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健康建筑声环境研究进展

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摘要 建筑及城市声环境是健康建筑质量的重要组成部分. 本文首先讨论了从噪声控制到声景营造, 即从降低负面健康影响到促进公众健康的发展趋势, 在这个从观念到理论到方法的转化过程中, 声环境对人的健康影响有了更为科学的研究视角和操作方法, 与基于健康理念的声环境设计共同成为声景研究持续关注的焦点. 在此基础上, 介绍了一些近期的创新研究成果, 包括声景感知对健康效应的影响, 及声景的心理生理学方面的系统性综述研究; 基于恢复性环境理论的城市公共开放空间声景恢复性效应的理论发展和实证研究进展、典型声景的生理指标变化的敏感性研究; 针对特定群体健康影响的研究, 包括儿童恢复性声景研究、环境噪声对儿童认知能力的影响研究; 针对特定空间的声环境健康研究, 包括医院声环境对住院病人健康、对医护人员工作效率的影响等. 总体而言, 声景的生理学和神经生理学研究尚处于起步阶段, 有许多方面值得研究; 城市公共开放空间声景恢复性效应, 其影响机理和主动调节层面还有值得深入研究的内容; 针对特定人群和特定空间的声景健康研究还将拓展到其他人群和空间, 研究也将从客观影响规律走向基于健康的声环境主动设计.

关键词 健康建筑, 声环境, 噪声, 声景, 恢复性, 生理学

“健康建筑”是当今社会对建筑功能和品质的新要求, 其理念和实践需要并正在突破传统学科的束缚, 向多学科、跨领域融合方向发展. 建筑及城市的声环境是健康建筑质量的重要组成部分, 而声环境对人健康的影响及相应的声环境设计亦是近年来该领域的研究重点. 本文在讨论从噪声控制到声景营造, 即从降低负面健康影响到促进健康趋势的基础上, 介绍近期的一些研究和实践的阶段性成果, 包括声景感知对健康效应的影响及声景的心理生理学方面的系统性综述研究、城市公共开放空间声景恢复性实证研究、声景恢复性表现及影响因素研究、典型声景生理指标变化的敏感性分析、针对儿童群体的恢复性声景研究、环境噪声对儿童认知能力的影响、医院声环境与健康等.

1 从噪声控制到声景营造——从降低负面健康影响到促进健康

过去几十年来, 国际卫生组织及全球范围内其他研究机构就环境噪声对人们健康的影响进行了较系统的研究[1,2], 证明噪声对健康的影响包括心血管疾病、睡眠障碍、耳鸣、烦恼、儿童认知障碍, 以及与压力有关的心理健康风险[3,4]. 研究者在降低环境噪声水平方面进行了大量努力, 如欧盟的“环境噪声法令”(Eur-

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opean Environmental Noise Directive, END)及一系列行动计划[5]. 但是大部分研究还聚焦于“不需要的”声音及其消极影响, 而对“想要的”、“喜好的”声音, 及其可以产生的积极情绪还考虑较少. 事实上, 很多情况下减少城市环境噪声并不一定能直接改善人们的幸福感和生活质量[6,7], 声景研究将研究重点从环境声音的负面影响转移到整体影响, 考虑人的感知, 将声音亦视为可能的资源, 促进健康和支持性环境[8]. ISO 12913-1标准将“声景”定义为“在某种场景下由个体或群体所感知、经历和/或理解的声学环境”[9]. 近10年来, 声景研究成为环境声学领域的热点[10].

1.1 声景感知对健康效应的影响

声景作为人对声环境的感知结果, 可以是正面的或负面的. 正面的声景感知(例如愉快、平静等)与积极的健康效应之间的关联(例如增加恢复、减少压力诱导机制等)是声景研究的关键问题之一. 就二者是否存在统计学上的显著关联, Aletta等人[11,12]对1991年1月1日~2018年5月31日期间Web of Science, Scopus, PubMed等数据库中的同行评审期刊论文进行了系统性综述. 检索关键词为声景(soundscape)、健康(health)/幸福(well-being)/生活质量(quality of life), 在此基础上对检索结果进行了手动搜索扩展, 纳入标准为: (1) 根据ISO 12913-1, 定义包括至少一种声景维度; (2) 包括至少一项与健康有关的指标(生理或心理); (3) 讨论声景对健康的积极效应. 由此得到130篇文献, 经删除重复、进一步筛选标题和摘要, 并进行初步分析, 最终纳入7项研究, 共2783名参与者, 包括较大规模的现场调查[13~15]及较小规模[16~18]的实验室研究.

前者的结果表明, 减弱消极声景(例如降低声烦恼)与自我报告的健康状况显著相关; 而后者的结果表明, 评价积极的声景(例如愉快、平静)与环境压力恢复性显著相关.

1.2 声景的心理生理学

人类天生倾向于寻求与自然的联系[19], 注意力恢复理论认为自然(例如暴露于瀑布等自然声音)可改善人的认知能力和帮助压力恢复[20~22]. 关于不同类型的声音, 如音乐声、自然声、城市环境声等, 如何影响中枢神经系统和周围神经系统的活动和功能, 已有较多研究[16,23~26], 但其内部机制还远未被理解. 为厘清声景在心理生理学方面的进展, Erfanian等人[27]对1990年1月1日~2019年2月1日期间Web of Science, Scopus, PsycINFO, PubMed等数据库中的同行评审期刊论文进行了系统性综述. 检索关键词为声景/环境噪声(soundscape, environmental noise or sound)、生理学(physiology or physiological)、心理学/感知属性/主观评价/评价(psychology or psychological, perceptual attribute, affective or subjective assessment, appraisal), 由此得到122篇文献, 经删除重复、进一步筛选标题和摘要, 并进行初步分析, 最终纳入5项研究[16~18,28,29].

该系统性综述的研究问题包括: 目前声景生理学研究的主要方法、生理指标在声景作用下的变化范围、生理指标与主观评价的关系等. 结果表明, 目前声景生理学研究的主要方法是基于被动聆听与事件相关或刺激锁定的实验设计, 实验对象主要是同质人群. 常用的生理指标包括心率、呼吸速率、皮肤电活动、肌肉骨骼活动等, 主观维度主要是评价和唤醒; 声景影响下的个体生理表现具有广泛的变化, 有上升也有下降; 而生理指标与主观评价的关系也有不同的结果, 尚无统一结论. 总体来讲, 声景的生理学和神经生理学研究尚处于起步阶段, 有许多方面值得深入研究, 例如单一和复杂环境声影响的不同、声景随时间变化的影响、中枢神经系统和周围神经系统各指标在环境声刺激下的相互作用等.

2 城市公共开放空间声景的恢复性效应

城市公共开放空间承载着为城市居民提供健康环境资源的社会功能, 中国城市面临着快速改变的城市环境和生活方式带来的众多健康挑战[30]. 根据Kaplan[31]的环境恢复性理论, 适宜的环境能够促进身处其中的个体从消耗状态(心理疲劳、压力伴随的消极情绪、注意力下降)获得恢复, 反之则会加剧消耗. 既往研究大多关注恢复性质量较高的自然环境[32,33], 针对高密度城市390份居民问卷调查和18个空间节点104位居民的现场访谈的数据表明, 生活节奏和工作压力导致城市居民消耗明显, 居民到访郊外自然环境的时间严重不足, 城市内部公共开放空间的恢复性质量特别值得关注, 作为重要的环境要素, 声景对环境恢复性质量产生显著影响[34].

2.1 声景恢复性的理论发展及实证研究进展

在环境恢复性研究中, 较早关注到听觉影响的研究者发现雪地摩托车噪声[35]和飞机噪声[36,37]对自然环

境恢复性存在潜在干扰. 根据恢复性环境的4项特征[31,38], 结合声景语义分析既有成果[39], 提出了声景恢复性特征及其语义量表, 并通过实证检验了其有效性[40,41](图1).

针对城市滨水公园进行的注意力恢复实验[22]由72名大学生被试参与, 实验采用组间设计(自然声组、交通声组、割草机声组、对照组), 各组所在环境视觉景观构成相同. 被试首先进行50 min思维消耗任务, 随即在各自区域环境内进行休息和放松. 被试恢复前后注意力水平变化指标表明, 处于思维消耗状态下的被试, 在自然环境中进行40 min恢复, 相较于没有经历该过程的被试, 注意力水平得到提升; 在相同的视觉环境中, 自然声、交通声、割草机声的存在使被试注意水平的变化存在显著差异.

基于空间地理信息系统(geographic information system, GIS)的声景地图技术[10,42~45]的发展为声景恢复性体验和评价提供了空间分析和图示化方法. 针对交通声对高密度城市公园声景恢复性质量的影响, 对49个公园进行周边道路普查, 结合2个公园的交通实测与噪声模拟, 以及公园内部空间网格声景评价GIS差值分析, 证实了公园受周边道路交通声影响较为显著. 影响程度由公园周边向内部逐渐衰减, 衰减梯度受到空间特征、景观特征、在场活动声掩蔽等因素影响[46]. 针对历史陵园与现代公园相结合的城市公园, 通过声学测量和声景漫步获取声压级、声音类型、声景恢复性特征等数据, 绘制声景地图并进行空间分析. 数据表明, 声景恢复性特征指标与背景噪声水平、声音类型在空间上分布呈现显著相关; 空间聚类分析发现, 声景属性的空间聚集性, 结合路径分析, 可以规划公园内声景最舒适路线和声景最具吸引力路线; 利用地理加权回归(geographically weighted regression, GWR)建立的局部空间回归模型可以较好预测声景和谐性.

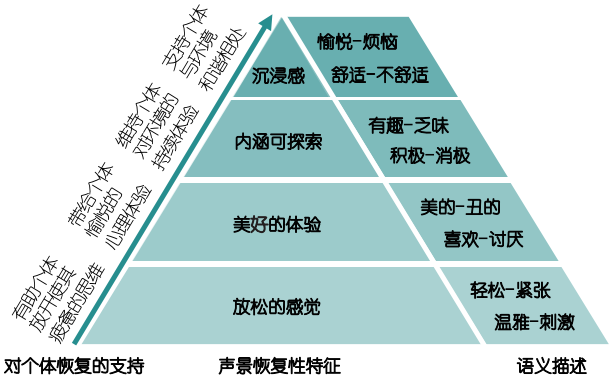

图 1 (网络版彩色)声景恢复性的特征

Figure 1 (Color online) Characteristics of soundscape restorative

2.2 声景恢复性的表现及影响因素研究

根据经典恢复理论(减压理论[47]及注意力恢复理论[37])及相关实证研究成果[48~53], 结合声景恢复性研究实践, 建构了声景恢复性表现理论模型[54](图2), 提出开放空间声景对个体的恢复性效应包含心理、生理、注意力3个方面的直接效应, 以及借助视听交互产生的间接恢复效应. 声景恢复性效应的表现和影响因素可以通过声景体验进行探索, 心理量表、生理监测技术、眼动追踪技术、虚拟现实(virtual reality, VR)体验技术为相关研究提供了有效的技术工具.

基于声景主观体验的实验, 证明了声景类型对恢复性体验的影响: 鸟叫、水声、风声、风吹树叶声等自然声和轻柔的背景音乐对被试心理恢复具有显著正效应, 且可以弱化负效应声景影响; 交通声和施工机械声负效应显著; 居民休闲活动声的恢复性效应存在时空差异、类别差异和个体差异[39]. 利用人机环生理监测同步平台进行的声景模拟体验实验, 证实了以皮肤电导反应(skin conductance response, EDA)为指标的生

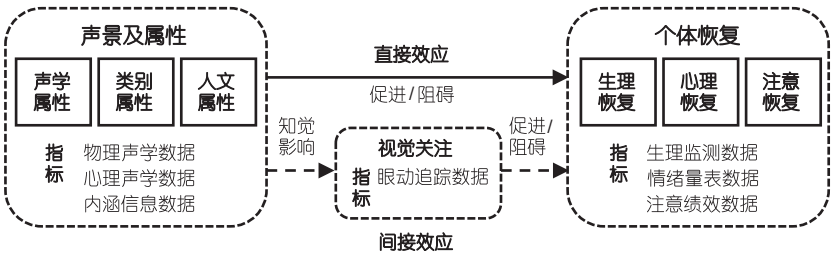

图 2 声景恢复性效应表现及影响因素

Figure 2 Performance and influencing factors of soundscape restorative effect

理恢复: 自然声、人文声、机械声刺激下, 个体皮肤电导变化率具有显著差异, 鸟叫、流水等自然声趋于降低被试的皮肤电导水平, 交通、机械声则相反; 与心理感受不同, 个体皮肤电导水平变化与性别、受教育程度等个体差异不具备统计相关性[55]. 利用视觉追踪任务进行学习空间声景对注意力影响的实验, 以任务绩效、反应时长和注视点个数为指标的数据表明, 来自外部空间的侵入噪声水平对被试的视觉注意产生显著影响(正确率下降、反应时增长), 且较高水平的噪声水平(sound pressure level, SPL)需要被试更多的脑力消耗(平均注视点个数增多)来维持注意力[56].

利用VR虚拟现实全景体验技术进行的街道声景体验实验, 表明了以交通声为主要声源的街道, 听觉烦恼度与感知响度、视觉景观的美景度显著相关, 建构了以感知响度、美景度、声景类型感知、个体噪声敏感性为指标的对交通声烦恼度回归方程[57]. 声景影响下的视觉景观体验实验, 定义“自然环境注视时长占比”指标, 证实了由于声景对视觉关注的引导而产生附加恢复性效应的理论假设. 在相同的景观构图中, 鸟叫声倾向于引导被试更加关注自然景物, 交通声倾向于引导被试对人工景物的关注, 这种引导作用与声音的信号提示功能和情绪感染作用均呈现显著相关性, 且前者影响高于后者[54].

2.3 典型声景生理指标变化的敏感性研究

人们在场景中如何感知和理解声环境一直是声景研究的主要问题之一[8]. 研究者对声景所引起的生理反馈进行了探索性的实证研究. 部分针对生理反应的研究旨在讨论情绪的变化, 实验刺激时长一般为几秒到十几秒[17,58~60]. 听觉的认知过程十分短暂, 相应的情绪也可在短时间内通过声音刺激唤起, 但要研究人在声景中的生理变化, 十几秒的时间是不够的. 目前, 有关生理的声景研究一般将声景片段选取在4 min左右[16,18,61], 在生理指标的选择上, 研究者普遍选择心电和皮肤电等反应敏感的指标, 也有论文分析声音对脑电[62]、断层扫描[63]以及核磁共振[28]相关指标的影响.

关于生理指标敏感性的研究分析了生理信号随时间和声景类型的变化规律, 与主观恢复性量表之间的关系[64]. 通过实验对66名在校大学生(男性32人, 女性34人, 平均年龄21.82岁)进行了生理测量, 选取4种典型声景(视频与音频同时录制): 森林声、海浪声、交通声、街道声, 并将等效声压级调整到70 dB(A), 得到被试心率、R波幅度、心率变异性、α脑电波、β脑电波、眨眼频率、呼吸频率、呼吸深度、皮肤电、皮温共10项生理指标. 实验采用恢复性声景感知量表(perceived restorative soundscape scale, PRSS)作为主观问卷, 该问卷由五部分(迷人性、引离性、远离性、兼容性和一致性)组成, 能够全面有效地评价声景中的恢复效应. 实验在测听室进行, 被试坐在屏幕前1.5 m处, 连接生理测量仪并戴上耳机, 4个典型声景随机呈现, 每段声景呈现5 min, 中间间隔90 s. 通过重复测量分析各项生理指标随时间和声景类型的变化, 并通过典型相关分析讨论生理指标和主观因子之间的相关性.

重复测量分析的结果表明[64]: (1) 在时间维度上. 随实验时间的增加, 呼吸频率加快, 呼吸深度变低, 说明人在融入声景之后呼吸会逐渐急促; β脑电波也随时间增加而不断升高; α脑电波相对稳定, 不随时间的增加而变化. 总体而言, 大部分生理指标在1 min左右会出现比较明显的拐点, 之后变化的趋势逐渐平缓, 说明在1 min时, 人们的生理反应最为强烈. 因此, 为更好地观察到生理指标带来的效应, 用1 min的时间来观察生理指标较为合适. (2) 在声景类别维度上. 皮肤温度和眨眼频率不受声景类型的影响, 其他指标在不同的声景下差别显著. 自然声会带给人更低的心率、呼吸频率和呼吸深度, 更高的R波幅度、心率变异性、α脑电波和β脑电波. 图3为部分生理指标(呼吸频率和皮肤电阻)随时间和声景类型的变化.

相关分析结果表明, 主观问卷与1 min内的生理数据之间相关性最大, 与3 min以后的生理数据相关性显著减小. 这意味着, 人们对声景恢复性的主观评价与其进入该声景内前1 min内的生理数据关系更大. 同时, α脑电、呼吸深度和皮阻与主观评价之间的相关性很小, 说明这三项指标与恢复性之间关系可能并不明显.

3 声景对特定人群的健康影响

研究者特别关注和探索了声景对特定人群的健康影响. 儿童由于处在身心发育尚未成熟的阶段, 其身体健康、心理健康, 以及认知表现受到声环境的影响更为明显[65]. 同时, 为营造健康舒适的医疗环境, 研究者们针对医疗建筑声环境质量的健康效益及其评价体系进行了深入研究.

3.1 针对儿童群体的恢复性声景研究

有研究表明儿童常常处于较高的压力和疲劳状态

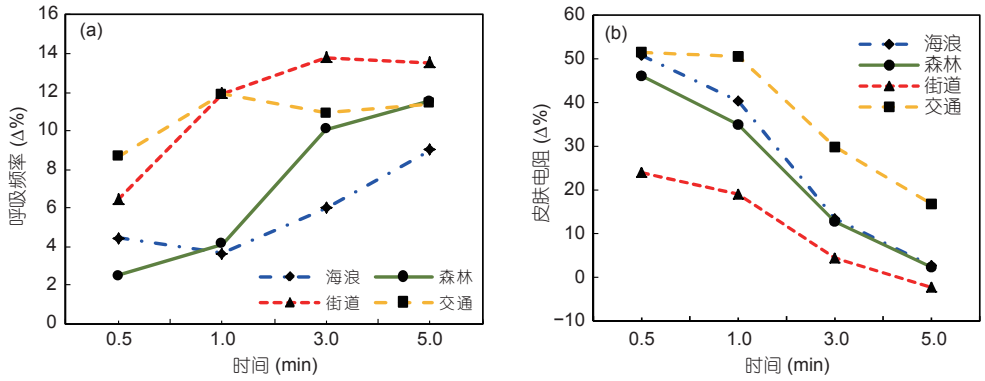

图 3 (网络版彩色)生理指标随时间和声景类型(相对静吸状态下基线)的变化. (a) 呼吸频率; (b) 皮肤电阻. 修改自文献[64]

Figure 3 (Color online) Changes in some physiological parameters with respect to time and soundscape type. (a) Respiratory frequency; (b) skin conductance level. Adapted from Ref. [64]

中[66], 社会调查也揭示了在中国的小学校中激烈的学业竞争导致了儿童过高的压力和疲劳水平[67]. 自然环境对成人[68,69]和儿童[70~72]健康的恢复性作用已经逐步被证实, 然而声景作为恢复性环境的一部分是否对儿童的认知和非认知能力具有恢复性作用呢?

针对以上问题, 通过呈现全景照片的方式来模拟小学教室和城市公园的视觉环境, 同时播放不同的声音去创设不同的声景体验[73]. 通过儿童(8~12岁)对恢复性声景感知量表(perceived restorativeness soundscape scale for children, PRSS-C)的评价, 探索了不同环境下对儿童群体具有潜在恢复性作用的声音类型和信噪比. 通过对压力水平较高的儿童呈现不同的潜在具有恢复性作用的声景, 对比研究了恢复性声景对儿童认知能力(持续性注意力和短时记忆力)和健康指标(皮肤电、心率、情绪评价)的影响与作用程度.

研究结果表明, 儿童群体对恢复性声景的感知维度与成人不同, 尽管在不同的环境下, 声景的恢复性特质也有所不同, 但总体而言, 音乐、鸟叫、溪流、喷泉、铃声是最具恢复性潜力的声音类型, +5 dB(A)是最具恢复潜力的信噪比[73]. 在模拟的教室环境下, 喷泉和溪流对儿童的反应时和短时记忆力有显著的恢复性作用, 其次是音乐和鸟叫[74]; 在模拟的公园环境下, 所有声景(包括安静和公园环境噪声)都对儿童的皮肤电和心率有显著的恢复性作用, 但是对儿童的心率变异性并没有恢复性的效果. 另外, 不同的声景在情绪评价(愉悦感和唤醒度)上有显著差异: 音乐、鸟叫和喷泉能显著地提高儿童的情绪愉悦感, 而溪流和安静却显著地降低儿童的情绪唤醒度. 图4分别表述了儿童对声景的恢复性感知评价, 以及声景对儿童反应时、皮肤电水平和情绪的影响.

3.2 环境噪声对儿童认知能力的影响研究

在噪声对人影响的研究中, 研究的主体是成年人. 儿童作为特定的群体, 抵抗噪声影响的能力相对较差, 也更容易受到噪声的危害, 这种危害甚至会成为一种记忆影响到儿童成年后的生活[75]. 一些研究通过社会调查的方法就噪声对儿童影响特别是对认知过程的影响进行了探讨[76~79]. 这些研究涉及噪声对儿童读写与计算能力[80~83]、注意力[84,85]和记忆能力[86]的探究. 然而由于这些研究主要采取社会调查的方式, 受到许多不可控因素的制约, 因此导致了研究结果的不一致.

通过实验室研究系统地探讨了环境噪声对儿童短时记忆力、注意力、阅读理解能力和计算能力等一系列认知活动的影响, 确定了不同噪声对儿童影响的特点、范围和趋势[87]. 在研究中, 针对每一个认知实验任务的难度, 分别选取了30或90名7~12岁的儿童作为被试, 在儿童完成相应认知任务的同时, 通过耳机给儿童随机播放35~65 dB(A)的交通噪声、白噪声和空调噪声, 考察不同噪声条件对儿童认知成绩和主观烦恼度的影响.

研究结果表明, 噪声对儿童的影响主要体现在引起主观烦恼度上, 不同的噪声条件并没有引起作业成绩的显著差异. 在噪声对儿童烦恼度的影响上起重要作用的是声压级的大小: 在所有认知活动中, 儿童烦恼度随着声压级的增加而增加. 声压级45~50 dB(A)是儿童开始出现烦恼感的临界点. 如图5所示, 不同噪声对不同认知活动的影响是不同的: 在空调噪声环境中, 儿童在4个认知过程中产生的主观烦恼度无显著差异; 在

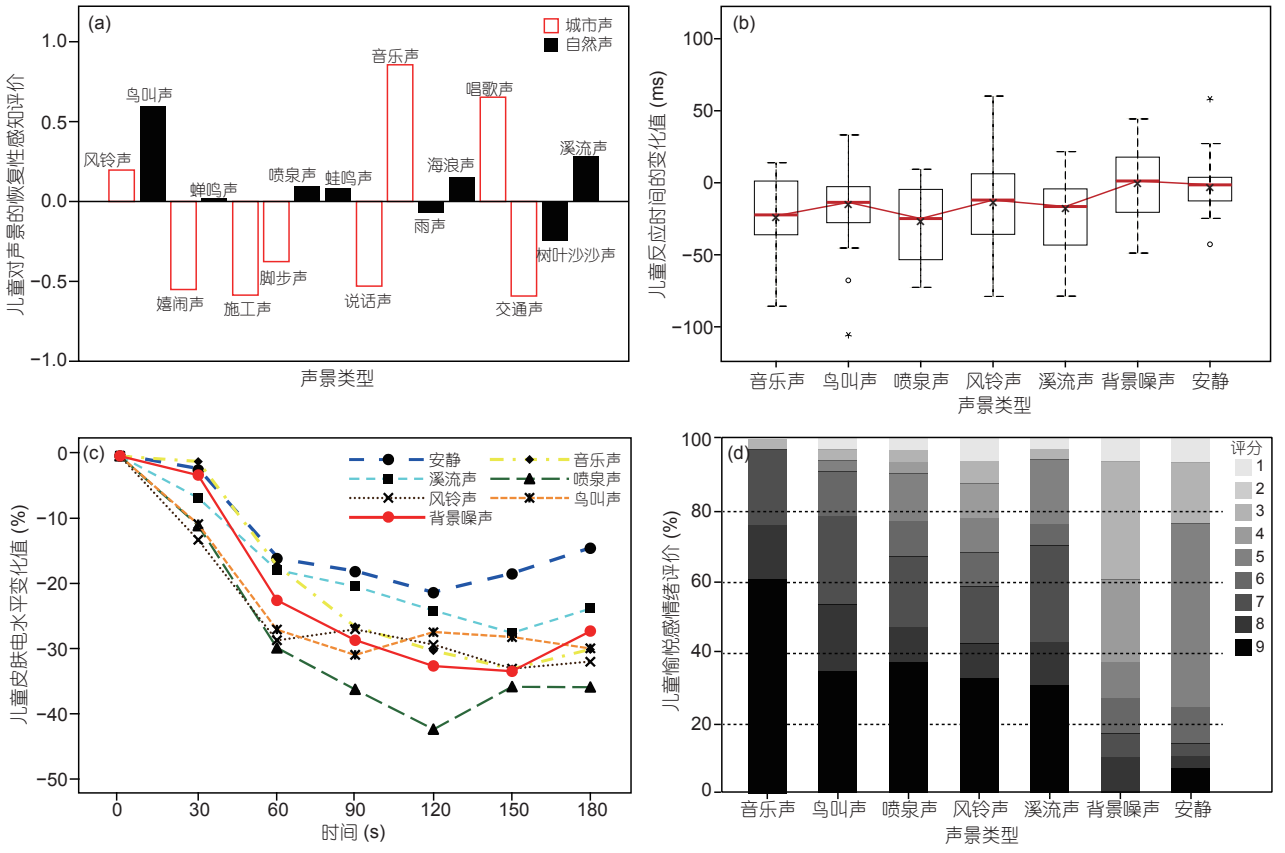

图 4 (网络版彩色)针对儿童群体的恢复性声景研究. (a) 儿童对声景的恢复性感知评价[73], 以及声景对儿童的反应时(b)、皮肤电水平(c)和愉悦情绪(d)的恢复性效应

Figure 4 (Color online) Restorative soundscape study for children. (a) Children's restorative perception of soundscapes[73]; restorative effects of soundscape on children's reaction time (b), skin conductance level (c), and pleasant emotion (d)

交通噪声的环境中, 儿童在短时记忆过程中产生的烦恼度显著高于计算; 在白噪声的环境中, 短时记忆和阅读过程中因噪声引起的烦恼感显著高于其他两个认知过程.

3.3 医院声环境与健康

病房作为住院病人接受治疗和康复的主要场所, 需要保障其安静舒适的疗养环境. 通过对各国大型医

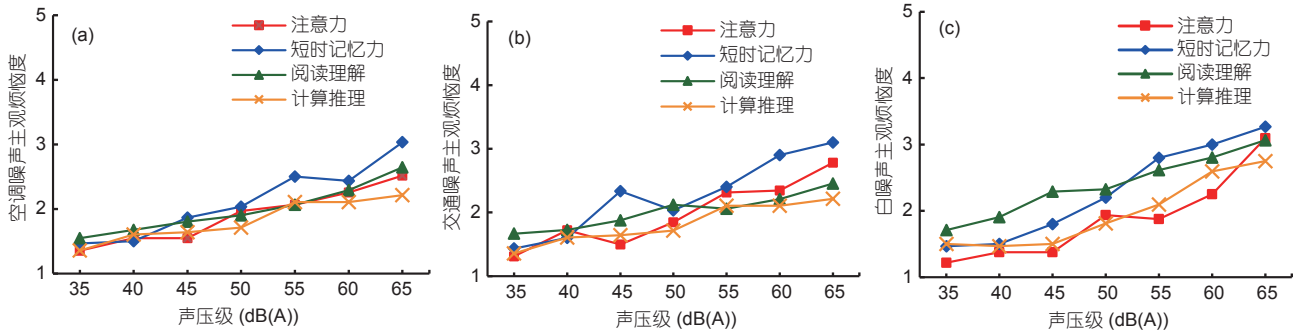

图 5 (网络版彩色)儿童在不同认知过程中对噪声的烦恼度评价. (a) 空调噪声; (b) 交通噪声; (c) 白噪声

Figure 5 (Color online) Noise annoyance evaluation of children in their different cognitive processes. (a) Air-condition noise; (b) traffic noise; (c) white noise

院的各科室病房进行深入研究, 揭示了不同国家、不同科室、不同类型病房声环境特征与病房类型、几何形态、典型声源之间的关系, 并分析了影响病房声环境的主要因素[88~90]. 在此基础上, 提出了基于病人康复效益的医院病房声环境评价模型, 证明了声环境改善对住院病人健康舒适、医生工作效率以及节约医疗资源的积极意义, 构建了有利于病人心理舒适和生理康复的病房声环境评价体系[91~93]. 同时, 还深入开展了医院声环境对病人生理与心理影响的研究, 证明了声环境改善有利于住院病人的休息、睡眠及住院情绪, 同时能提升医护人员的工作效率, 并揭示了住院病人在不同声环境下的各项生理指标差异[94,95]. 图6展示了病房声环境实测与改造的案例. 手术部作为综合医院的重要组成部分, 是为病人提供手术及抢救的场所, 其噪声可能会导致医护人员注意力和表现受损、干扰沟通、增加压力, 而患者也可能变得更加焦虑. 研究揭示了手术部声环境特征与典型噪声源的行为模式, 发现了医护人员对声环境评价的规律, 并且提出了手术部声环境的改善策略[96]. 目前, 我国第一个医院声环境标准正在编制中, 预计2020年将颁布实施. 通过建声和电声处理手段对门诊与病房环境进行了恢复性声景的营造, 发现声景作为重要环境要素具有缓解精神压力的功能, 为抑郁症的治疗新途径提供了临床证据[97].

4 结论与展望

近年来, 声景成为声环境研究的热点和重点, 从单纯重视噪声负面影响转移到全面考察声环境的综合影响, 将环境中的声音亦视为可能的有益资源, 重视人的听觉感知和体验. 在这个从观念到理论到方法的转化过程中, 声环境对人的健康影响有了更为科学的研究视角和操作方法, 与基于健康理念的声环境设计共同成为声景研究持续关注的焦点.

声景的生理学和神经生理学研究尚处于起步阶段. 生理指标与主观评价的关系已有一些研究, 但尚无统一结论. 有许多方面还值得研究, 例如, 单一和复杂环境声影响的差异、声景影响随时间的变化规律、各项影响的机理和效应价值、中枢神经系统和周围神经系统各指标在环境声刺激下的相互作用等. 随着研究样本的丰富和探索的深入, 研究工具的有效开发, 将逐渐实现指标体系和研究范式的规范化, 以继续推进研究深化, 并形成评价性标准.

已有一系列基于主观评价, 并结合实证技术进行的公共开放空间声景恢复性研究, 证明声景要素及声景评价与自我报告的健康状况及环境恢复性体验显著相关, 与此同时也出现了声景恢复性特征及其语义量表等理论研究成果; VR体验、视听交互、生理监测等技术为声景恢复性研究提供了有效的技术支持, 近红外、脑电等更为精确的技术工具的应用也在探索中. 声景恢复性效应在影响机理和主动调节层面还有大量值得深入研究的内容, 以创造有利居民获得良好恢复性体验的公共开放空间.

声景对人健康的影响亦扩展到不同人群, 如对儿童群体具有恢复性作用的声景研究等. 同时, 对不同功能的建筑进行了研究, 尤其是医院建筑, 证明了声环境

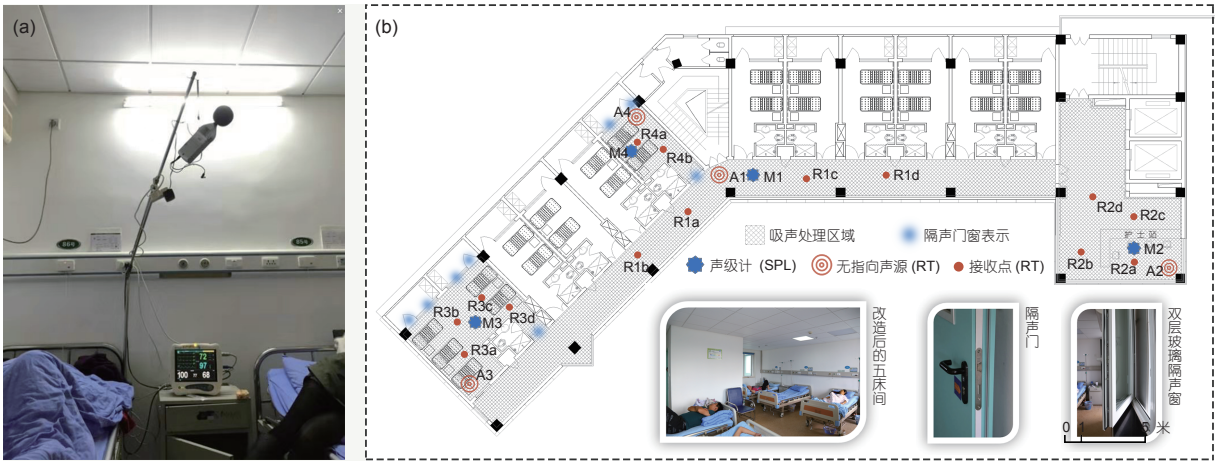

图 6 (网络版彩色)病房声环境实测与声学改造. (a) 病房实测场景; (b) 声学改造案例

Figure 6 (Color online) The measurement of sound environment of wards and the acoustic treatments. (a) Acoustic measurement in the ward; (b) case study site of acoustic treatments

改善有利于住院病人的休息、睡眠及住院情绪, 同时能提升医护人员的工作效率. 以上针对儿童和医院建筑的相关研究业已取得了一定的成果, 尚有持续深入的必要; 研究还将拓展到其他人群, 如职业噪声暴露相关人群、高压力职场工作人员等, 其他专项空间, 如养老建筑、交通空间、开放式办公建筑等; 研究也将从客观影响的规律探究走向基于健康的声环境主动设计.

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Summary for “健康建筑声环境研究进展”

Research progress on the acoustic environments of healthy buildings

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Building and urban acoustic environments greatly contribute to the quality of healthy buildings. This paper first discusses the developmental transitions from noise control to soundscape construction, and the changing focus from negative effects on public health to the promotion of health benefits. During this transition, the impacts of acoustic environments on human health have been investigated from various research perspectives, from concept to theory to methods. In current soundscape research, sound environment designs are based on health concepts. Innovative results have been introduced from this focus. First, the impacts of soundscape perception on human health and the psychophysiological effects of soundscape have been extensively reviewed. Reduced negative soundscapes are significantly positively correlated with the self-reported health conditions of subjects. Especially, soundscapes reported as positive (e.g., pleasant and calm) are significantly positively correlated with environmental stress restoration. The physiology and neurophysiology of soundscapes are emerging subjects that require extensive further research. Research on the restorative effects of urban public open spaces has included the development of relevant theories and practice, experimental studies of restorative performance and its influencing factors, and sensitivity studies, which measure the response magnitude of physiological indicators to typical soundscapes. The restorative quality of public open spaces in the urban context is of particular interests. Soundscapes in public open spaces are known to directly affect the psychology, physiology, and attention span of individuals. They also exert an indirect recovery effect through audio-visual interactions. A study on the sensitivity study of physiological indicators analyzed the change of the physiological signals over time, the type of scenery, and the restoration effect was quantified from the relationships among different subjective scales. Stressed children exposed to different potentially restorative soundscapes perceive the restorative sound scenery differently from adults. The effect of noise on the cognitive performance of children is primarily reflected in the degree of subjective annoyance, and children’s test performances do not significantly depend on the varying noise conditions. In specific spaces such as hospitals, the acoustic environment is known to affect inpatient health and the efficiency of hospital staff. Studies have confirmed that improving the acoustic environment benefits the resting ability, sleep, and mood of inpatients, and this can also improve the efficiency of hospital staff.

With the broadening and deepening of acoustic environment research and the effective development of research tools, indicator systems and research paradigms will become more standardized. Such standardization will further deepen the research and lead to evaluative standards. Much scope remains for investigating the impact mechanism and efficiency of various soundscape restorative treatments in urban public open spaces. Furthermore, the health effects of soundscape treatments for other specific groups of people and other specific spaces should be elucidated. Finally, research should move from revealing the influence patterns and tendencies of soundscapes toward the active design of healthy acoustic environments.

healthy building, acoustic environment, noise, soundscape, restorative effect, psychology

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