

综述

## 基于心跳知觉的内感知研究进展

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**[摘要]** 早期经典的一些情绪理论中, 心理学家JAMES提出情绪是对身体生理变化的知觉, 即生理变化(如心跳加快)先于恐惧、紧张等情绪产生。之后有研究者将人体对其身体内部生理信号(如心跳、呼吸、胃肠蠕动等)的感知能力定义为内感知。其中心跳知觉的行为学评估受到广泛关注。目前较为公认的观点认为内感知可从准确性、敏感性、意识三大维度进行测量; 多个研究表明内感知同情绪体验强度高度相关, 且在患有焦虑障碍、抑郁障碍、精神分裂症等精神障碍的临床群体中, 亦可观察到内感知的变化。借助功能磁共振成像等技术, 研究者发现大脑岛叶可能为内感知过程的中枢, 这同情绪体验的活动脑区有重叠, 为情绪理论提供了神经解剖学证据。近年来, 越来越多的研究聚焦于内感知领域。国内已发表的相关综述大多侧重于心理学方面, 尚缺乏内感知紧密联系临床的综述发表。该文就基于心跳知觉的内感知维度、测量方法、研究技术及其在临床上的相关研究进行综述, 并对内感知的研究方向进行了展望。

**[关键词]** 内感知; 心跳知觉; 内感知准确性; 内感知敏感性; 岛叶; 精神障碍

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## Progress of interoception based on heartbeat perception

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**[Abstract]** In some early classical emotional theories, psychologist JAMES has proposed that emotions are the perception of physiological changes in the body, *i.e.*, physiological changes (such as rapid heartbeat) occur before emotions such as fear and tension. Later, researchers defined the human body's ability to perceive internal physiological signals (such as heartbeat, breathing and gastrointestinal peristalsis) as interoception, in which behavioral evaluation of heartbeat perception has received extensive attention. At present, it is generally accepted that interoception can be measured in three dimensions, *i.e.*, accuracy, sensitivity and awareness. Several studies have shown that interoception is highly correlated with the intensity of emotional experience, and the changes in interoception can also be observed in the clinical groups suffering from anxiety disorder, depression disorder, schizophrenia and other mental disorders. Using functional magnetic resonance imaging and other techniques, the researchers has found that the insula may be the center of interoception, which overlaps with the active brain regions of emotional experience, providing the neuroanatomical evidence for the emotional theory. Recently, more and more studies focus on the field of interoception, but the published domestic reviews mostly concentrated on psychology without connection with clinical practice. Therefore, this paper comprehensively reviews the interoceptive dimensions, measurement methods, research techniques and clinical researches based on heartbeat perception, and prospects the research directions of interoception.

**[Key words]** interoception; heartbeat perception; interoceptive accuracy; interoceptive sensitivity; insular; mental disorder

感知大致可以分成3类, 分别是外感知、本体感知和内感知。外感知是指对外部环境刺激的感知能

力, 本体感知是感知身体部位位置及姿势的能力, 而内感知是感知身体内部信号(如呼吸、心跳、胃肠道

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蠕动、激素水平等)的能力。近年来,研究者们发现内感知的变化与情绪的产生相关,甚至可能导致精神障碍。其中心跳知觉相比较于其他内感知更易于测量,具有一定代表性;近期国内已有侧重心理学方面的相关综述发表,但其在临床上的意义讨论较少。故本文就基于心跳知觉的内感知维度、测量方法、研究技术及其在临床上的研究进行综述。

## 1 内感知的维度及测量方法

内感知的3个维度由GARFINKEL等<sup>[1]</sup>提出,后被描述为内感知准确性、敏感性及意识。

### 1.1 内感知准确性

内感知准确性即感知身体内部信号的客观准确度。经典的评估方法有2种:①心跳追踪任务。让被试者将注意力集中在自己的身体上,给定几个时间间隔,要求他们在时间间隔内计数自己的心跳次数;同时连接心电图,记录其真实心率,据此计算被试者的心跳知觉分数,即 $(\text{实际心跳数}-\text{计数心跳数})/\text{实际心跳数}$ 。此分数越高说明内感知准确性越差<sup>[2]</sup>。该公式后被改良为 $1/N \sum (1-|R-C|/R)$  ( $N$ 为时间间隔数, $R$ 为实际心跳数, $C$ 为被试者计数心跳数),根据该转换,心跳知觉分数可以在0到1之间变化,分数越高,表示内感知准确性越高。②心跳识别任务。给予被试者周期性的外部刺激(如闪光等),要求其判断这个外部刺激与自己心跳是同步的( $S+$ ,即刺激出现在R波后128 ms)还是不同步的( $S-$ ,即刺激出现在R波后384 ms)。计算被试者的标准化准报(hits)率和标准化误报(false alarms)率之间的差值来计算反应偏差,即 $d'=z(\text{hits})-z(\text{false alarms})$ ;  $d'$ 越大,说明内感知准确性越高<sup>[3]</sup>。比较上述2种经典测量方法,对前者的争议更大。WINDMANN等<sup>[4]</sup>通过远程操作将装有心脏起搏器患者的起搏器设置为高、中、低3档起搏心率,同时执行心跳追踪任务,发现高起搏心率患者心跳知觉分数显著下降,并推测知觉分数更多反映的是人们对心率的“信念(beliefs)”,而非对心跳真实的敏感性。另有研究表明<sup>[5-6]</sup>,心脏知觉分数可能受到所设时间间隔长短及被试者对心率的先验知识所影响,且心率慢的个体内感知准确性更高。考虑到上述因素,传统的心跳追踪任务需要改进,如在静脉滴注异丙肾上腺素后再进行

实验<sup>[7]</sup>,或由心跳识别任务取代。但是后者也并非完美,因为识别任务默认被试者心脏收缩后的延迟时间相近,但实际上存在个体差异<sup>[8]</sup>,而且在心跳追踪任务的执行中,被试者的注意力仅集中在身体内部信号(即心跳)上,但心跳识别任务需要同时整合内部和外部信号(如心跳和声音)以给出同步判断,这使它在有多感觉缺陷的患者群体,如精神分裂症患者中的运用受限。因此,最近不少研究者提出新的实验范式。PLANS等<sup>[9]</sup>在心跳识别任务基础上进行改进,提出了相位调整任务,即给被试者播放与自己心率的频率一致但不同步的音调,由被试者根据自己感受到的心跳调整音调的相位,使两者同步,而不是给定一个延迟,如此便可减少个体差异带来的影响。POHL等<sup>[10]</sup>则融合了2种经典范式,根据被试者各自的R波设定时间间隔,要求他们在相应间隔内计数心跳次数,结合2项强迫选择,共设计了4种实验条件,产生“准报(hits)”“假警报(false alarms)”“失误(misses)”“正确拒绝(correct rejections)”4种结果,据此计算其灵敏度和反应偏差。灵敏度越高,反应偏差越小者准确性越高。除此之外,还有LEGRAND等<sup>[11]</sup>提出的心率辨别任务、HODOSSY等<sup>[12]</sup>的心跳反馈任务等,但新范式或使用特殊的软件及设备,或采用繁杂的算法,故其可行性及有效性有待考证。

### 1.2 内感知敏感性

内感知敏感性反映了个体内在注意的倾向,可通过2种方法进行测量。一种方法是用自我报告的问卷来评估。常用问卷有内感受知觉多维评估(Multidimensional Assessment of Interoceptive Awareness, MAIA)和身体知觉问卷(Body Perception Questionnaire, BPQ)等。MAIA包含8个分量表(注意、不分心、不担心、注意调节、情绪意识、自我调节、身体倾听、信任),共32个条目。BPQ包含意识、压力反应、自主神经系统反应及压力风格4个分量表。其他问卷包括自我意识问卷(Self-Awareness Questionnaire, SAQ)、个人身体意识量表(Private Body Consciousness Subscale, PBCS)等,但较少使用。近期,有学者提出三维度感受问卷(Three-Domain Interoceptive Sensations Questionnaire, THISQ),用于同时评估自我报告的呼吸、心脏和胃食道感觉<sup>[13]</sup>,但尚未推广使用。另

一种方法是让被试者对自己完成内感知任务时的主观信心进行评级,如使用视觉模拟量表(Visual Analogue Scale, VAS),一端描述为“完全是猜测”,另一端为“完全有信心”,让被试者进行评分<sup>[1]</sup>。

### 1.3 内感知意识

内感知意识是对内感知准确性的一种元意识,即在多大程度上相信自己内感知准确性的判断,主要是通过任务判断的主观信心来预测客观心跳检测的准确性,可以使用受试者操作特征曲线(receiver operator characteristic curve, ROC 曲线)下面积来测量<sup>[1]</sup>,也可以通过内感知特质预测错误来体现,正值表明个体倾向于高估自己的内感知能力,而负值则表明个体倾向于低估自己的内感知能力<sup>[14]</sup>。

### 1.4 3个维度的关系

GARFINKEL 等<sup>[1]</sup>认为内感知准确性与敏感性、内感知意识存在相关关系;但只有准确性超过了一定阈值后,这种关系才显著。与之相反,MEESSEN 等<sup>[15]</sup>否认三者存在相关关系。最近一项基于健康人群的生态瞬时评估实验<sup>[16]</sup>发现:同一个体的内感知准确性、敏感性和意识是随时间波动的,且在反复执行心跳追踪任务后,内感知准确性及意识并无显著变化,而敏感性有所改善。因此,为强调被试者在日常生活中对内感知刺激的注意和运用身体信息程度的个体差异,MURPHY 等<sup>[17]</sup>提出了2×2模型,具体描述了内感知的4个核心测量:①内感知准确性的客观测量(如心跳追踪任务或识别任务)。②内感知准确性的自我评估(如主观信心评级)。③内感知注意的客观测量(即内感知信号作为注意对象的测量)。④内感知注意的自我报告(即内感知信号作为注意对象的主观信念,如BPQ中“在大多数情况下,我知道我的心脏跳得有多厉害”的量表条目)。

## 2 内感知的相关研究技术

目前主要通过脑电和功能磁共振成像(functional magnetic resonance imaging, fMRI)技术展开内感知相关研究:①心跳诱发脑电电位(heartbeat-evoked brain potential, HEP)。它可能是通过多条生理通路(如压力感受器、传入心脏神经元、通过皮肤的体感映射、皮层的神经-血管耦合)和神

经结构(如岛叶、扣带回、杏仁核、躯体感觉皮层)来观察心跳感知过程中脑电生理的变化。研究<sup>[18]</sup>发现心跳追踪任务得分高的个体有更高HEP振幅,这可能因为HEP更多反映的是个体对内感知的注意力<sup>[19]</sup>。②fMRI。它具有高空间分辨率的优势,可通过新陈代谢的变化间接地反映神经系统的活动。多个研究<sup>[20-21]</sup>发现内感知准确性与右侧前岛叶及额叶岛盖活动有关。HASSANPOUR 等<sup>[22]</sup>观察了内感知过程中脑区激活的动态变化,发现右侧岛叶中部、左内侧额叶及前运动皮层的脑血流量在心肺感觉的高峰时期达到最大。而在心率基本恢复到基线水平后,右岛叶的前、后部分以及左岛叶中部区域显著激活。上述2种方法相比,虽然HEP可观察心跳感知过程中大脑头皮电位变化,具有较高时间分辨率,但其空间分辨率较低,而fMRI则可弥补该不足。因此,未来的研究可以尝试将两者结合,或开发其他新兴技术。

## 3 内感知的相关临床研究

内感知与情绪的关系最早可以追溯到JAMES的情绪理论——情绪是对于身体所发生变化的感知,如果没有了身体变化,如肌肉紧张、心跳加剧等,也就没有情绪产生。之后陆续有一些使用心跳感知任务的研究<sup>[23-25]</sup>表明,内感知和情绪体验强度之间存在正相关。ZAKI 等<sup>[26]</sup>用实验证实了内感知与情绪体验有一致的活动脑区,即前岛叶及额叶岛盖部。2017年一篇meta分析<sup>[27]</sup>得到了相似的结论,并发现在临床上右岛叶前部和额颞区梗死的患者存在内感知、情绪调节和社会认知方面的障碍。因此,不难推测,伴有情绪异常的精神障碍患者,其内感知能力或多或少发生了变化,目前以焦虑障碍及抑郁障碍相关的研究最多,但亦有研究证实内感知同精神分裂症、孤独症谱系障碍(autism spectrum disorder, ASD)、物质使用障碍、躯体形式障碍(somatoform disorder, SFD)等精神障碍相关。

### 3.1 与惊恐障碍相关的研究

早在20世纪末便有研究<sup>[28]</sup>发现惊恐障碍(panic disorder, PD)的患者内感知准确性更高,且内感知的变化参与了惊恐症状维持。LIMMER 等<sup>[29]</sup>的研究证实了该结论,并发现共患抑郁障碍会提高PD患者的内感知敏感性,同时降低其准确性。



WOLK等<sup>[30]</sup>则发现心跳知觉准确性提高会影响他们的决策能力。而且,多个研究<sup>[31-32]</sup>发现PD患者述情障碍的检出率和内感知敏感性高于健康人群,这与其双侧顶上小叶的活动呈正相关<sup>[33]</sup>。CUI等<sup>[34]</sup>运用fMRI发现PD患者躯体感觉皮层和丘脑之间的功能连通性增加,且与其症状的严重程度相关。不仅如此,胡强等<sup>[35]</sup>还发现PD患者,尤其是女性患者的心跳知觉水平高于正常对照及广泛性焦虑障碍(general anxiety disorder, GAD)患者。

### 3.2 与GAD相关的研究

PANG等<sup>[36]</sup>使GAD患者和健康对照组分别在睁眼(外感知)和闭眼(内感知)的情况下进行测试,记录2种条件下的心电图、脑电图,结果发现:GAD患者在2种不同条件下的HEP幅度变化小,因此推测其内感知调节能力差,还发现GAD患者焦虑症状的严重程度与内感知条件下右侧前额叶HEP振幅相关。CUI等<sup>[34]</sup>认为GAD症状严重程度还与其海马/副海马和颞叶梭状回之间的功能连通性增加程度相关;不仅如此,还发现GAD人群通常表现出主观内感知敏感性的增加,且在心跳感知过程中,左前岛叶、左后岛叶和右前岛叶的激活程度更强<sup>[37]</sup>。李惠<sup>[32]</sup>发现GAD患者右侧额中回功能相对增强,可能对心跳知觉异常有部分代偿作用。近期通过基于体素的形态测量软件发现,GAD患者左内侧前额叶、右眶额回和前扣带回的皮质灰质体积明显减少,且左内侧前额叶皮质灰质体积与心跳感知敏感性呈负相关<sup>[38]</sup>。金海燕<sup>[33]</sup>则发现其敏感性与左前岛叶活动呈正相关。李伟<sup>[39]</sup>通过fMRI研究发现GAD患者在执行内感知检测任务时,其右侧舌回、左侧顶上回及右侧颞中回激活减弱,而文拉法辛能够调节情绪相关脑区的激活,改善焦虑症状。

### 3.3 与抑郁障碍相关的研究

内感知同抑郁症状的关系尚无定论。POLLATOS等<sup>[40]</sup>发现在高焦虑水平的健康被试者中,抑郁程度和内感知准确性呈显著负相关;而在低焦虑水平,两者却呈正相关,但无统计学意义。考虑到这点,FURMAN等<sup>[41]</sup>以没有共病焦虑的抑郁症患者为实验组,发现他们比健康对照组的内感知准确性差;TERHAAR等<sup>[42]</sup>将抑郁障碍患者的HEP同健康人群比较,得出了一致的结论。而DUNN等<sup>[43]</sup>发现抑郁

严重程度与内感知准确性之间存在U型曲线关系:从轻度到中度抑郁,抑郁程度的增加对应的心跳感知的准确性降低;而从中度到重度抑郁,抑郁程度的增加对应的心跳感知的准确性增加。

### 3.4 与精神分裂症相关的研究

ARDIZZI等<sup>[44]</sup>较早发现精神分裂症患者的内感知准确性明显降低。之后,KOREKI等<sup>[45]</sup>证实了该结论,并发现内感知准确性下降程度与阳性症状(尤其是幻觉)的严重程度之间存在正相关关系。该研究还发现精神分裂症患者群体MAIA的注意量表分数更高,而不分心量表分数则更低,且内感知准确性与注意量表分数的差值同妄想症状正相关。TORREGROSSA等<sup>[46]</sup>同样证实了精神分裂症患者的内感知准确性缺陷,并发现这个缺陷在整个病程中均有体现,但在早期/急性期的患者中更加明显;与先前结论不同的是,该研究并未发现内感知准确性下降同症状严重程度相关。

### 3.5 与ASD相关的研究

SCHAUDER等<sup>[47]</sup>发现同正常发育儿童相比,ASD患儿内感知准确性并未随所设时间间隔延长而下降,这可能与其对内部信号注意力的维持时间更长有关。而针对成年ASD患者的研究均表明其内感知准确性下降,但内感知敏感性变化不一致,也可能与评估所用量表不同有关,尚待进一步研究<sup>[14, 48]</sup>。儿童和成年ASD患者内感知变化的不同趋势可能与年龄有关。MASH等<sup>[49]</sup>研究发现,当智商值<115时,其内感知准确性与年龄增长呈负相关;这与在健康人群中观察到的规律一致<sup>[50]</sup>。

### 3.6 与物质使用障碍相关的研究

多个基于心跳追踪任务的内感知行为学研究<sup>[51-54]</sup>表明,酒精使用障碍患者的内感知准确性显著降低。尽管数据有限,在尼古丁、海洛因及大麻成瘾的患者中也发现了内感知准确性的下降<sup>[54-55]</sup>。这可能与物质成瘾患者的岛叶灰质体积减少<sup>[56-57]</sup>,从而影响到内感知加工过程有关。

### 3.7 与SFD相关的研究

对于SFD患者,其内感知准确性的变化目前仍未确定,可能是因为躯体化症状普遍存在于抑郁障碍

及焦虑障碍人群中,难以单独分离出来。有研究<sup>[58-59]</sup>认为SFD患者的内感知准确性下降。但SCHAEFER等<sup>[60]</sup>发现SFD患者同健康对照组的内感知准确性并无显著差异,而是患者症状严重程度同准确性呈负相关关系。该研究团队还发现可以通过心跳反馈训练提高患者的内感知准确性,从而减轻症状<sup>[61]</sup>。

综上所述,内感知同精神障碍关系密切,但大多数研究样本量较小,多采用传统心跳追踪任务,且未控制年龄<sup>[50]</sup>、性别<sup>[62]</sup>、体质量指数(body mass index, BMI)<sup>[63]</sup>等已知的混杂因素,故其相关结论有待进一步研究证实。

## 4 结语与展望

近年来随着心跳知觉相关研究领域得到重视,基于心跳知觉的内感知研究开始向临床干预聚焦,个体的内感知改变可能有助于定向地实施针对身体的治疗。但目前的研究仍存在诸多不足:①研究者们仍在质疑心跳知觉能否代表其他内感知知觉能力。HERBERT等<sup>[64]</sup>通过心跳追踪任务评估心跳知觉,用水负荷试验评估胃敏感性,发现对心跳信号更敏感的个体对胃的信号也更敏感,并就此推测胃和心脏的内感知过程有普遍的敏感性。但GARFINKEL等<sup>[65]</sup>却发现心跳内感知准确性与呼吸内感知准确性不相关,而两者内感知意识相关。因此,关于心跳知觉对内感知的代表性还有待研究。②针对内感知的治疗尚不成熟。经颅磁刺激(transcranial magnetic stimulation, TMS)是一种新兴的非侵入式的电生理刺激技术,其利用磁场在大脑中产生感应电流,使神

经元去极化,从而诱发脑内神经电活动。2016年,POLLATOS等<sup>[66]</sup>通过连续脉冲刺激(continuous theta-burst stimulation, cTBS)抑制右岛叶和右躯体感觉皮层活动,降低了GAD患者心跳内感知准确性、提高了敏感性;但其使用的治疗刺激可能尚未达到岛叶深度<sup>[67]</sup>,且无法排除浅皮层刺激间接影响了内感知的可能。目前新型H型线圈可以到达更深部位,有望能刺激到岛叶。但截至目前,尚未有相关临床研究发表。针对内感知的其他治疗,如身体定向疗法、身体扫描练习等,大多以健康人或是有临床症状的个例为研究对象,缺乏以大规模临床样本为主体的研究。③同样伴有情绪症状,有关双相情感障碍患者内感知变化的研究却非常少,躁狂发作与抑郁发作时同一患者的内感知是否有相应变化,双相抑郁与单纯抑郁障碍患者的内感知变化是否一致,聚焦于内感知的治疗对他们是否有帮助等,这些都是今后研究的方向。

### 利益冲突声明/Conflict of Interests

所有作者声明不存在利益冲突。

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### 作者贡献/Authors' Contributions

梁宇璇负责搜集整理文献,撰写综述。李春波负责审阅、批改综述内容。所有作者均阅读并同意了最终稿件的提交。

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