did not complete the post-training mindfulness questionnaire ($n = 1$; 1.72% of the sample) were removed from the analyses altogether. To test our hypothesis that a shift toward a more positive valence bias is associated with reduced symptoms of depression and anxiety following MBSR training, we fit a linear regression model with post-training symptoms as the outcome and (1) pre-training symptoms and (2) change scores of valence bias as predictors. After, we fit additional models including change in the non-reactivity facet of the FFMQ as a predictor, showing that change in valence bias accounts for unique variance in post-training symptoms above and beyond training-related changes in non-reactivity. We chose the non-reactivity facet, specifically, because earlier work identified it as the sole statistically significant predictor of post-training valence bias (Harp et al., 2022). To improve interpretability of the intercepts, regressors were z-scored.

Results

Change in valence bias. Consistent with our prior report using a slightly larger sample (Harp et al., 2022), we compared valence bias from pre- (i.e., sessions one and two) to post-training (i.e., sessions three and four). Because we previously found a shift toward positivity in the larger sample, we conducted a one-tailed paired t-test and found that positive categorizations increased following the eight-week MBSR course ($t(41) = 1.80$, $p = .04$; two-tailed $p = .08$), even in this slightly smaller subset of the sample. We used t-tests for this analysis because seventeen additional participants were removed for missing data in at least one cell of the repeated measures design. Thus, the repeated measures ANOVA is less representative of the sample included in the analyses with depression and trait anxiety. For a repeated measures ANOVA, see the supplemental material.

Depression. The model accounted for a significant portion of variance in post-MBSR depression scores ($F(2, 39) = 17.23$, $p < .001$, Adjusted $R^2 = 0.44$). Pre-training depression scores were positively associated with post-training depression scores ($b = 3.74$, $se = 0.77$, 95% CI [2.18, 5.29], $t = 4.86$, $p < .001$). A shift toward a more positive valence bias was associated with less severe depression symptoms (b = -2.72, $se = 0.77$, 95% CI [-4.28, -1.17], t = -3.54, $p = .001$; Fig. 1). Notably, the effect of valence bias on post-treatment symptoms remains significant (b = -2.15, $se = 0.80$, 95% CI [-3.78, -0.52], t = -2.67, $p = .01$), even when including change in non-reactivity as a covariate.

Trait Anxiety. A similar pattern of effects was found for the anxiety model ($F(2, 39) = 23.04$, $p < .001$, Adjusted $R^2 = 0.52$). Pre-training anxiety scores were positively associated with post-training anxiety scores ($b = 6.94$, $se = 1.10$, 95% CI [4.71, 9.18], $t = 6.29$, $p < .001$). Additionally, a shift toward a more positive valence bias was associated with less severe post-training anxiety scores (b = -4.15, $se = 1.10$, 95% CI [-6.38, -1.92], t = -3.76, $p = .001$; Fig. 1). As in the depression model, the effect of valence bias on post-treatment symptoms remains significant (b = -2.75, $se = 0.97$, 95% CI [-4.72, -0.78], t = -2.82, $p = .008$), even when including change in non-reactivity as a covariate.

[1] Consistent with our prior report using a slightly larger sample (Harp et al., 2022), two-tailed paired t-tests revealed no evidence of change in valence bias for session one vs. two ($t(35) = 0.71$, $p = .48$) and session three vs. four ($t(30)$ = -0.82, $p = .42$).

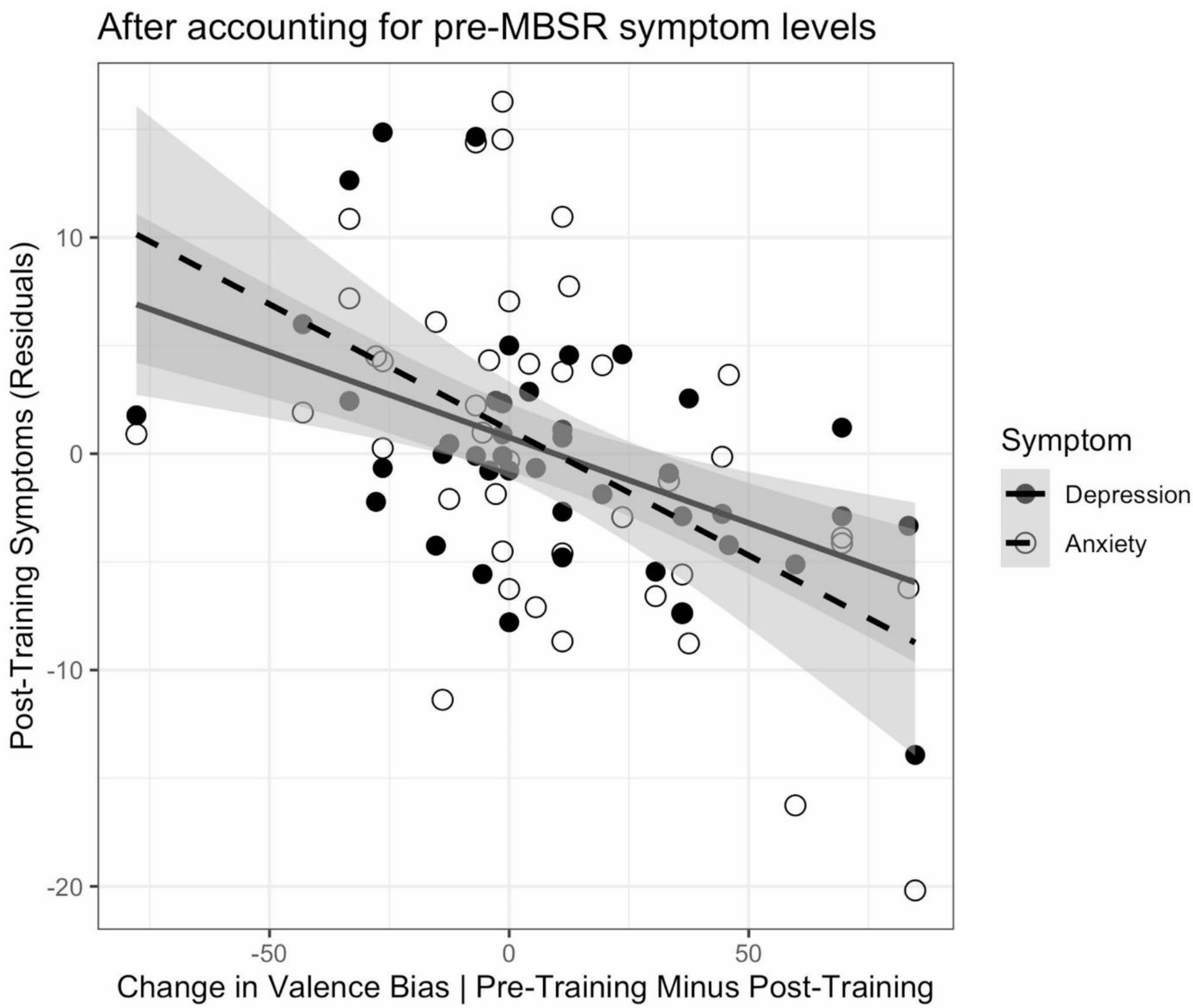

Fig. 1 Change in valence bias is associated with post-training symptoms after controlling for pre-training symptoms

Discussion

Here, we examined the degree to which a shift in one's valence bias during MBSR training corresponded with lower post-training affective symptoms (i.e., depression, anxiety). In other words, we asked if the same individuals that showed the largest shift toward a more positive valence bias after MBSR training also showed the lowest levels of post-training depression and anxiety symptoms, after accounting for pre-training symptom levels. We found that this was indeed the case. As such, the findings provide novel evidence that a shift in one's valence bias tracks with shifts in affective symptoms. Below, we discuss the results in the context of the current mechanistic model of valence bias, followed by a discussion of future directions for targeting valence bias in intervention research.

The present findings have relevance to the current mechanistic model of valence bias, known as the initial negativity hypothesis. The model posits that emotional ambiguity is characterized by an initial negativity across persons, and that only a subset of individuals – those who regulate the initially negative response – ultimately interpret ambiguity more positively (Petro et al., 2018). Some evidence suggests that the regulatory mechanism giving rise to a more positive valence bias resembles cognitive reappraisal (Neta et al., 2022; Petro et al., 2018), but that it likely occurs on a relatively fast, automatic, and perhaps even unconscious, level (Braunstein et al., 2017). As such, failing to regulate and maintaining the initially negative response could, at least in some instances, represent emotion dysregulation and contribute as a risk factor for affective symptomology (e.g., depression, anxiety; Neta & Brock, 2021; Park et al., 2016). Crucially, the present data are the first to suggest that the valence bias tracks with the severity of affective symptoms over time, underscoring the importance of valence bias as a regulatory process relevant to symptom reduction.

Though highly speculative, it is likely that the shift in valence bias, and corresponding symptom reduction, arise from alterations to underlying neural circuitry. For instance, MBSR dampens amygdala reactivity and strengthens the coupling of amygdala and ventromedial prefrontal cortex, perhaps facilitating more effective automatic emotion regulation (Kral et al., 2018). Intriguingly, there is growing evidence that the emotion regulation strategies used in MBIs (e.g., mindful acceptance) do not recruit lateral prefrontal regions (Kober et al., 2019), which are commonly implicated in effortful control and reappraisal (Buhle et al., 2014). Instead, mindfulness-based emotion regulation strategies appear to influence emotion in a more "bottom-up" fashion, though it is possible that "top-down" control occurs, at least initially, in individuals with relatively less prior meditation experience (i.e., short- vs. long-term practitioners; Chiesa et al., 2013). Such a neural mechanism would be well-suited to modulate valence bias, given that the regulatory processes shaping one's valence bias appear to be fast and automatic. Future studies – with both larger, more representative samples and randomized designs that include active control conditions – intended to examine intervention-related shifts in valence bias could directly examine such hypotheses (e.g., by including neuroimaging).

Certainly, the pattern of results warrants future randomized, mechanistic investigations. Both theoretical and empirical evidence supports the notion that change in valence bias could contribute to the beneficial effects of MBSR on affect. In the context of depression, theories have long proposed a role for biased interpretations in maintaining symptoms (e.g., Beck, 1979). Likewise, the present findings dovetail with research on cognitive bias modification, which aims to alter attention and interpretation biases, in ameliorating anxiety (see MacLeod & Mathews, 2012 for a review). Importantly, as individuals become more mindful, there is a tendency toward more positive appraisals that can feedback into greater mindfulness (i.e., an upward spiral; Garland et al., 2011). Thus, it is feasible that mindfulness is the source of symptom reduction. However, we found that shifts in valence bias explained unique variance in post-training symptom severity, even when accounting for changes in mindfulness (i.e., self-reported non-reactivity). As such, it will likely prove valuable to continue examining the role of a shifting valence bias in MBIs and in intervention research more broadly (e.g., pharmacological, cognitive-behavioral therapies), and to carefully design studies capable of making mechanistic claims (see Kazdin, 2007).

Limitations. The study is not without its limitations. For example, the chronology of the relationship between valence bias and symptom reduction is unclear; that is, the change in valence bias could occur prior to symptom reduction, or vice versa, or it is possible that both occur simultaneously and perhaps elicit whole arrays of psychological changes. Additionally, many task-based psychological measures suffer from low test-retest reliability, in part due to an emphasis on isolating cognitive processes by minimizing between-person variability (Enkavi et al., 2019). Fortunately, the valence bias task leverages between-person variability, and shows excellent test-retest reliability over the period of one year (i.e., $r = .72$; Neta et al., 2009). As such, it could be a useful and easy-to-implement clinical tool, and might easily pair with affordable and accessible web-based mindfulness interventions (Mrazek et al., 2019). Further, the sample size is small, and the analyses may have been underpowered; thus, future research should aim to recruit larger sample sizes and use randomized designs with adequate control groups. Lastly, we cannot be confident that the current results generalize to other forms of contemplative practices and MBIs (Hirshberg et al., 2018) or that the results generalize to males, given that the participants in these data are almost entirely female. This is a known issue in much of the MBI research (Macinko & Upchurch, 2019), and future research should aim include more representative samples with diverse gender identities. Further, given that we did not assess income, education, and sociodemographic factors, future research should examine the impact of such measures.

Conclusion. To summarize, the present findings provide evidence that a shift in valence bias tracks with a reduction in affective symptom severity following MBSR. As such, future research should aim to examine whether the salutary effects of MBSR, and perhaps other MBIs, manifest, at least in part, through a shifting of valence bias; that is, randomized clinical trials are warranted. Further, the findings align with the initial negativity hypothesis in that shifting negative valence bias tendencies is associated with a reduction of affective symptoms, likely reflecting enhanced regulatory abilities. To better understand the neural mechanisms underlying the association between shifting valence bias and reduced affective symptoms, future intervention research targeting valence bias in MBIs, as well as other interventions (e.g., cognitive-behavioral therapy), will be necessary.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10608-023-10437-x.

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Data and/or code availability Data and/or code availability: Data cannot be shared publicly because the participants consented to the report of the data in terms of group means and not individualized data. The University of Nebraska-Lincoln Institutional Review Board completed review of the original research protocol including data sharing restrictions. Data requests can be sent to the current contracts manager in the Office of Sponsored Programs at University of Nebraska-Lincoln. All data sharing requests are first subject to a contract agreement through the Office of Sponsored Programs. Analysis code and stimuli lists are available on the Open Science Framework (https://osf.io/3n578/).

Declarations

Competing Interests The authors have no financial or non-financial interests to report.

Ethics Approval All research protocols were approved by University of Nebraska-Lincoln's Institutional Review Board (Approval #20171217871EP) and in accordance with the Declaration of Helsinki.

Informed Consent All participants provided informed consent.

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