认知灵活性与情感灵活性的加工机制及其对心理健康的影响

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摘要

认知灵活性和情感灵活性与个体的心理健康密切相关。作为认知控制的一个子成分，认知灵活性和情感灵活性分别属于“冷”、“热”认知控制系统。目前，两者共享相同还是特异性的加工机制尚不清楚。此外，认知灵活性和情感灵活性加工机制的异常与多种心理疾病相关，然而，两者对心理健康的影响尚未系统梳理。因此，本文将阐述认知灵活性和情感灵活性加工机制的异同，以及异常个体的认知灵活性和情感灵活性的加工机制，指出提升认知灵活性和情感灵活性的途径以及未来研究方向。这将有利于厘清认知灵活性和情感灵活性的神经机制，并从认知灵活性和情感灵活性角度为改善重度抑郁症、自闭症和精神分裂症的神经干预靶点、治疗方法和愈后手段提供重要的参考信息。

关键词 认知灵活性，情感灵活性，心理健康，神经机制

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认知灵活性 (cognitive flexibility) 和情感灵活性 (affective flexibility) 是心理灵活性的重要组成部分 [1]，被认为是心理健康的基石 [2]。认知灵活性是指个体为应对环境需求变化在任务间或心理设置间快速切换或灵活改变策略的能力，情感灵活性是指个体在情绪和非情绪刺激之间切换的能力。认知灵活性和情感灵活性与心理健康密切相关。研究表明个体的认知灵活性和/或情感灵活性能够促进他们的学业成绩，

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增加心理韧性，情绪调节能力，以及主观幸福感 [3,4]。而认知灵活性和/或情感灵活性功能受损的人群通常伴随着心理健康和精神疾病，比如重度抑郁症 (major depressive disorder)、自闭症 (autism) 以及精神分裂症 (schizophrenia) 等 [5,6]。此外，研究发现个体认知灵活性的降低伴随着抑郁风险的增加 [2]，而提高情感灵活性有助于降低抑郁程度 [7]，说明高认知灵活性和高情感灵活性都有利于个体的心理健康。一项青少年的研究表明心理健康状况与情感灵活性联系更紧密。采用认知和情感任务集转移任务，研究发现有心理健康问题历史的青少年在情感灵活性上的表现比在认知灵活性上的表现差，而认知灵活性和情感灵活性大小在没有心理健康问题历史的青少年上没有差异 [8]。

根据认知控制的“冷”、“热”系统划分 [9]，认知灵活性属于“冷”认知控制系统，涉及非情绪背景下认知控制自上而下的加工；而情感灵活性属于“热”认知控制系统，涉及情绪或动机（奖赏和惩罚）背景下认知控制自上而下的加工。元分析发现情绪和非情绪的冲突加工在背侧前扣带回、前辅助运动区、右侧前脑岛和右侧额下回脑区有共同激活 [10]，说明认知控制的“冷”、“热”系统有共享的加工机制。也有元分析发现认知控制的“冷”、“热”系统在前额-扣带网络上表现出不同的加工机制。其中，“冷”认知控制系统与外侧前额叶（包括背外侧前额叶和腹外侧前额叶）和背侧前扣带回更相关，而“热”认知控制系统与内侧前额叶、眶额叶、腹侧前扣带回和后部扣带回更相关。此外，“热”认知控制系统与边缘系统脑区密切联系，包括腹侧纹状体、伏隔核和杏仁核。而海马和外侧前额叶的功能连接参与“冷”认知控制系统的加工 [11]。这些研究说明认知控制“冷”、“热”系统有相同和特异性的加工机制。然而，由于“冷”认知控制系统不仅包括认知灵活性，还包括反应抑制和工作记忆 [12]，在认知灵活性和情感灵活性的加工上，两者的加工机制异同问题仍缺乏系统的梳理和总结。

因此，本文主要目的是阐明认知灵活性和情感灵活性加工机制的异同，以及认知灵活性和情感灵活性对个体心理健康的影响（图 1）。基于此，我们首先介绍了认知灵活性和情感灵活性的测量范式；然后梳理了两者的加工机制并总结了两者加工机制的异同。接着，在异常个体（重度抑郁症、自闭症和精神分裂症）上讨论认知灵活性和情感灵活性加工机制的失常与心理健康的关系。最后，我们总结了几种有助于提高认知灵活性和情感灵活性的训练方法，并对未来的研究方向进行了展望。本文致力于从认知灵活性和情感灵活性角度更好地理解、预防和治疗心理健康问题。

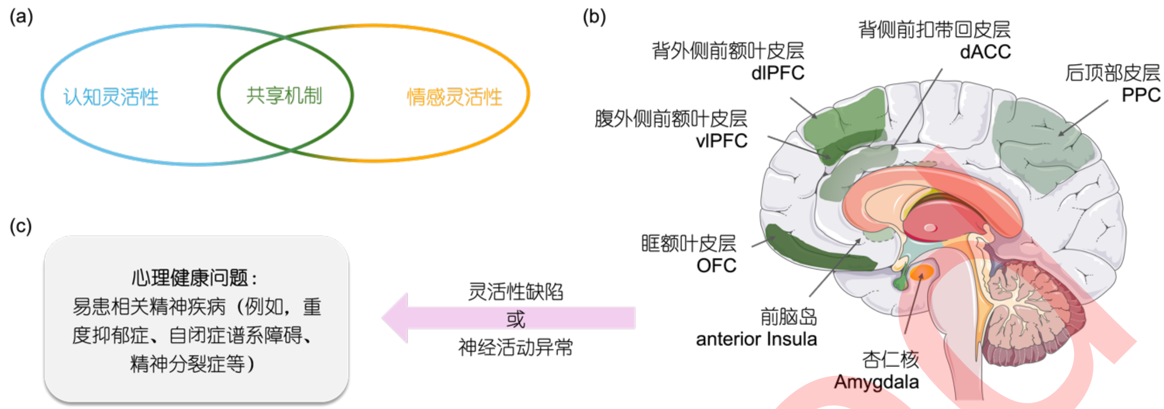

图 1 (彩) (a) 认知灵活性和情感灵活性共享相同和特异性加工机制的示意图。(b) 认知灵活性和情感灵活性的神经基础。绿色部分脑区为认知灵活性和情感灵活性的共享神经机制，橙色标注出的杏仁核为情感灵活性的特异性脑区。(c) 与灵活性缺陷或神经活动异常相关的心理健康问题。PCC: posterior parietal cortex; dACC: dorsal anterior cingulate cortex; dlPFC: dorsolateral prefrontal cortex; vlPFC: ventrolateral prefrontal cortex; OFC: orbitofrontal cortex.

Figure 1 (color) (a) Diagram illustrating the common and distinct processing mechanisms shared between cognitive flexibility and affective flexibility. (b) Neural bases of cognitive flexibility and affective flexibility. Green areas indicate brain regions shared by cognitive flexibility and affective flexibility, while the amygdala, marked in orange, is specific to affective flexibility. (c) Psychological health issues related to deficits in flexibility or abnormal neural activity.

1 认知灵活性与情感灵活性的测量范式

认知灵活性是指个体为应对环境需求变化，在任务间或心理背景间快速切换或灵活改变策略的能力 [13,14]。作为认知控制的重要成分之一，认知灵活性与工作记忆和抑制能力密切相关 [15]。当任务改变时，要实现认知灵活性，个体需要抑制先前的任务表征，并将新的任务表征加载和更新到工作记忆中进行加工。情感灵活性是认知灵活性在情绪背景下的表现，更多指个体在情绪和非情绪刺激之间切换的能力 [16]。情感灵活性对个体情绪调节和压力应对意义重大 [17]。测量情感灵活性的任务范式通常涉及评估个体在面对不同情境和刺激时，能否灵活地调整自己的情绪反应和情绪表达能力。常见的测量认知灵活性和情感灵活性的任务如下：

威斯康星卡片分类测验 (Wisconsin Card Sorting Test, WCST) [18]。该测验向被试展示一系列的卡片，卡片有颜色和形状两个特征维度。实验开始时，被试不知道在哪个维度上进行匹配，他们的任务是通过试误找出规则。随着实验进行，规则会不断变化，被试需要时刻学习规则变化才能完成任务。通过测量被试在规则改变时的

表现测量个体的认知灵活性，正确完成的类别数越多，错误率越低，代表被试的认知灵活性越高。测量情感灵活性的情绪威斯康星卡片分类测验 (emotional Wisconsin Card Sorting Test, emotional-WCST) 是由原始 WCST 改编而来，该任务将情绪刺激纳入，向被试展示一系列卡片，被试需要学习不断变化的规则才能正确执行任务。情感灵活性越高，个体越能够根据反馈迅速调整反应模式，并有效生成和测试新规则 [12]。该范式能够反映出人们的情感灵活性 [5]，已被证明在不同人群中有效，包括自闭症患者 [19]、中风康复患者 [20]和儿童群体 [21] 等。

任务转换任务 (task-switching task) [22]。在该类任务中，被试需根据给定的规则，从一系列项目中选择符合条件的项目。这些规则会在测试过程中改变，因此被试需要快速适应新规则，调整其选择策略。该任务以转换代价（任务转换条件与重复条件的差值）为指标，测量个体的任务转换能力。较低的转换代价意味着更好的认知灵活性，表明个体能有效地加工新信息，适应变化的环境和要求。任务转换任务在心理学研究以及临床诊断中都有广泛应用，能够帮助识别有认知灵活性障碍的个体，如注意力缺陷多动障碍、老年痴呆症 [23]。而测量情感灵活性的情感转换任务 (affective switching task, AST) 由 De Lissnyder 等人于 2010 年开发 [24]。在 2010 年的原始 AST 中，被试要在四个面孔刺激中根据线索维度（如性别、肤色或情绪）挑选出其中与其他三个不同的一张面孔。而在其他类的情感转换任务中，可能要求被试根据情绪的效价或根据图中人的数量进行分类 [25]。这类任务研究发现个体从负性情绪刺激中转移困难的程度（如从负性情绪加工切换到中性情绪刺激加工）与较低的心理韧性水平 [26]，更高的日常反刍 [27]，以及压力后更差的重评表现相关 [28]。

反转学习任务(reversal learning task)。在反转学习任务中，被试首先学习辨别两个视觉刺激或空间位置，其中一个刺激每次被选择时都会获得奖励，而另一个则不会。当被试表现达到特定的标准，即被试完成辨别学习后，与这两个刺激相关的结果将被反转。被试需要再次进行训练，直至达到新的标准。该任务的目的是评估个体在学习和适应变化的奖励关联时的认知灵活性。通过被试在奖励结果被反转后重新学习过程中的表现，测量其认知灵活性和适应新信息的能力。在该任务中，较快的反转学习成功率代表着更高的认知灵活性，表明个体能更快适应环境的改变，并做出正确的决策 [29]。此外，研究者还发现反转学习能力在强迫症 [30] 和精神分裂症 [31]患者上下降。

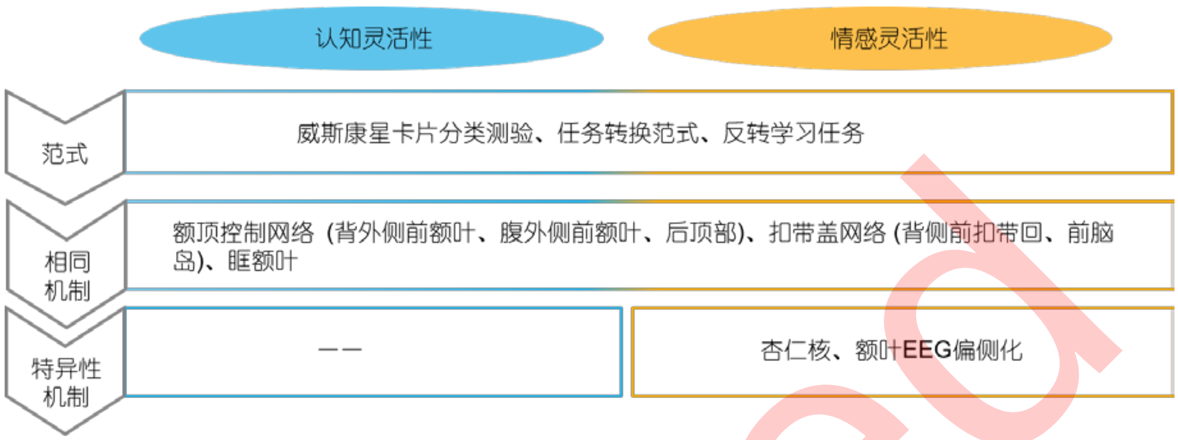

图 2（彩） 认知灵活性和情感灵活性的测量范式以及相同和特异性的加工机制

Figure 2 (color) Paradigms, common and distinct neural mechanisms in cognitive flexibility and affective flexibility

2 正常个体的认知灵活性与情感灵活性的加工机制

2.1 认知灵活性的神经机制

认知灵活性属于“冷”认知控制系统，涉及非情绪背景下自上而下的认知控制加工。采用功能磁共振成像 (functional Magnetic Resonance Imaging, fMRI) 技术，已有证据表明认知灵活性的加工与额顶控制网络和扣带盖网络的加工密切相关。前者的重要脑区包括背外侧前额叶、腹外侧前额叶、额下联合皮层、额下回和后顶部脑区；后者的重要脑区包括背侧前扣带回和前脑岛 [5,32,33]。使用任务转换任务，研究发现左侧额下联合皮层和后顶部脑区参与不同类型转换任务的加工，分别负责任务表征的更新和任务集表征，在认知灵活性加工中起着一般性的作用 [34]。此外，研究发现左侧额下联合皮层的神经变异与认知灵活性大小呈正相关，即该脑区的神经变异越大，被试在任务转换中表现越好 [35]。说明左侧额下联合皮层在认知灵活性的加工中起着重要作用。在一项被试可以自由决定重复或者转换的任务中，研究发现在转换条件下，额下联合皮层、前脑岛、前扣带回和背外侧前额叶皮层的脑激活增强 [36]。在反转学习任务中，研究发现认知灵活性加工涉及其他脑区，包括眶额叶皮层和杏仁核 [29]。这些结果说明额顶网络和扣带盖网络在认知灵活性的加工中起重要作用，而眶额叶皮层和杏仁核在某些条件下也参与认知灵活性的加工。

使用脑电 (Electroencephalography, EEG)/脑磁 (Magnetoencephalography, MEG) 技术，先前研究分别从时间加工进程和神经振荡上考察认知灵活性的加工机制。在时间加工进程上，已有研究发现一些脑电成分（如 P2 和 P3）的幅值在转换条件下

比重复条件下高 [37]。其中，前额 P2 成分与任务集的激活有关，是刺激-反应联结提取的神经指标，而顶部 P3 成分是注意资源分配的指标。这一结果表明认知灵活性的加工在早期是任务集的加工，在晚期涉及注意资源的分配。使用向后抑制任务，该任务能测量认知灵活性加工中的抑制控制过程。研究发现，相比于控制条件，向后抑制条件的 P3 幅值增大，反映了背景更新过程中注意资源分配的增加 [38]。在神经振荡指标上，发现相比于控制条件，下顶部和后顶部的 theta 能量在向后抑制条件下增强 [39]，说明 theta 振荡在任务表征的抑制中扮演着重要角色。使用任务转换任务，脑磁研究发现与重复条件相比，扣带盖网络和额顶网络内部的 alpha 和 beta 频段能量降低，gamma 频段能量增加，并且行为上的转换代价与右侧前额和顶叶下部 alpha 能量的降低呈正相关，与前扣带和颞顶区的 gamma 能量的增加呈负相关，即这些脑区 alpha 能量降低的越多、gamma 能量增加的越多，个体的认知灵活性越高 [40]。这些结果说明 theta，alpha 和 gamma 振荡在认知灵活性的加工中起着重要作用。

2.2 情感灵活性的神经机制

与认知灵活性不同，情感灵活性属于“热”认知控制系统，关注个体在情绪和非情绪刺激之间切换的能力，是大脑对情绪信息的自上而下认知控制的加工 [9,16]。与认知灵活性的加工类似，情感灵活性的加工涉及外侧前额叶、背侧前扣带回、后顶部脑区和前脑岛 [41–43]。采用情感转换任务，发现情感转换激活了额-顶控制网络，并且不对称的转换代价激活了右侧额下皮层和背侧前内侧皮层，这两个脑区可能与增强认知控制从而抑制情绪刺激加工有关 [42]。采用经颅直流电刺激，研究发现对右侧背外侧前额叶的电刺激能够促进个体从情绪刺激到非情绪刺激的切换 [44]。眶额叶皮层被认为是大脑情感回路的中心节点 [45,46]，参与情绪调节。此外，杏仁核在调控情绪反应方面扮演着核心角色 [47]。Pierce 等人 2022 年的研究表明，儿童和青少年在情绪调节任务中杏仁核活动的减少与更强的情感灵活性表现相关 [48]。在情感转换任务中，杏仁核与右侧腹外侧前额叶皮层的功能连接增强 [49,50]。这些结果说明额顶控制网络（外侧前额叶、后顶部）和扣带盖网络（背侧前扣带回、前脑岛），以及眶额叶皮层和杏仁核在情感灵活性的加工中发挥着重要作用。

目前，关于情感灵活性的 EEG/MEG 研究主要集中在额叶 EEG 偏侧化与情感灵活性的关系上。采用 EEG，研究发现静息态的额叶 EEG 偏侧化与情感灵活性紧密相关。额叶 EEG 偏侧化是指左侧和右侧额叶间 alpha 能量的差异。在一项研究中，给被试播放正性和负性声音刺激，发现在静息状态下表现出额叶 EEG 左侧化（左侧

EEG > 右侧 EEG）的被试能够灵活地对情绪刺激反应，并能够高效地从负性刺激中恢复；而额叶 EEG 右侧化的被试对情绪刺激不反应 [51]。使用情绪电影观看任务，研究也发现静息态下额叶 EEG 左侧化的个体有更灵活的情绪反应，额叶 EEG 右侧化的个体表现出较弱的情感灵活性 [52]。这些研究说明额叶 EEG 偏侧化模式能够预测情感灵活性。

2.3 认知灵活性与情感灵活性相同和特异性的加工机制

实证研究发现认知灵活性和情感灵活性共享相同的加工机制。在行为上，Kraft 等人 (2020) 采用基于线索的任务转换任务测量了被试的认知灵活性和情感灵活性，发现两者的转换代价存在正相关 [53]。说明认知灵活性和情感灵活性可能在控制转换效率上共享相同的加工机制。在神经上，不同研究发现认知灵活性和情感灵活性的加工都激活了额顶控制网络（外侧前额叶和后顶部）和扣带盖网络（背侧前扣带回和前脑岛）[5,43]，说明额顶网络和扣带盖网络在认知灵活性和情感灵活性的加工中起着一般性的作用。此外，眶额叶皮层能够进行反应抑制，灵活地表征刺激-结果之间的联系，以及表征情绪 [54]，因此参与认知灵活性和情感灵活性的加工 [29,45]。

也有研究发现认知灵活性和情感灵活性的加工机制具有特异性。杏仁核能够根据当前目标灵活地处理与动机和情绪相关的评价信息，在情感灵活性加工中扮演着重要角色 [55]。尽管采用反转学习任务发现杏仁核参与认知灵活性的加工 [29]，由于反转学习涉及奖赏和学习，与 WCST 和任务转换任务测量的认知灵活性的加工机制不同，因此，本文将杏仁核划分为情感灵活性特异性的脑区。此外，额叶 EEG 偏侧化程度能够预测情感灵活性大小 [51,52]。额叶 alpha 活动强度被认为是测查个体情绪调节能力的指标，alpha 活动越强表明该脑区活动越弱 [56,57]，因此，EEG 偏侧化的结果与 fMRI 研究发现的右侧前额叶在情感灵活性中的加工一致 [44]。说明右侧额叶可能在情感灵活性的加工中扮演着重要角色，并且额叶 EEG 偏侧化可能是情感灵活性的一个特异性加工机制。由于情感灵活性的 EEG/MEG 研究主要集中在额叶 EEG 偏侧化上，缺乏时间加工进程和神经振荡机制的研究，认知灵活性和情感灵活性加工机制的比较主要在 fMRI 脑区和额叶 EEG 偏侧化上（参见图 2 中总结）。

3 异常个体认知灵活性与情感灵活性的加工机制

认知灵活性和情感灵活性有助于个体较好地应对各种非情绪或情绪任务，对个体心理健康有重要影响。当灵活性较差时，个体在认知和行为反应上表现出僵化，情绪调节能力下降，表现出较差的认知和情绪加工能力。而当灵活性受损时，个体将表现出一些心理和精神疾病，比如重度抑郁症 [58]、自闭症 [59]、精神分裂症

[60] 等。本部分将从认知灵活性或情感灵活性严重受损的代表性疾病，比如重度抑郁症、自闭症和精神分裂症，阐述认知灵活性和情感灵活性对心理健康的影响。

3.1 重度抑郁症

重度抑郁症是一种普遍且具有较高自杀倾向的疾病，给患者及其家庭和社会带来沉重负担 [61]。据世界卫生组织披露数据显示, 全球有超过 3.5 亿人罹患抑郁症，近十年来患者增速约 18%。重度抑郁患者主要表现为反刍思维或在应对悲伤情绪或经历时更关注痛苦想法 [62]，这使得重度抑郁患者很难从负性情景中切换出来。重度抑郁患者的认知灵活性和情感灵活性受损，在行为上表现为认知灵活性和情感灵活性比正常个体低 [63]。研究者使用 WCST 发现重度抑郁个体的抑郁程度与认知灵活性下降相关 [64]。在另一项纵向研究中，研究者发现学前儿童认知灵活性受损程度与 5 年后的抑郁程度相关 [65]。这些结果说明认知灵活性和抑郁程度有较强联系。在神经上，一项 fMRI 元分析发现与正常个体相比，重度抑郁患者额顶控制网络功能降低，并且内侧前额叶与海马和杏仁核之间的功能连接降低 [66]。这些结果说明自上而下的认知控制能力减弱，可能使得重度抑郁患者对先前无关任务的抑制能力下降，表现出低认知灵活性。而前额叶对边缘系统（海马和杏仁核）调控能力减弱，可能使重度抑郁患者在情绪背景下表现出低情感灵活性 [67]。

3.2 自闭症

自闭症是一种广泛性发育障碍，主要表现为社会交往障碍（包括语言交流障碍）和重复刻板行为 [68]。尽管自闭症的病因尚不清楚，但已经确定了一些遗传和神经生物学因素 [69]。其中执行功能损伤是自闭症的重要临床表现之一，执行功能涵盖了从童年开始发展的一系列认知操作，包括工作记忆和认知灵活性 [59 70,71]。神经影像学研究发现自闭症患者存在额叶区域的结构和功能改变 [72,73]。大量研究发现，自闭症患者存在认知灵活性困难和社交困难增加 [74]、限制性和重复性行为增加 [75] 以及与行为同时产生的焦虑和情绪低落等症状 [76,77]。鉴于一部分无智力障碍的自闭症成年人报告就业率和独立生活率较低 [78]、人际关系较少 [79] 和生活质量下降 [80]，对自闭症患者认知灵活性的研究和理解将有助于改善他们面临的处境。

3.3 精神分裂症

精神分裂症是一种慢性、经常致残的精神疾病，据估计大约 4.9% 的精神分裂症患者会实施自杀 [81]。精神分裂症患者伴随认知和情绪加工相关的障碍 [60]。大量

研究发现精神分裂症患者的认知灵活性比正常个体低 [63]。采用 WCST，研究发现精神分裂症患者的前额叶活动比正常个体低 [82]。在任务转换加工中，精神分裂症患者全脑功能连接模式表现出较低程度的网络整合和分离，提示精神分裂症患者在总网络水平上的信息沟通效率比正常个体低 [83]。研究者发现，精神分裂症患者对任务转换的监测能力下降，表现为前扣带回的活动在加工正确和错误转换试次的差异上与正常人相比减弱 [84]。然而，目前较少有研究探究精神分裂症患者情感灵活性的加工机制。

综上，与正常个体相比，不同异常群体存在认知灵活性或情感灵活性加工的异常，且在行为和神经上表现不同。比如，重度抑郁症患者的认知灵活性和情感灵活性比正常个体低，在行为上表现为反刍思维和负性情绪解脱困难，在神经上表现为额顶控制网络功能降低，并且额叶与海马和杏仁核之间的功能连接降低。自闭症主要与认知灵活性缺陷有关，表现为重复性和局限性行为，在外侧额顶网络和扣带盖网络上表现出异常 [85]。精神分裂症患者主要表现为认知灵活性下降，伴随着外侧额顶网络和扣带盖网络加工异常 [5]。对不同异常群体的大样本系统分析，将有助于更好地总结其异常模式和提供个性化干预方案。

4 提高认知灵活性与情感灵活性的方法

4.1 认知训练方法

认知训练通常聚焦于执行功能的某一特定方面，如工作记忆、抑制控制或认知灵活性等。目前，认知训练能否提升认知功能存在争议。有研究表明认知训练能提高受训练的特定领域，但难以在认知控制的其他领域进行迁移 [5]。比如，研究发现工作记忆训练很难迁移到抑制控制领域 [86]。由于老年人的认知灵活性下降，较多研究关注认知训练对老年人的影响。大量研究表明认知训练能够提高老年人的认知灵活性[87–89]。一项研究表明认知训练，包括推理、工作记忆和注意方面训练，能够提高老年人的认知灵活性 [90]。此外，老年人大脑在训练后呈现皮层下活动增加以及额叶和顶叶活动减少的模式 [87]，说明认知训练能够改变健康老年人的大脑结构和功能。此外，有研究发现认知训练能够提高自闭症儿童的认知灵活性 [91]。然而，最近一项研究对儿童进行 8 周的抑制训练后没有发现儿童行为或脑的变化 [92]。也有研究发现学龄前儿童的认知灵活性训练对认知灵活性的提升与控制组没有差异 [93]。这些不一致的研究结果可能与不同研究采用了不同的认知训练任务，训练强度和时长有关，也可能与被试的年龄段等因素有关。

4.2 双语训练方法

大量研究表明双语训练能够提高个体的认知灵活性 [94]。可能是因为双语者的两种语言在一定程度上都处于活跃状态，并不断进行选择竞争，从而增强了认知功能 [87]。以往研究发现第二语言学习能够改变大脑的功能和结构，包括额下回脑区，这一脑区与认知灵活性的加工密切相关 [95]。然而，也有研究发现双语者和单语者的认知灵活性表现没有差异。在一项针对老年人的研究中，研究人员发现老人在第二外语学习的前测和后测中，转换代价没有显著差异。作者认为这可能是因为双语训练的时间不够长所致[96]。双语训练对情感灵活性的影响目前缺乏相关研究。

4.3 情绪调节方法

情绪调节是指个体采取特定的策略来影响自己的情绪状态。有效的情绪调节对于维持心理健康、促进个人成长和改善人际关系至关重要。情绪调节方法对提高个体的认知灵活性和情感灵活性有显著作用。在各种情绪调节方法中，正念(mindfulness)、冥想(meditation)和认知行为疗法(Cognitive Behavioral Therapy, CBT)应用比较广泛。正念、冥想依赖于每时每刻对注意力的（重新）投入，因此能增强以非习惯方式做出反应的能力，提高参与者抑制干扰信息以及集中和引导注意力的能力，从而锻炼我们的认知灵活性和情感灵活性 [97]。正念、冥想训练需要关注训练时长，研究表明更广泛的正念训练（8 周以上）能有效改善注意切换能力 [98]。CBT 是一种协作式的心理治疗疗法，它要求患者积极参与并掌握技能，特别是在治疗过程之外的练习和技能使用，来提高患者的适应性思维和认知灵活性能力。研究表明，CBT 能有效提高患者和正常人的认知重评能力，产生更具适应性的想法 [99]。此外，相比于正常个体，抑郁个体的左侧背外侧前额叶的功能连接在时间上的变异降低，而 CBT 能够提高该脑区的神经变异 [100]。这些研究说明 CBT 可能是提高认知灵活性和情感灵活性的一种有效方法。

4.4 基于神经反馈和脑机接口的灵活性训练方法

脑机接口(Brain-Computer Interface, BCI)作为一种新兴的交互技术，允许大脑直接与外部设备通信，为那些因疾病或伤害而失去正常动作能力的人群提供了新的希望。当前，BCI 系统可作为中风后遗症患者运动功能恢复的有效辅助工具。在灵活性训练方面，BCI 的应用也展现出了独特的优势 [101]。例如，在动作灵活性中，众多研究通过运用 BCI 技术，促进了患者的运动功能重建，并通过神经网络增强了运动控制的精细度及其可塑性 [102]。与此同时，神经反馈和 BCI 技术也在健康成年人群的认知增强方面展现了其潜力，特别是在提升注意力调控和加快决策过程方面

https://engine.scichina.com/doi/10.1360/TB-2024-0469

[103]。此外，随着可穿戴 BCI 设备的出现，其应用范围已得到显著扩展。这些设备由于其便携性和对用户日常活动的低干扰性，使得在自然环境中进行灵活且不受约束的认知训练成为可能。此外，在青少年阶段，伴随前额叶功能成熟和神经反馈训练的快速商业化，基于神经信号反馈和 BCI 技术日益受到儿童和家长的青睐 [104]。

以上不同训练方法可能适用于不同人群，因此，需要有针对性的选择提升认知灵活性和情感灵活性的训练方法。例如，包括正念和冥想等在内的情绪调节策略更多针对情感灵活性的提升。此外，虽然大部分方法适用于正常人，但是部分训练方式可能更适合临床病例，如基于神经反馈的方案等。

5 总结与展望

认知灵活性和情感灵活性对个体的心理健康起着重要作用。相比于认知灵活性的研究，情感灵活性的研究较少，且情感灵活性的脑电研究主要集中在额叶 EEG 偏侧化上。通过梳理两者的加工机制，本文发现认知灵活性和情感灵活性有着相同和特异性的加工机制。在相同机制上，两者都与额顶控制网络和扣带盖网络加工密切相关。在特异性加工机制上，情感灵活性表现出额叶 EEG 偏侧化和杏仁核的激活。认知灵活性或情感灵活性异常通常伴随着各种心理健康和精神疾病，包括重度抑郁症、自闭症和精神分裂症等。因此，本文总结了几种提高认知灵活性和情感灵活性的方法，包括认知训练、双语训练、情绪调节和基于神经反馈和脑机接口的灵活性训练方法。在当前研究的现状上，将来研究可以考察认知灵活性和情感灵活性对积极心理的影响、刻画认知灵活性和情感灵活性的发展轨迹、以及使用神经变异对认知灵活性和情感灵活性进行预测。

5.1 认知灵活性和情感灵活性对积极心理的影响

认知灵活性和情感灵活性是幸福感、心理韧性等积极心理状态的重要决定因素 [105]。以往关于幸福感的研究主要集中在社会和环境因素 [105]。然而，幸福感与内部动态紧密相关 [106]，较少有研究从个体的认知灵活性和情感灵活性上考察如何提升主观幸福感。认知灵活性和情感灵活性能够帮助个体有效地处理压力和挑战，从而提高心理韧性。高认知灵活性使个体能够从多个角度看待问题，找到更多的解决方案，减少因固定思维模式带来的挫败感 [107]。同时，高情感灵活性允许个体在面对负面情绪时，能够有效地调节和管理自己的情绪状态，避免情绪过度消极影响决策和行为，从而在挑战面前保持更高的适应性和恢复力 [108]。然而，目前通过训练认知灵活性和情感灵活性来提升心理韧性的研究较少。因此，将来可以从多元文化

适用的幸福感提升角度，探究认知灵活性和情感灵活性对主观幸福感和心理韧性的积极影响。

5.2 刻画认知灵活性和情感灵活性的发展轨迹

情感灵活性是认知灵活性在情绪背景下的表现，在发展轨迹上，情感灵活性的发展可能滞后于认知灵活性的发展。研究表明认知灵活性从童年早期开始发展，在 6-9 岁快速增加，在 10 岁-12 岁达到大部分成熟，之后在青春期逐渐增加，大概在 21 岁达到顶峰 [109]。目前，缺乏情感灵活性轨迹的刻画。值得注意的是，不同种类的心理和精神疾病的易发病时间在个体发展的不同时间点上。比如多动症出现在较早期，而重度抑郁症和精神分裂症较多出现在青少年期 [5]。因此，准确地刻画出认知灵活性和情感灵活性的发展轨迹，有助于构建科学、高效的青少年精神疾病预警、干预和康复模式。

5.3 神经变异对认知灵活性和情感灵活性的预测

近年来，研究发现大脑信号的变异能够较好地预测个体在认知灵活性上的差异。大脑信号的变异，即神经变异，代表着神经系统能够大范围地动态变化和有效地处理外部刺激的能力 [110]。认知灵活性在个体间具有较大的差异，这为使用神经指标来预测行为表现提供了可能性。大量的 fMRI 研究表明，神经信号在时间上的变异能预测认知灵活性 [110,111]。如研究发现扣带盖网络的静息态功能连接在时间上的变化与个体的认知灵活性成正相关 [112]。然而，神经信号变异与情感灵活性关系的研究比较缺乏。在灵活性受损的个体中，神经信号在时间上的变异与认知灵活性和情感灵活性的关系仍不清楚。探究能够预测认知灵活性和情感灵活性的神经变异指标，将有助于认知灵活性受损个体的诊断和治疗。

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Cognitive Flexibility and Affective Flexibility: Processing Mechanisms and Impact on Mental Health

Abstract:

Cognitive flexibility and affective flexibility are closely associated with an individual's mental health. Higher cognitive flexibility and/or affective flexibility are related to better ability to cope with various non-emotional or emotional tasks, increased psychological resilience, emotion regulation ability, and subjective well-being. However, when cognitive flexibility and/or affective flexibility are impaired, individuals may exhibit decreased behavioral performance, and in severe cases, they may exhibit psychological and mental disorders such as major depression, autism spectrum disorder, and schizophrenia. The main objective of this article is to elucidate the processing mechanisms of cognitive flexibility and affective flexibility, as well as the impact of cognitive flexibility and affective flexibility on mental health.

In terms of processing mechanisms of cognitive flexibility and affective flexibility, cognitive flexibility and affective flexibility belong to the "cold" and "hot" cognitive control systems, respectively. Previous research has indicated common and distinct processing mechanisms between the "cold" and "hot" cognitive control systems, however, it remains unclear whether cognitive flexibility and affective flexibility, as subcomponents of cognitive control, share the same processing mechanisms. Regarding the relationship between cognitive flexibility, affective flexibility, and mental health, there is a lack of systematic understanding of the impact of cognitive flexibility and affective flexibility on an individual's mental health, especially in individuals with psychological and mental disorders.

Therefore, this article first introduced the classical paradigms used to measure the cognitive flexibility and affective flexibility, including the Wisconsin Card Sorting Test, task-switching task, and reversal learning task. Then we reviewed studies utilizing these tasks to reveal the mechanisms underlying cognitive flexibility and affective flexibility. We summarized that cognitive flexibility and affective flexibility had common and distinct processing mechanisms. In terms of the common mechanisms, both of them were associated with the frontoparietal network and midcingulo-insular network. In terms of distinct mechanisms, affective flexibility specifically exhibited hemispheric lateralization in the prefrontal cortex and activation in the amygdala. In abnormal individuals, abnormalities in the processing mechanisms of cognitive flexibility or affective flexibility have been observed in individuals with major depression, autism spectrum disorder, and schizophrenia, with different abnormal groups showing distinct behavioral and neural characteristics.

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Next, we summarized several training methods that could enhance cognitive flexibility and affective flexibility, including cognitive training method, bilingual training method, emotion regulation method, and flexibility training based on neurofeedback and brain-machine interfaces method. Finally, we proposed that future studies could investigate the effects of cognitive flexibility and affective flexibility on positive psychology, characterize the developmental trajectory of cognitive flexibility and affective flexibility, and utilize neural variations to predict cognitive flexibility and affective flexibility. This will help to clarify the neural mechanisms of cognitive flexibility and affective flexibility, and provide important reference information for improving neural intervention targets, treatment methods, and recovery approaches for major depressive disorder, autism, and schizophrenia from the perspectives of cognitive flexibility and affective flexibility.

Keywords: Cognitive Flexibility, Affective Flexibility, Mental Health, Neural Mechanisms