·基础、实验与工效·

心理意象对恐惧学习的影响及神经机制*

金雨萌[1] 王艺桢[2] 张 婕[2] 王金霞[1] 窦皓然[1] 张火垠[1,3] 雷 怡**[1]
（[1]四川师范大学脑与心理科学研究院，成都，610066）
（[2]华南师范大学心理学院，广东，518100）（[3]深圳大学心理学院，深圳，518060）

摘 要 基于心理意象的条件性恐惧范式研究发现，以心理意象为辅助的干预方法为焦虑相关精神障碍的临床治疗提供了关键的参考依据。首先，从心理意象与恐惧的关系探讨了心理意象在其特征、神经机制和发生发展的时间机制方面对恐惧的影响，发现视觉心理意象在影响恐惧情绪方面具有与实际感知相同的效果；其次，作为临床干预方法的意象暴露与意象重写等可消退个体消极心理意象产生的恐惧；最后，从条件性恐惧范式研究的不足出发，讨论了未来可以基于心理意象的恐惧学习继续开展神经机制和临床干预方面的研究，如继续探索恐惧泛化的神经机制和利用多种干预技术促进恐惧消退等。

关键词 心理意象 恐惧学习 意象暴露 意象重写

1 引言

心理意象（mental imagery）既是一种行为（Lang, 2016），也是一种内部感知（Suggate & Lenhard, 2022），能够在没有直接外部刺激的情况下，产生感官上的表征并伴随着相应的体验（Burleigh et al., 2022; Pearson, 2019）。心理意象有多种感官形式（Brogaard & Gatzia, 2017），包括视觉心理意象、听觉心理意象等。在本文中，除特别说明外，“心理意象”特指视觉心理意象。

患焦虑相关精神障碍的群体通常会对无任何实际危险刺激表现出过度恐惧反应（Ji et al., 2015; Michopoulos et al., 2017），这可能是由于他们在脑海中不由自主地产生了威胁的心理意象（Morina et al., 2011; Pile & Lau, 2019）。这种心理意象往往与患者的核心恐惧有关，并会引发身体和情绪症状（Brewin et al., 2010; Stavropoulos et al., 2024），包括侵入性的记忆闪回（flashback）以及对未来事件具体且痛苦的心理意象（Chiu et al., 2022）。这些心理意象具有生动的图像和声音，进而加重了他们的病理性恐惧（Chen et al., 2018; Dunsmoor & Paz, 2015; Holmes & Mathews, 2005）。因此，对这类人群进行基于心理意象的干预可以降低他们的恐惧（Hunt & Fenton, 2007; Thoresen et al., 2016）。基于此，本文通过梳理过往研究，从心理意象与恐惧的关系出发，探讨心理意象对恐惧学习的影响及未来可能的研究

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** 通讯作者：雷怡，E-mail：leiyi821@vip.sina.com
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方向，这对于焦虑相关的精神障碍患者的治疗有重要的临床意义。

2 心理意象与恐惧

2.1 心理意象的可描述性、生动性和可加工性

心理意象可与任何感知方式产生联系，让人们在脑海中重现或构造出与实际感官经验相似的体验（Williams et al., 2017）。负性心理意象在各类焦虑障碍的发生发展中起着关键作用。例如，创伤后应激障碍（posttraumatic stress disorder, PTSD）的核心症状之一是闪回，患者会不自主地反复“看到”或“感受到”创伤事件，由此引发严重的焦虑及恐惧（Clark & Mackay, 2015）。这种负面心理意象具有三个突出特征：可描述性、生动性和可操作性。这些特征共同影响个体的恐惧感知和反应。

首先，可描述性指的是心理意象能够被具体地报告（Ji et al., 2019; Pearson et al., 2015）。如焦虑群体往往会经历更具体的负性侵入性心理意象，包括过去的创伤记忆（Guarnera et al., 2019）和对未来产生担忧（Beck & Clark, 1997）。其次，在生动性上，高生动度的威胁心理意象会引发更强的恐惧（Hoppe et al., 2022; Stopa & Jenkins, 2007）。例如，患有 PTSD 的青少年报告的负性心理意象更频繁、更生动、更令人痛苦；在经历负性心理意象时，他们报告了更多的厌恶、无助、内疚、无价值感、焦虑以及愤怒的感觉（Lawrence et al., 2023; Steil et al., 2022）。最后，心理意象还具可操作性。改变已有的心理意象及其相关意义会影响个体的情绪和行为（Di Corrado et al., 2020; Gravano et al., 2021; McCarthy et al., 2022），如将未来事件的负性心理意象转变为积极心理意象后，个体会变得更乐观（Renner et al., 2014, 2021）和更能接纳自我（Zhou et al., 2020）。此外，恐惧的增加会提高个体操作心理意象的速度（Kaltner & Jansen, 2014）。因此，在利用心理意象干预恐惧时，相对于健康群体，焦虑患者操作心理意象的速度会更快，且积极心理意象强化他们积极情绪的效果也更好。

2.2 心理意象的神经机制

初级视觉皮层（primary visual cortex, V1、V2 和 V3）在形成心理意象时扮演着关键角色，这是由于眼睛看不到的部分可能由心理意象来补充（Huang et al., 2024; Keogh & Pearson, 2014; Nanay, 2021; Pearson et al., 2015）。V1 区能够处理实际的视觉输入以及心理意象，它的表面积与心理意象的强烈程度呈负相关（de Borst & de Gelder, 2019; Pearson, 2019）。V2 和 V3 区在形成心理意象的过程中编码视觉刺激，与心理意象的精确度呈正相关（Bergmann et al., 2016; Greening et al., 2022）。此外，心理意象与真实视觉在 V3AB 区（枕顶叶交界处）所引发的神经激活模式没有显著差异（Li et al., 2023）。因此，心理意象与真实视觉存在神经相似性。

除视觉皮层外，心理意象的加工还涉及多个其他脑区。比如，海马能够形成具有空间分布特征的心理意象（Pearson, 2019），杏仁核与前扣带回能够形成关于特定事件的心理意象（Ji et al., 2016）。此外，不同类型的心理意象可以激活不同的脑区。恐惧心理意象会激活脑岛、丘脑、杏仁核、海马等（Dymond et al., 2015）；中性心理意象会激活与运动控制、语言和注意力相关的区域（Hoppe et al., 2021）；正性心理意象会激活伏隔核（nucleus accumbens, NAc）和内侧前额皮层等。其中，恐惧相关脑区在心理意象和真实感知加工时会有相似的激活模式（Adhikari et al., 2015），如在心理意象产生的过程中，特定恐惧症患者的躯体感觉皮层也会有明显激活（Hunt et al., 2006）。因此，基于这些发现，未来研究可以在神经激活模式的相似性、差异性基础上探讨观看真实图像和形成心理意象时神经激活模式的相互影响。综上所述，在心理意象中，个体可能会经历与实际感知相似的感官体验。以下将从心理意象发展的时间进程进一步了解心理意象与恐惧之间的关系。

2.3 心理意象发生发展的时间进程

前人使用事件相关电位（event-related potentials, ERPs）探究了面孔心理意象发生发展的时间进程。首先，当个体形成面孔心理意象时，会引发后腹外侧枕颞叶皮层更强的 N170（170ms），这揭示了面孔识别的早期神经活动。接着，颞枕部的 P2（200~260ms）有效反映了自上而下的心理意象信号和自下而上的感知信号的整合（Ganis & Schendan, 2008; Lu et al., 2017）。另外，这种面孔的心理意象会诱发早期后部负电位（early posterior negativity,

EPN, 200~300ms），它可能与心理意象导致的情绪增强有关（Suess & Abdel Rahman, 2015; Yamamoto & Mukai, 1998）。在更晚期的电位研究中，相对于无意象关联的刺激，与负性心理意象相关的刺激会诱发更强的 P3（280~360ms）（Wang et al., 2024）。在形成负性心理意象后的 300ms（MacNamara, 2018）到 400ms（Bauer & MacNamara, 2021）之间，晚期正电位（late positive potential, LPP）会显著增强，并会提高唤醒度和不愉快度（MacNamara, 2018）。这些 ERPs 成分的发现有助于理解心理意象的时间动态及其与情绪和感知过程的交互作用。通过分析不同时间窗口的 ERPs 成分，可以揭示心理意象形成过程中的关键阶段，有助于深入理解心理意象和情绪加工的认知过程，为未来的研究提供了新的视角和思路。

综上所述，心理意象显著影响情绪体验。心理意象和情绪存在广泛的相互作用，尤其是恐惧。以下将从条件性恐惧作用的角度出发，探讨心理意象对恐惧学习的影响及神经机制。

3 心理意象对恐惧学习的影响及神经机制

条件性恐惧范式是研究恐惧和焦虑相关障碍病因学的主要范式之一，包括恐惧习得、消退和泛化等（Maren, 2001; Mertens et al., 2020）。恐惧条件反射（fear conditioning）可以塑造行为、改变认知和情绪反应。在该范式中，一个中性刺激作为条件刺激（conditional stimuli, CS）与令人恐惧的无条件刺激（unconditional stimuli, US）多次配对，从而使个体能够在没有 US 的情况下对 CS 产生条件反应（conditional response, CR）。CS+ 是指与 US 配对的条件刺激，CS– 是指不与 US 配对的条件刺激。有研究者将心理意象应用于条件性恐惧范式以探究其对恐惧学习的影响。

3.1 恐惧能够通过心理意象习得

条件刺激 CS 与无条件刺激 US 反复配对后，即使没有 US 出现，个体仍会对 CS 产生条件反应，这一过程被称为恐惧习得（Espinosa et al., 2022）。以往研究发现，心理意象能够习得恐惧（Mueller et al., 2019）。在比较真实感知与心理意象在恐惧习得中的作用后，研究者发现个体在心理意象条件下，对 CS+ 的恐惧大于 CS–，表明个体成功习得恐惧（Burleigh et al., 2022）。进一步研究显示，在心理意象与视觉习得阶段，枕极和外侧枕叶皮层均显著激活，且右侧前脑岛在观看刺激和心理意象条件下的激活没有差异（Burleigh & Greening, 2023; Greening et al., 2022）。然而，当利用心理意象反复习得恐惧后，恐惧会保留更长时间（Joos et al., 2012）。此外，在恐惧习得的过程中，威胁心理意象能够改变个体的生理反应（Williams et al., 2017）。这也许与个体的防御机制有关，当遇到威胁时，个体会出现“战或逃”反应，或在某些情况下表现为冻结（freezing）行为。有研究发现，当个体产生威胁相关的心理意象时也会出现冻结反应（Hagenaars et al., 2015），以此获得更好的注意力，为快速行动做好准备，有助于了个体预测未来事件的潜在结果并根据预期调整行为（Chiu et al., 2022）。这种预测和行为调整的能力，是个体适应环境变化、优化生存机会的关键因素。因此，心理意象在恐惧习得中不仅影响恐惧记忆的形成和维持，还与个体的生理反应和防御机制紧密相关，它有利于焦虑相关精神障碍患者在面对不确定性时做出更加合理的选择。

综上所述，心理意象与真实感知在恐惧习得上有相似的神经基础。据此可以推测在恐惧习得过程中心理意象加工的潜在机制。首先，心理意象信号激活视觉皮层进行“自下而上”的加工，然后，高级认知相关脑区对其完成“自上而下”的评估并发出反应的指令。例如，高焦虑者对威胁具有持久的注意偏向（Mogg & Bradley, 2018），而威胁刺激会让个体加速产生负性心理意象及回避反应（Borst & Kosslyn, 2010），也会给焦虑症患者带来更多的侵入性痛苦（Starr & Moulds, 2006）。因此，未来也要更关注心理意象对焦虑症发生发展的作用，如负性心理意象可能恶化焦虑、积极心理意象能够缓解焦虑等问题。

3.2 视觉感知恐惧能够泛化到心理意象

个体在习得恐惧后，这种恐惧并不局限于特定的威胁刺激 CS+，而是对与其相似的刺激也会产生恐惧反应，这种条件性恐惧的转移被称作恐惧泛化（Dou et al., 2022; Dymond et al., 2015; Lissek et al.,

2014）。在泛化过程中，与 CS+ 相似的刺激称为泛化刺激（generalized stimuli, GS）。有研究发现，现实习得的恐惧与心理意象习得的恐惧可以相互泛化。例如，被试先习得对右偏光栅的恐惧，随后在听到形成右偏光栅的心理意象指令时，同样会产生恐惧反应，反之亦然，该结果表明感知习得的恐惧会泛化到相应的心理意象（Burleigh et al., 2022; Burleigh & Greening, 2023），心理意象习得的恐惧也会泛化到相应的感知中去（Siegel et al., 2017）。另外，心理意象可以实现对刺激的恐惧泛化，与 CS+ 相似的 GS 也能引发个体的恐惧反应（Meulders et al., 2015）。一项研究发现了被试在习得 CS 与 US 之间的联结后，无论是通过心理意象还是真实感知，对 GS 的恐惧在泛化阶段都显著增强（van Dis et al., 2024）。在临床上，PTSD 和焦虑症等患者常常报告他们会受到生动且令人痛苦的侵入性心理意象困扰（Meulders et al., 2015; Meulders & Vlaeyen, 2013; Steil et al., 2022）。这可能是由于他们在经历了创伤性事件后，与创伤相关的各种刺激都可能诱发他们强烈的恐惧和焦虑反应，即使在安全的环境中，也能够触发他们的侵入性心理意象，这种现象与恐惧泛化紧密相关。

综上所述，心理意象与真实感知的恐惧可以相互泛化，并且心理意象能够激发与创伤或恐惧相关的认知和情感反应（López-Pérez et al., 2022; Pratt et al., 2004），也会对创伤相似的刺激产生泛化反应，进而维持了焦虑相关精神障碍患者的恐惧。然而，心理意象也能消除恐惧，它能够降低 US 的负性效价（Dibbets et al., 2018）。因此，利用心理意象消除焦虑个体的过度恐惧对他们具有重要意义。以下将从心理意象消退恐惧的角度进行讨论。

3.3 心理意象能够消退恐惧记忆

恐惧消退是指个体反复暴露于不再伴有 US 的 CS 中时，CR 逐渐消失，从而实现消除恐惧的过程（Hermans et al., 2006）。心理意象的消退也可以减少恐惧条件反应（Jiang & Greening, 2021）。心理意象消退主要通过初级感觉皮层、腹内侧前额皮层（ventromedial prefrontal cortex , vmPFC）、杏仁核和伏隔核（nucleus accumben, NAc）之间的相互作用来更新与条件刺激有关的表征，从而改变威胁反应（Reddan et al., 2018）。Reddan 等人（2018）的研究发现，心理意象消退和真实消退的神经机制相似，其中 vmPFC 作为中心枢纽在恐惧消退时的激活缓慢增加。然而，心理意象与真实感知在消退过程中的神经机制也并不完全一致。NAc 的激活强度可预测心理意象消退的效果，而海马则与真实感知消退效果有关（Reddan et al., 2018）。也有研究者提出真实的消退会激活 vmPFC，但心理意象的消退会减少杏仁核的激活（Nitta et al., 2019）。还有研究探讨了恐惧消退之后，心理意象是否能够重新激活恐惧及其再消退，结果发现与真实感知消退相比，心理意象可能更有利于恐惧消退（Grégoire & Greening, 2019; Hoppe et al., 2022; Keogh & Pearson, 2011）。

综上，心理意象可以与真实感知一样习得恐惧并泛化，也能够消退已经习得的恐惧。以往研究发现，相比用单一 CS 进行消退，利用新的 GS 或在 CS 的基础上加入 GS 进行恐惧消退后，恐惧的保留会更少（Lipp et al., 2020）。因此，相对于只有 CS 的心理意象，GS 的心理意象对消除恐惧的效果可能更好，未来研究可以更关注将心理意象的泛化刺激用于恐惧消退的效果。

个体在现实中遭遇的负性事件留下的创伤性记忆会引起强烈的负性情绪，在许多临床研究中发现，利用心理意象可以改写侵入性记忆。在临床干预中加入心理意象作为辅助，可以有效加强对病理性恐惧的干预效果，主要包括意象暴露疗法和意象重写疗法（Pile et al., 2021）。以下内容将讨论心理意象在临床研究中对恐惧的影响。

4 临床心理意象对恐惧的影响

4.1 意象暴露对恐惧的影响

意象暴露（imaginal exposure, IE）是将个体反复暴露于恐惧相关的心理意象（Rus-Calafell et al., 2013），以降低恐惧记忆带来的痛苦（Pile et al., 2021）。意象暴露疗法对 PTSD 患者的治疗效果优于其他传统治疗方法（McLean et al., 2022; Shemesh et al., 2011），能够更好地改善 PTSD 症状（Cusack et al., 2016），这是因为意象暴露能够使个体在不直接接触创伤性情景的条件下消除条件性恐惧。

在意象暴露的过程中，由于心理意象能够生动

地重现创伤性经历，因此精确控制暴露的持续时间对于治疗效果和患者安全至关重要。一般来说，10分钟的暴露比6小时的暴露能更好地实现恐惧消退（Agren et al., 2017）。还有研究者提出，闪点暴露（即在10mins内每隔6s进行一次7s的暴露）能够替代10分钟的持续暴露（Hoppe et al., 2021）。简短干预会获得更好的效果，可能是由于在短时间内多次暴露于恐惧刺激中诱发了个体更强烈的恐惧，这种恐惧与生活中突如其来的创伤场景引起的恐惧相似，而长时间的暴露或许更适用于有长期创伤经历的个体。因此，未来研究可以更详细地区分个体的恐惧类别，并探索找到分别适用于缓解长期与短期创伤的意象暴露方法。

4.2 意象重写对恐惧的影响

意象重写（imagery rescription, IR）是指个体首先形成生动的创伤性心理意象，然后重写一个更新的、更安全的结局，这使个体能够修改创伤的意义（Paulik et al., 2021; Strachan et al., 2020）。这项技术侧重于个体对事件的解释，促使个体能够在心理意象形成的过程中表达出被抑制的情绪（Kunze et al., 2019）。

焦虑个体较多的忧虑（Feng et al., 2020）和较高的焦虑（Monzel et al., 2023）往往会造成其负性侵入意象增多（Hirsch et al., 2015），而积极心理意象能够减少负性情绪（Landkroon et al., 2022）。所以，如果个体可以在脑海中建构未来的积极图像，就更有可能获得积极的体验（Blackwell et al., 2020）。意象重写能够将负性心理意象改写为正性心理意象，从而有效干预焦虑相关精神障碍症状。例如，社交焦虑的个体在经历意象重写后，他们关于自我、他人、世界和心理意象本身所代表的核心信念变得更积极（McCarthy et al., 2022）；PTSD患者的创伤性回忆被重写后，它的侵入性和痛苦程度都显著降低（Langkaas et al., 2017）。有研究比较了意象重写与其他干预方法的效果，例如，对于童年创伤性记忆，意象重写与一般疗法的效果无异（de Haan et al., 2020），它可以将过往的负性记忆改写成更加积极的记忆，减少创伤性经历带来的影响。然而，另一些研究者发现，相对于直接改变恐惧情景，个体在意象重写过程中的皮肤电显著更低，主观痛苦程度更小（Dibbets et al., 2012; Hagenaars & Arntz, 2012）。由于意象重写时涉及对记忆的改变，它可能会激活心理意象相关脑区和记忆相关脑区，因此，未来可以对意象重写的神经机制做更多探索。

综上所述，心理意象可以在脱离现实情景时消退恐惧。意象暴露和意象重写是最常用的基于心理意象的干预方法，两者效果有所差异。有研究者认为意象暴露仅仅改变了与创伤相关的恐惧，但意象重写可以改变创伤的意义（Kindt et al., 2007），因此意象重写比意象暴露有更持续的效果（Nitta et al., 2019）。这可能是由于意象重写使用的是更贴近生活情景或事件的心理意象，而意象暴露是单个刺激的心理意象，二者诱发的恐惧强度或类型不同，未来研究可以进一步比较这两种方法对于消退恐惧的效果。

5 总结与展望

焦虑是一种常见的情绪障碍，可分为广泛性焦虑、社交焦虑、惊恐障碍等多种亚型，其中恐惧是焦虑的主要情绪成分（Borkovec, 1985），而侵入性心理意象和闪回是焦虑相关障碍的典型症状。心理意象具有可描述性、生动性和可加工性，影响着个体对恐惧的感受和反应。心理意象形成时会激活与真实感知相似的脑区，如视觉皮层和NAc等；此外，心理意象可以替代真实刺激对恐惧学习产生影响，包括恐惧习得、消退和泛化；最后，基于心理意象的治疗方法中，意象重写会有较好的干预效果。因此，心理意象对于焦虑相关精神障碍的发生发展以及干预具有重要作用，结合心理意象本身的特点，未来的研究可以集中在以下几个方面：

第一，关注心理意象在恐惧泛化中的神经机制。大量研究发现，恐惧的过度泛化是焦虑障碍患者的核心症状之一（Struyf et al., 2018）。恐惧泛化会受到心理意象的影响。例如，侵入性记忆能够诱发从未发生过的“创伤”性记忆（Blackwell, 2021; McEvoy et al., 2022），这种泛化与心理意象的条件性恐惧习得有关（Lewis et al., 2013）。因此，研究心理意象与条件性恐惧泛化的关系具有重要意义。由于心理意象与真实感知的相似性，心理意象与真实刺激的恐惧泛化可能也有类似的神经活动，然而

目前基于心理意象的恐惧泛化的神经机制尚不清楚，未来可以探讨心理意象与恐惧泛化之间的神经机制联系，以利于我们理解和干预焦虑相关精神障碍。

第二，关注应用心理意象在干预恐惧消退过程中的神经机制。心理意象是一种内部生成的视觉体验，它涉及视觉皮层的活动，模拟了真实视觉刺激时的神经反应模式。有研究显示，对视觉皮层进行抑制性的重复经颅磁刺激（rTMS）能够降低侵入性情绪的强度（Herz et al., 2022），并且，通过对视觉皮层的认知干预，如执行视觉空间任务，可以降低心理意象的生动性及其情绪影响（Agren et al., 2023）。除此之外，在理解视觉皮层对心理意象影响的基础上，可以进一步探索背外侧前额叶皮质（dorsolateral prefrontal cortex, DLPFC）与海马在干预负性心理意象上的作用。DLPFC 与海马在情绪和记忆过程中的紧密联系以及它们在社交焦虑障碍治疗中的显著激活变化（Santos et al., 2019），表明这些脑区可能在恐惧的形成和消退中扮演着关键角色。具体来说，DLPFC 参与情绪调控，而海马则作用于情绪性刺激的编码和长时记忆的形成（Behrendt, 2013; Fernández-Ruiz et al., 2019; Ganella et al., 2017; Han et al., 2023; Oliva et al., 2020; Schneider et al., 2017）。这表明，DLPFC 和海马在处理真实感知刺激和形成或消退心理意象中均起到关键的作用。值得注意的是，侵入性心理意象可能因长时记忆形成过程中背景信息的整合不足而产生（Malcolm et al., 2015），这进一步强调了这些脑区在心理意象中的重要性。因此，通过 rTMS 等技术调节 DLPFC 的活动，可能间接调节海马的功能，从而影响情绪性刺激的编码和长时记忆的形成，为减少情绪性侵入性记忆提供一种新的治疗策略。

第三，探索生动心理意象对恐惧的影响。在健康个体形成心理意象时，往往需要付出更大的努力使其更生动（Pearson et al., 2011）。然而，焦虑相关精神障碍个体能够在不需要刻意努力的情况下，仅仅外部刺激或内在联想就能够产生生动的心理意象（Pearson & Westbrook, 2015）。然而，他们往往会对生动的心理意象进行负性解释，从而导致更多的回避行为（Holmes et al., 2009; Schneider et al., 2018），也会带来更多的侵入性痛苦（Gagnepain et al., 2017; Starr & Moulds, 2006）。所以，未来研究可以考虑如何降低焦虑群体的心理意象生动程度，以找到更有效减轻焦虑的方法。

第四，关注焦虑相关精神障碍患者与健康群体在加工恐惧相关心理意象时的脑激活差异。最新的研究表示，在对字母形成心理意象时，相较于健康个体，焦虑症患者的左内侧额上回更容易被激活（Tomasino et al., 2024）。然而，另一项研究显示，在意象重写过程中，惊恐障碍患者相较于健康人群来说前额叶皮层的激活更少（Burkhardt et al., 2019）。这种矛盾可能使临床治疗产生不确定性。未来研究可深入探讨健康个体与焦虑相关精神障碍患者在形成心理意象过程中的脑区结构和功能差异，为提出更精准的治疗方案提供支持。

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The Impact of Mental Imagery on Fear and its Neural Mechanisms

Jin Yumeng[1], Wang Yizhen[2], Zhang Jie[2], Wang Jinxia[1], Dou Haoran[1], Zhang Huoyin[1,3], Lei Yi[1]

([1] Institute for Brain and Psychological Sciences, Sichuan Normal University, Chengdu, 610066)

([2]South China Normal University School of Psychology, Guangdong, 518100) ([3] School of Psychology, Shenzhen University, Shenzhen, 518060)

Abstract Anxiety is a prevalent emotional disorder that can be divided into several subtypes, including generalized anxiety disorder, social anxiety disorder, and panic disorder, all of which are characterized by fear as the primary emotional component. Mental imagery, a complex cognitive phenomenon, is characterized by the generation of sensory representations in the absence of direct sensory input, and is particularly relevant to the study of visual perception and its associated neural correlates. The current review examines the role of visual mental imagery in the context of fear and anxiety, its neural underpinnings, and potential therapeutic applications.

The discussion of the relation between mental imagery and fear begins by examining the impact of mental imagery on fear with respect to its defining attributes, neural substrates, and the temporal course of its manifestation. Research has revealed that mental imagery, serving as a "simulation" akin to actual visual perception, engages a multitude of brain regions that are identical to those activated during genuine sensory experiences. Consequently, this mental simulation exerts equivalent effects on the induction and modulation of fear responses. The neural underpinnings of this phenomenon implicate a complex interplay between the sensory cortices. Visual mental imagery is known to engage the primary visual cortex (V1, V2, and V3), with a robust body of neuroimaging research highlighting the similarities in neural activation patterns between actual visual perception and mental imagery. The vividness and modifiability of mental imagery are critical in shaping emotional responses, particularly fear, which is a cardinal feature of various anxiety disorders. Individuals with anxiety-related conditions may exhibit exaggerated fear responses to innocuous stimuli due to the involuntary generation of threatening mental images that are closely linked to their core fears and can provoke both physiological and emotional responses. The neural substrates of mental imagery have been extensively investigated, with studies demonstrating that the primary visual cortex is involved in processing both actual visual stimuli and mental imagery. The cortical surface area of V1 has been found to be negatively correlated with the intensity of mental imagery, suggesting a role in the modulation of imagery vividness. The temporal dynamics of mental imagery have been studied using event-related potentials (ERPs), revealing early neural activities associated with face recognition, such as the N170 component, which occurs around 170ms post-stimulus onset. The integration of top-down imagery signals with bottom-up perceptual signals is reflected in the P2 component (200ms-260ms). Furthermore, the early posterior negativity (EPN) and late positive potential (LPP) components have been implicated in the emotional response associated with mental imagery, with enhanced activity observed during the processing of negative mental imagery.

Additionally, the recruitment of other brain regions, such as the hippocampus and amygdala, during mental imagery processing points to a distributed neural network underlying the generation of imagery related to fear. Mental imagery has been shown to influence the acquisition, generalization, and extinction of conditioned fear responses. Fear conditioning, a well-established paradigm in the study of fear and anxiety, involves the pairing of a neutral stimulus (CS) with an aversive stimulus (US), leading to the development of a conditioned response (CR) to the CS in the absence of the US. Research has indicated that mental imagery can facilitate the acquisition of fear, with the imagined presence of a threat capable of eliciting a fear response similar to that provoked by actual perception. Moreover, fear acquired through perception can generalize to mental imagery, thereby perpetuating the cycle of fear in individuals with anxiety-related disorders. Subsequently, clinical interventions utilizing mental imagery, such as imaginal exposure and imagery rescripting, have demonstrated efficacy in the treatment of anxiety-related disorders. Imaginal exposure involves the repetitive presentation of fear-related mental images to attenuate the distress associated with fear memories. Imagery rescripting allows individuals to alter the narrative of traumatic memories by envisioning a new, safer outcome, thereby modifying the emotional significance of the memory. Both approaches have shown promise in reducing fear and improving symptoms associated with anxiety-related disorders.

Finally, acknowledging the limitations of current research within the conditioned fear paradigm, the discussion shifts towards the potential for future studies to further explore the neural mechanisms and clinical interventions related to fear learning from the perspective of mental imagery. This approach could provide novel insights into the intricate interplay between mental imagery and fear, offering a more comprehensive understanding of the cognitive and neural processes that underlie fear conditioning and its modulation. By leveraging the unique advantages of mental imagery as a research tool, future studies can contribute to the development of more targeted and effective therapeutic strategies for the treatment of fear-related disorders, ultimately enhancing the effectiveness of clinical interventions and improving patient outcomes.

In conclusion, mental imagery represents an important avenue for understanding and treating anxiety-related psychological conditions. The vividness and malleability of mental imagery, its neural correlates, and its impact on fear learning and extinction offer valuable insights for the development of targeted therapeutic interventions. Future research endeavors should focus on delineating the neural mechanisms underlying mental imagery in the context of fear generalization and extinction, investigating the effects of vivid mental imagery on fear, and examining the differential neural activation patterns between individuals with anxiety-related disorders and healthy controls during the processing of fear-related mental imagery. These investigations have the potential to enhance our understanding of the role of mental imagery in fear and anxiety, thereby informing the development of more effective treatment strategies.

Key words mental imagery, fear conditioning, imaginal exposure