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内观自我：正念中的内感受注意

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摘　要

内感受注意(Interoceptive Attention)是正念冥想(Mindfulness Meditation, MM)的核心，指个体以稳定、非评判的方式觉察并调节对呼吸、心跳等身体内部信号的加工权重，在情绪调节与自我意识形成中发挥关键作用。本文基于预测编码理论，系统综述正念冥想中的内感受加工机制，重点探讨内感受注意如何通过精度加权与预测误差修正优化生成模型，进而促进情绪调节能力与自我意识的发展。未来研究可进一步结合计算建模方法，对精度加权与先验更新进行参数化检验，并在不同训练剂量与临床人群中验证其机制差异，以深化对正念干预靶向性的理解。

关键词

正念冥想，内感受，预测编码

Self-Observation: Interoceptive Attention in Mindfulness

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Abstract

Interoceptive attention is a core component of mindfulness meditation (MM). It refers to astable, non-judgmental focus on internal bodily signals (e.g., breathing, heartbeat), and the regulation of their relative weighting in perceptual processing. This process plays a critical role in emotional regulation and the formation of self-awareness. Based on Predictive Coding theory, this review synthesizes current findings on interoceptive processing in mindfulness, with a particular focus on how interoceptive attention optimizes internal generative models via precision weighting of prediction errors and the subsequent correction of these errors, thereby enhancing emotional regulation and promoting the development of self-awareness. Future research may integrate computational modeling

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approaches to parameterize precision weighting and prior updating, and examine mechanistic differences across varying training doses and clinical populations, in order to deepen our understanding of the targeted mechanisms underlying mindfulness-based interventions.

Keywords

Mindfulness Meditation, Interoception, Predictive Coding

1. 引言

近年来，正念冥想(Mindfulness Meditation)作为一种重要的身心训练，逐渐受到心理学、神经科学和临床实践的广泛关注。其核心目标在于通过持续稳定、非评判性的注意力训练，使个体增强对当下思维和身体体验的觉察，尤其是对内感受信号的敏感性和调节能力。研究表明，内感受注意的质量直接影响正念干预效果，尤其在情绪调节和自我意识提升等方面(Farb et al., 2013; Price & Weng, 2021; Wu et al., 2022)。

与此同时，预测编码(Predictive Coding)理论为理解大脑如何处理感官输入提供了强有力的神经计算框架(Friston, 2010)。根据该理论，大脑不仅仅是感知外部信息的被动接收器，它还通过建立模型来预测感官输入，并根据预测误差(Prediction Error, PE)不断调整内部表征，以达到更高效的信息处理。在这一框架下，知觉、注意力和情绪等心理现象都可以被解释为预测与误差修正的动态过程。

内感受是指个体对来自身体内部信号(如心跳、呼吸、消化活动等)的感知、整合与解释，它不仅维持着机体的生理稳态，也是情绪与自我意识的核心基础(Tallon-Baudry, 2023)。正念训练通过内感受注意这一核心技能来增强对内感受信号的觉察，已有研究指出，内感受能力与注意力分配密切相关(Garfinkel et al., 2014; Ujiie & Takahashi, 2022)。预测编码理论则进一步提出，注意力分配上的差异可以通过精确度加权(Precision Weighting)来解释，即大脑如何在不同情境下会调整对预测误差与先验信念的相对权重。

预测编码理论为解释正念冥想中的内感受加工提供新的理论框架(Engelen et al., 2023)，本综述旨在探讨正念冥想中的内感受加工机制，特别关注内感受注意这一核心技能。我们试图回答的一个核心问题是：预测编码理论如何解释正念冥想通过内感受注意影响内感受加工？

2. 内感受加工中的预测编码

在预测编码视角中，内感受加工可被理解为一个“先验–证据(感官输入)–精度加权–误差最小化”的循环。在这一过程中，身体信号(如心脏跳动、呼吸和胃肠道活动等)通常呈现一定的节律性，大脑基于这些规律性信号，通过生成模型主动预测即将发生的生理变化和相应的认知行为。生成模型的形成不仅依赖于先验经验和当前的生理状态，还融合了对未来身体状态的预期，主动构建对内感受的期望。生成模型并非完全被动地接收来自感官的输入，大脑还会通过主动预测来估算和调节内部状态。

然而，由于感官输入和预测之间的不一致，预测误差在这一过程中是不可避免的，这是预测编码理论的核心概念。预测误差是指大脑对内感受信号的预测与实际感知之间的差异，反映了大脑对当前生理状态理解的不准确性。每当实际感知的内感受信号(如心跳、呼吸节律等)与生成模型的预测发生偏差时，预测误差就会产生。这种预测误差会被反馈回大脑，并驱动大脑对生成模型的进一步调整和优化。通过这一不断反馈的过程，生成模型逐步更新，以实现对身体内部状态的更精确预测，从而支持情绪调节和

生理平衡的维持。最终，生成模型的精度得到提高，使得大脑能够更加准确地感知和处理内感受信号，并在多变的生理环境中做出适应性的调整。

针对预测误差大脑一般会采取两种手段进行处理，包括感知推断和主动推断。感知推断是指大脑基于感官输入与先前的经验来推断当前的环境或生理状态，它依赖于大脑对感官输入的实时评估，并通过不断比较预测与实际信号的差异来更新和调整对内感受的理解，是一种自下而上加工。这种机制有助于快速确认呼吸心跳(van Elk et al., 2014; Zaccaro, 2025; Zaccaro et al., 2024)、焦虑(Hein et al., 2022)、疼痛感知(Sharp et al., 2021)、奖励动机(Costa et al., 2025; Yaghoubi et al., 2024)和自我意识(Gatus et al., 2022)等内部体验；相对地，主动推断是一种自上而下加工，是指个体通过主动调整其行为或生理状态来减少预测误差，而不仅仅是被动地调整内部模型。主动推断不仅依赖感官输入的反馈，还可以通过行为来主动影响内感受加工和生成模型的建构。在内感受加工过程中，主动推断使个体能够基于当前的生理状态，调整自身的生理反应，以尽可能减少预测误差，从而优化大脑对身体状态的预测。这种主动调控的过程增强了个体的自我调节能力，使其能够在面对情绪波动或身体不适时，主动调整生理状态(如调整呼吸节律、放松肌肉等)，以促进生理状态的平衡与稳定(Chemis et al., 2025; Kibler & Foreman, 1983; Luo et al., 2025; Merakou et al., 2019; Y. Wu et al., 2025)，提高情绪调节策略使用的灵活性(Giuliani et al., 2011; Jakubczyk et al., 2020; Ma et al., 2024; Tan et al., 2023; Zamariola et al., 2019)，这有助于个体更好适应环境的动态变化。

预测编码理论提出，影响生成模型建构的关键在于注意力，其作用是不断地优化精度加权。注意力的任务是根据情境和任务的需求，动态调节不同信号的可信度与权重，从而尽可能减少预测误差的产生(Clark, 2013)。通过这种精度加权机制，大脑能够选择性地增强或减弱对不同感官信号的关注，使得更有价值的信号在生成模型中占据主导地位。当预测与实际感官输入之间出现误差时，注意力的作用使得大脑能够灵活调整对这些信号的敏感度，从而帮助生成模型持续更新，优化预测过程。在这一过程中，内感受信号相比于外感受信号尤其依赖注意力的精度调控机制。通过这种机制可以增强内感受信号在预测误差修正中的权重，使其在与外部输入的竞争中得到更优先的加工(Kritzman et al., 2022)。内感受和外感受加工使用不同的神经机制(Marshall et al., 2018; Farb et al., 2013; Salomon et al., 2018; Scheibner et al., 2017)，且外感受往往涉及较为简单的认知操作，个体可以依靠发达的感觉技能完成，而内感受对认知要求更高，所依赖的加工机制往往训练较少，因此内感受加工需要更多的注意力资源来提高信号的精度权重，从而使个体能够更敏锐地觉察身体状态并进行有效的调节(Gibson, 2019)。

总而言之，在预测编码框架下，内感受加工的关键机制在于通过感知推断与主动推断不断修正和优化生成模型，两种机制都高度依赖于注意力的精度加权，通过动态调节不同信号权重，决定哪些信息在生成模型的更新中占据主导地位。与外感受加工相比，内感受信号存在更多噪声且难以区分，更依赖注意力资源来提升信号的显著性和加工优先度。由此可见，内感受加工不仅受到注意力分配的影响，也受到对先验灵活性的调节以及个体对内感受信号的态度等因素的制约，而这些因素恰恰涉及正念冥想训练的核心内容。

3. 正念冥想与内感受推断

已有研究表明，正念冥想的诸多益处如情绪调节和自我意识的提升，很大程度上源于内感受能力的改善，这主要依赖于注意力机制对内感受加工的增强(Ardi et al., 2021; Datko et al., 2022; Hadash et al., 2025; Pang et al., 2025)。在预测编码框架下，研究者认为正念冥想主要通过削弱源自过往经验的习惯性预测来提升认知灵活性，使大脑减少对僵化先验的依赖，从而保持生成模型的开放性(Laukkonen & Slagter, 2021; Lutz et al., 2019)。同时，越来越多的研究发现了内感受在情绪和自我意识等方面的中介作用(Ardi et al., 2021; Datko et al., 2022; Davey et al., 2022; García-Cordero et al., 2017; Matthias et al., 2009; Weng et al., 2020;

Wu et al., 2022)，这有助于我们更加完整用预测编码来解释正念冥想的作用机制。

正念训练得以改善情绪、疼痛感知、记忆和自我意识等方面，是因为正念能够提高个体对内外部负性刺激和经验的抗干扰能力，而这种抗干扰能力的获得源于正念训练所导致的个体思维模式的转变，进一步比较可以发现这一过程中注意功能改变的重要性(彭彦琴，居敏珠，2013)。大量佛教研究也表明对内在体验的关注是正念冥想的核心，正念冥想被描述为涉及对呼吸、身体、思想和意识本身的关注(Anālayo, 2020; Lutz et al., 2008; Prakash et al., 2020)。因此，要全面理解正念冥想的作用机制，必须以内感受注意为切入点，再进一步探讨其如何通过预测误差修正与精度加权等机制，促进认知灵活性与身心调节，接下来，我们将从两个方面讨论正念冥想的预测编码机制：一个是主动推断，强调正念冥想如何通过内感受注意优化生成模型使个体能够采取行动来修正预测误差；另一个是感知推断，聚焦于正念如何通过削弱习惯性预测来减少僵化先验的影响。

在正念冥想的实践中，对呼吸与心跳等内感受信号的持续关注可被视为一种主动推断的训练形式。个体通过持续的内感受注意可以主动调整自身的生理状态，使其逐步与大脑的预测保持一致。内感受注意可以直接作用于精度权重，这使得真实的内感受输入获得更高的信号权重，这一机制可以有效提高个体对内感受信号的敏感性(Pollatos, 2017)。进一步地，内感受加工可以将这种优势拓展到其他领域中，精度权重可以根据情境需要在不同对象上进行灵活的调节，研究者采用重复抑制范式发现，内感受训练使得个体在处理重复刺激时额顶叶区域 P2 和 P600 振幅降低但反应准确率却显著提升，虽然注意资源投入减少，但提高了信号的处理效率(Marshall et al., 2022)。正念训练通过提升内感受信号在多模态竞争中的权重，使大脑在生成模型更新时依赖更加可靠而精准的身体反馈，这不仅有助于改善个体对内感受信号的辨识能力，还能增强对正常与异常情绪状态以及自我与他人界限的区分能力(Azevedo et al., 2018; Sel et al., 2016)，并进一步有意识地采取更加适应性的策略来调节情绪(Matthias et al., 2009; Tan et al., 2023; Wu et al., 2022)，或者可以通过主动调节呼吸节律来缓解焦虑情绪(Harrison et al., 2021; Vlemincx et al., 2013)。

在正念训练的长期过程中，个体逐渐发展出感知推断的能力，这一过程通过自下而上的加工方式进行，依赖于大脑对感官输入的实时评估。大脑根据过往经验和当前的生理状态建立生成模型，这些模型本质上是对外部世界的预测。然而，先验信念常常受到过往经验的固化影响，形成习惯性思维和自动反应模式，进而影响个体对外界和自身状态的感知。内感受注意帮助个体识别和修正先验信念中的误区，尤其是在情绪和生理反应的自动化模式中，然后通过元认知过程，促使个体对自身情绪和生理反应进行更清晰的觉察，从而打破习惯性反应的循环，并引导个体主动地调整对身体状态的预测。正念冥想通过练习非评判性和无所欲求的觉察，帮助个体减少自动化的情绪和生理反应，降低固化先验对当前体验的干扰，从而使个体不再依赖以往的习惯性反应模式，而是通过新的预测模型和当前的感官输入来适应不断变化的环境(Chan & Mak, 2015; Chen & Reed, 2023)。

正念冥想促进情绪调节和身心状态的稳定性可能是通过调节预测误差来帮助大脑减少先验信念和实时感官输入之间的偏差(Kong, 2015; Lim et al., 2020)。随着先验信念的作用逐渐弱化，先验生成模型的可能性变得更加灵活多样，大脑能够更有效地调整模型以适应当前的感官输入，最终实现预测误差的最小化。根据自由能原理，大脑通过调整生成模型以最小化预测误差，当生成模型的预测误差增大时，模型的整体稳定性会受到威胁，这可能会导致生理上的不适，还可能引发情绪波动(Seth & Critchley, 2013)，甚至导致身心障碍或疾病的发生(Keysers et al., 2024; Sterzer et al., 2016)。随着正念训练的长期进行，大脑在结构和功能上表现出可塑性变化，主要包括岛叶(Insula)、前额叶皮层(Prefrontal Cortex, PFC)、前扣带回(Anterior Cingulate Cortex, ACC)。岛叶作为内感受信息的处理中心，涉及对身体内部状态的感知和整合，并进一步解释为情绪和自我意识的认知体验。正念训练通过加强岛叶与其他脑区(如 PFC、ACC)之间

的功能联结，增强了个体对内感受信号的感知和处理能力，并促进了情绪和生理反应的自我调节(Brewer et al., 2011; Giuliani et al., 2011; Hasenkamp & Barsalou, 2012; Salomon et al., 2018; Tang et al., 2019; Xiao et al., 2019; Datko et al., 2022; Costa et al., 2025)。通过这些结构性和功能性的调整，大脑的预测模型可以变得更加开放和灵活，从而在情绪波动和生理反应的预测误差处理中，能够快速反应并实现更加高效地修正和调节。

此外，两种推断机制与认知灵活性密切相关，冥想练习帮助个体逐渐摆脱对过去经验和固定模式的依赖，这涉及生理、神经和认知方面。从生理层面来看，正念训练通过增强对内感受信号的觉察，提高了个体对身体反应的敏感度，这使得个体能够更加灵活地调节生理状态，如调节呼吸频率和心率，从而更好地应对情绪波动和外部压力(Pollatos, 2017)；在神经层面，长期的正念冥想训练有助于改善以岛叶为核心的内感受网络与 PFC 和 ACC 等脑区的功能联结，这种神经适应使得个体能够更精确地感知和调节内感受信号，从而提高情绪调节和生理反应的灵活性；在认知层面，正念训练帮助个体从新的视角观察并解决问题，使其在面对相似情境时能够超越惯性思维，尝试不同策略，进而积累新的经验并形成更适应的认知模式。

个体在面对重复情境时，通过训练学会采用不同视角和策略来解决问题，积累新的经验。随着长期训练，个体逐步固定更具开放性的先验模式，当现有策略无法解决新问题时，原有的模式被视为失效，并更新为适应新情境的生成模型。这种“解锁－固定－再解锁”的过程有助于个体更好地适应变化，提高自我调节能力。研究表明正念冥想有助于个体在面对焦虑或压力时，不再依赖旧有的应对策略，而是能够灵活调整身体状态或情绪调节策略(Keysers et al., 2024; Sterzer et al., 2016)。总之，正念冥想可以使个体能够对内感受信号进行更精确地处理，减少过往经验对当前感受的影响，从而提升情绪调节和自我意识。随着训练的深入，个体能够更加灵活地调节对内感受信号的反应，进一步增强其身心平衡的能力。

4. 总结与讨论

本文基于预测编码理论框架，探讨了正念训练如何通过优化内感受加工机制，影响注意的精度加权与先验信念的修正。核心观点是：正念冥想通过两条主要路径促进情绪调节和自我意识的提升。首先，正念训练通过精度加权提升内感受信号的权重，尤其是在多模态竞争中增强内感受信号的优先处理。其次，通过非评判的态度削弱僵化先验信念，从而使大脑的生成模型更加开放，优化内感受加工和预测误差的修正。这两个机制协同作用，推动了感知推断与主动推断的良性循环，进而表现为行为和认知层面上更稳定的情绪调节和更灵活的自我相关加工。

预测编码虽为理解正念机制提供了统一的计算框架，但其解释仍具有一定限制。该框架强调误差最小化与模型更新，对正念中非评判性觉察、接纳等主观体验的生成机制刻画较为间接；此外，其核心变量在经验层面的可测量性仍面临挑战(Bowman et al., 2023)。相比之下，其他认知理论模型从不同层面补充了这一不足。例如，注意机制相关模型区分了内部注意与外部注意的不同子系统，指出正念训练主要作用于对身体、情绪与思维的内部注意，并通过与执行控制等晚期外部注意的资源共享间接影响认知表现，从而解释了正念对不同注意任务影响不一致的现象(Hadash et al., 2025)。进一步地，认知效率模型提出，正念带来的认知改善未必源于认知能力的提升，而更可能体现为对走神与情绪干扰的减少，使个体能够更高效地利用既有认知资源(Cásedas et al., 2024)。不同理论在解释正念机制时各有侧重：预测编码提供计算层面的统一框架，注意模型细化了加工层级结构，认知效率模型揭示了行为表现机制，而拓展的预测模型则更多强调经验层面的重构。

目前研究仍存在若干不足。首先，关于正念训练的剂量效应，多数研究仍停留在整体效果，缺乏对训练剂量(如时长、频率、持续时间等)与内感受加工机制之间关系的深入探讨。未来研究需要进一步考察

不同的正念冥想方案及其剂量效应如何与内感受精度、情绪调节等因素相关联，以提供更为精细的训练指导；其次，研究应更加关注个体差异，尤其在临床应用中，正念作为一种内感受行为干预方案主要针对身心障碍患者。然而，仅有少量研究关注正念冥想在临床人群中的应用，主要是针对焦虑症、抑郁症等精神障碍患者(Chiesa et al., 2025; Datko et al., 2022; Kang et al., 2022; Oser et al., 2021)。未来研究有必要进一步探讨正念冥想调节不同临床个体的内感受加工机制上是否存在差异，这有助于理解正念干预的靶向性；最后，现有大多数研究停留在理论框架解释层面，缺乏可以验证的计算假设(例如，参数化精度、先验方差、层级深度的可观测代理)。已有一些研究尝试使用机器学习方法来区分内感受与外感受信号(Toussaint et al., 2024; Weng et al., 2020)，这为建立更加具解释性的计算模型提供了新的思路和方向。

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