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情绪的红绿灯：实时调节驾驶中的愤怒情绪

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摘　要

驾驶者的不良情绪是导致交通事故的重要诱因，“路怒”是驾驶中不良情绪的极端表现，预防“路怒”的发生对保障交通安全有重要意义。本文回顾了驾驶过程中“路怒情绪”的实时调节方法，这包括驾驶环境的调控、利用语音助手对驾驶者进行的情感支持和利用生物反馈技术进行的驾驶情绪调节。目前调节技术已有长足发展，但仍存在一些局限和挑战，未来的研究需要从有效融合多模态技术、研发路怒的个性化干预手段、注重车内因素对路怒的诱发三个方面进行深化。

关键词

驾驶情绪，愤怒调节，人机交互，共情

Emotional Traffic Light: Real-Time Regulation of Driving Anger

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Abstract

The negative emotions of drivers constitute a significant contributing factor to traffic accidents, and road rage represents the extreme manifestation of such negative emotions during driving. Preventing the occurrence of road rage holds crucial significance for ensuring traffic safety. This article reviews the real-time regulation approaches of driving anger in the driving process, encompassing

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the regulation of the driving environment, the provision of emotional support to drivers through voice assistants, and the modulation of driving emotions by means of biofeedback technology. Currently, although the regulation techniques have witnessed substantial development, certain limitations and challenges persist. Future research needs to be further intensified in three aspects: the effective integration of multi-modal technologies, the development of personalized intervention measures for road rage, and the focus on the factors within the vehicle that trigger road rage.

Keywords

Driving Emotions, Anger Regulation, Human-Computer Interaction, Empathy

1. 引言

根据《中国统计年鉴 2023》的数据，2022 年我国发生的道路交通事故数量高达 25 万起。研究者发现，驾驶者的不良情绪是导致这些事故的诱因之一(Braun et al., 2019b; Deffenbacher et al., 2007; Zimasa et al., 2017)。驾驶员在行驶过程中的负面情绪，如愤怒和悲伤，会显著影响其警觉性和决策能力。美国汽车协会(American Automobile Association, AAA)对攻击性驾驶行为的定义是：驾驶者故意采取的、可能增加交通事故风险的行为，这些行为通常是由愤怒、焦虑、敌意等负面情绪，或出于节省时间的目的所驱动(AAA Foundation for Traffic Safety, 2009)。“路怒(Road Rage)”这个术语最早出现在 20 世纪 80 年代的美国，它通常被视为攻击性驾驶的一种表现形式。路怒被定义为对其他驾驶者的敌对行为，包括但不限于尾随、言语辱骂等(Shinar, 1998)。但也有研究认为，路怒仅指那些更加极端的、可能导致直接对抗的攻击性或威胁行为，例如故意撞击他人车辆、下车发生肢体冲突等(Wells-Parker et al., 2002)。

研究表明，路怒与攻击性、冒险性驾驶以及驾驶失误之间存在着显著的相关性，与道路交通事故的发生有着密切的联系(Zhang & Chan, 2016)。如何在驾驶过程中有效调节路怒情绪，已成为研究者关注的焦点问题。过去对于路怒的干预往往采用认知行为疗法，如放松训练等(Deffenbacher, 2016)，但这些方法需要事先练习且受个体差异影响，在实际驾驶中难以快速调节情绪。如今人机交互(Human-Computer Interaction, HCI)的应用已经延伸至视觉、听觉、嗅觉、温度感知等多个感官维度的交互体验(Wang et al., 2022b)。在驾驶领域，通过先进的 HCI 技术，智能车载系统不仅能根据驾驶员的语言指令调整车内环境、播放音乐或导航，还可以通过情绪识别实施相应的车载环境动态调整，从而创造出一种既能满足功能性需求又能兼顾心理舒适度的驾驶体验，有助于降低驾驶情境下的潜在风险发生。目前基于感官通道的驾驶环境调节技术、借助语音助手提供的情感支持，以及运用生物反馈技术进行情绪调节的方法，都已应用于实践中。

2. 驾驶环境的调控

车载环境是驾驶员身处的物理空间，通过合理运用车载环境中的多感官刺激可以调节驾驶员的路怒情绪，这种方法主要利用特定的物理刺激来触发和改变人的情绪反应。

2.1. 利用视觉信息的驾驶情绪调节

视觉可以与情绪相互影响，一些视觉刺激会产生相应的情绪唤醒(Nicol et al., 2013; Shang et al., 2021)。

例如，光照设计能有效引导视线焦点，赋予环境色彩层次(David et al., 2019)，合理的光照设计可以在特定场合微妙地调节人们的情绪并提升整个空间的舒适度与和谐感(Xie et al., 2022)，减少用户的消极情绪，增加积极情绪(Xiong et al., 2022)。

车辆人机界面中的视觉属性同样可以调节驾驶者的情绪(Li et al., 2022b)。环境色彩主要通过亮度和饱和度两个关键维度影响和调节情绪，亮度与饱和度较高的颜色往往更能触发愉悦情绪，前者与低唤醒的情绪状态相关联，后者与高唤醒的情绪状态相关联(Valdez & Mehrabian, 1994)。如黄绿色的光有助于调节驾驶者的悲伤情绪，当蓝、黄色的光刺激活跃时，则对调节愤怒情绪有所帮助(Li et al., 2022b; Spiridon Fairclough, 2017; 李正盛等，2021)，而车内红色的光比其他颜色更能引起紧张感、情绪低落等负面情绪反应(Kim et al., 2022; Kim et al., 2021; Li et al., 2022b; 李正盛等，2021)，在驾驶中应当减少使用。

除了氛围光的颜色对情绪有调节作用，灯光变化对情绪也有影响。呼吸灯是通过周期性的光线变化而创造的一种动态光照环境，也可以作为一种有效的工具，帮助驾驶者调节情绪。呼吸灯设计能够显著降低人们受到情绪刺激后的 EDA 值和心率，说明呼吸灯有助于减少情绪刺激后的生理唤醒水平(Wang et al., 2022a)。在驾驶情境下，平滑过渡的呼吸灯效相较于闪烁的灯光效果能获得更良好的视觉体验，更受驾驶者青睐。同时，高频的闪烁灯光容易引起驾驶者的紧张情绪，更适合作为一种警告信号。在驾驶中，选择更为舒缓、低频变换的灯光模式，能够提供更为舒适的驾驶环境并有助于行车安全(Kim et al., 2021)。

2.2. 利用听觉信息的驾驶情绪调节

音乐通过激活大脑中与情感相关的多个区域(如杏仁核)、影响神经递质的释放(如多巴胺)以及触发生理和情感反应，从而显著调节人的情绪状态和影响驾驶行为(Braun et al., 2021; FakhrHosseini & Jeon, 2019; Kim et al., 2022; Navarro et al., 2023; Ouyang et al., 2023; Schaefer, 2017; Zhang et al., 2024)。听觉刺激与呼吸信号之间存在着关联，研究发现音乐具有调节呼吸的作用(Innocenti et al., 2022; Reza Namazi, 2017)，进而增加副交感神经系统的活动，减少交感神经系统的活动，有助于降低 HR 和血压、提高 HRV，从而改善情绪(Shao et al., 2024)。柔和、慢节奏的音乐可以通过调节驾驶者的呼吸频率缓解驾驶的负面情绪(Braun et al., 2021; Ouyang et al., 2023)。但音乐受个体差异的影响较大，不同参与者对同一首音乐的反应可能是正面的也可能是负面的(Chamorro-Premuzic & Furnham, 2007; Kim et al., 2022)。值得注意的是那些蕴含悲伤、失望或遗憾情绪的消极音乐，反而可能进一步影响其驾驶表现和决策判断，促使驾驶者的驾驶行为呈现更加激进的趋势(Navarro et al., 2023)。但当驾驶者自主选择播放音乐时，缓和路怒情绪的音乐调控策略往往面临执行上的挑战，难以有效应用。

2.3. 利用嗅觉信息与温度感知的驾驶情绪调节

嗅觉通路和大脑边缘系统之间有大量重叠部分，与视觉刺激相比，气味能够更强烈地调节杏仁核的神经元反应(Billot et al., 2017)。嗅觉调节可以作为一种有效的手段来改善驾驶员的情绪，但研究也发现，不同个体对气味的反应存在差异。佛手柑、紫苏、沉香木、茉莉精油等诸多嗅觉刺激均能有效地调节驾驶者的愤怒情绪(Kim et al., 2022; 唐帮备等，2023；王晴艺，2022；魏婷，2024)，未来可能需要个性化的嗅觉刺激选择，以更好地满足不同驾驶员的需求和偏好。

驾驶环境的温度对驾驶员的情绪和警觉性也有影响，在高温环境下，驾驶者更容易出现路怒倾向(Kenrick & MacFarlane, 1986)。研究表明，适度的冷气流刺激可以提升驾驶员的警觉性，并增加交感神经活动，从而带来更好的驾驶表现。然而，这种效果往往是短暂的，通常在刺激结束后几分钟内就会减弱，因此需要进行间断的温度刺激(Schmidt et al., 2017; Schmidt & Bullinger, 2019)。

3. 利用语音助手对驾驶者进行情感支持

人类作为社会性生物，除了通过物理刺激进行情绪调节外，社会心理因素也在情绪管理中扮演着重要角色，对愤怒情绪的缓解同样有作用。语音助手作为一种新兴的 HCI 技术，正成为驾驶情绪调节的重要工具。

通过集成共情计算能力，语音助手能够模拟和理解人类的情感反应(Hu et al., 2023; Sharma et al., 2023; Yalçın & DiPaola, 2020)，在出现负面驾驶情绪时提供共情交流、积极反馈，与驾驶者产生情绪共鸣、传染，帮助驾驶者进行认知重评，有效降低驾驶过程中的愤怒情绪(Braun et al., 2019b; Li et al., 2020; Wu et al., 2022; Yoo et al., 2023; Zhao et al., 2024)。Braun 等人(2019b)，Hu 等人(2023)和 Zhao 等人(2024)均发现共情语音助手能通过提高情景意识以优化接管绩效、驾驶表现，从而提高驾驶安全性。此外，能够提供个性化语音的语音助手可以更好地改善驾驶体验和增强驾驶者信任度，如使用亲近人士的语音、服从性语音、幽默语音等可以给予驾驶者更多的情感支持，帮助其更好地调节情绪，有效减少愤怒及其引起的分心和路怒行为(Braun et al., 2019a; Wu et al., 2022; Yoo et al., 2022; Zhang et al., 2023)。而语音干预中的积极评论和责备他人策略可以更有效地减少驾驶员愤怒状态，且不会增加认知负荷(Li et al., 2020; Yoo et al., 2023)。随着 AI 的不断发展，语音助手在驾驶中的应用将更加广泛，为驾驶员提供更加人性化的交互体验。

4. 利用生物反馈技术进行驾驶情绪调节

生物反馈技术通过心理暗示展现出改善驾驶情绪的潜力。如 Ota 等人(2024)使用了更慢的听觉假心率(Auditory False Heart Rate)，即采用比驾驶者自身更低的心率的模拟心跳声，能够显著减少驾驶中的认知负荷以及挫败感，改善驾驶者情绪。Li 等人(2022b)发现，与给驾驶者呈现消极表情相比，积极表情在调节驾驶员愤怒情绪方面更有效。Yu 等人(2024)通过在 AR-HUD 中显示笑脸表情，增加了驾驶者与车机之间的社交互动感，使其感受到了更多的快乐与满足感。

5. 未来研究展望

综上所述，路怒情绪的实时调节技术可以从车载环境的多感官调控、情感支持类语音助手的设置以及生物反馈技术的应用等方面实现。但以车内情绪识别和调节系统为例，尽管这些技术被视为创新前沿，已经在一些车型(AION Y、哈弗初恋、起亚 R.E.A.D.系统)上进行了初步应用，它们声称能够根据驾驶者的情绪状态调整氛围灯、播放音乐等，以提升驾驶体验。但在实际应用中，这些系统大多还处于初级阶段或仅作为概念验证，其在个性化适应性和实际效用方面仍存在不足，导致用户对这些系统的接受度并不高。未来可以尝试将上述多种调节手段协同应用，构建一个综合的多模态情绪支持系统。该系统将根据驾驶者的个体差异和实时情绪状态，动态调整干预策略，以实现对驾驶者情绪的个性化精准干预。

5.1. 有效融合多模态技术

相比于研究中对单一技术或方法的验证，目前路怒监测与调节领域的有效专利大多同时采用了多种技术对路怒情绪进行识别和干预。然而，多模态不等同于单模态的简单加总，不同模态之间的信息可能存在冗余或矛盾(Gandhi et al., 2023; Lahat et al., 2015)。同时，在驾驶中由于路况复杂程度以及个体差异，驾驶者对信息的处理能力和认知负荷的感受各不相同(Agrawal et al., 2022)，随着调节技术越来越多，驾驶者需要同时注意道路、车辆信息，还受到如语音提示等干预刺激，可能引发认知过载，即信息量超过其认知处理能力时发生的现象(Sweller, 1988)，反而会影响到驾驶安全。因此，如何有效地整合多模态信息以提高怒路情绪调节的有效性是一个挑战。

此外，现有的调节技术在实验室条件下表现良好，但在实际驾驶环境中的有效程度以及时效性还有待验证，特别是在复杂或极端的天气和光照条件下，以及在极度拥堵等恶劣的路况环境下(Katiyar et al., 2024)。因此，车辆接管技术被广泛采用作为一种预防路怒的保底方案，当检测到驾驶者出现严重的路怒情绪时，会自动采取措施，如降低车速、实施停车，或者直接切换到自动驾驶模式，以防止驾驶者因情绪失控而采取危险或破坏性的行为(例如，丁同强等，2024；臧珂欣等，2024)。

5.2. 开发个性化干预手段

个体在情绪调节以及偏好方面都存在着差异(Chamorro-Premuzic & Furnham, 2007; Kim et al., 2022; Larsen, 2000; Sorella et al., 2022)，如特质愤怒高的驾驶者本身出现愤怒以及路怒行为就更频繁(Deffenbacher et al., 2007; Ge et al., 2017; Wang et al., 2024)；再比如有些人可能对音乐干预更为敏感，而另一些人可能使用视觉或嗅觉刺激效果更优(Braun et al., 2019b; Kim et al., 2022; Wang et al., 2024)。

因此，未来的研究需要考虑这些个体差异，设计实时信息及其传递系统时考虑驾驶员的认知和心理因素，开发个性化的调节方案。例如，可以利用 AI 根据驾驶者的情绪状态和偏好自动调整干预措施，如在长期驾驶中智能分析何种情绪调节策略更适合于驾驶者，或智能结合多种策略协同调整，同时还要保证这些干预策略不干扰到驾驶行为。通过采用自适应算法，该模型能够根据驾驶者的行为和情绪反应，动态调整调节机制，从而为驾驶者提供更加个性化和有效的情绪支持。

5.3. 注重车内因素的权重分析

实际上，除了交通拥堵和他人驾驶行为等外部因素之外，车内因素——例如与乘客的争执或不适宜的车内环境，同样能够诱发路怒情绪(Hu et al., 2012; Nakagawa & Park, 2014; Smart & Mann, 2002; Ye et al., 2023)。而车内因素引起的路怒可能需要不同的调节和干预策略，如通过改善车内交流环境、提供冲突解决指导等方法来减少车内引起的路怒情绪，但目前市场上的专利产品尚未充分考虑这些内部影响因素。

此外，随着自动驾驶技术的发展，驾驶者的角色可能发生变化，从主动驾驶转变为监督或与车辆交互(Meschtscherjakov et al., 2017)，其路怒的诱因和表现可能与当前情形有显著差异(Li et al., 2022a)。这也要求研究者们探索路怒未来的变化以及开发新的干预手段，以适应未来驾驶环境中可能出现的新挑战。

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参考文献

丁同强, 张克鑫, 李洪君, 刘宇佳, 修桂红, 王立强, 牟凯, 李兴佳, 殷慧娟, 刘诗楠, 邰文龙, 杨雨菁, 陈文浩, 席建锋, 郑黎黎(2024). *基于行驶状态的驾驶愤怒指数检测与车辆控制方法及系统*. 国家知识产权局, Patent No. CN117584985B.

李正盛, 邢文, 何灿群, 邓亮(2021). 氛围灯色彩对驾驶情绪安抚作用的设计研究. *人类工效学, 27(2),* 14-20.

唐帮备, 朱明鑫, 邓凌云, 胡志安, 陈柄言(2023). 基于嗅觉刺激的驾驶员负向情绪正向调控方法研究. *汽车工程学报, 13(6),* 832-843.

王晴艺(2022). *四种芳香植物挥发物成分分析及其对人体身心健康的影响研究*. 硕士学位论文, 杭州: 浙江农林大学.

魏婷(2024). *多模态交互情境下的智能车载产品用户体验设计方法研究*. 博士学位论文, 西安: 陕西科技大学.

臧珂欣, 席建锋, 周尚, 付如依, 王潇菁, 郑黎黎(2024). *面向公交车司乘冲突的人员预警和行车控制方法及系统*. 国家知识产权局, Patent No. CN117445805B.

AAA Foundation for Traffic Safety (2009). *Aggressive Driving: Research Update.* AAA Foundation for Traffic Safety.

Agrawal, S., Benedyk, I., & Peeta, S. (2022). *Development of In-Vehicle Information Dissemination Mechanisms to Reduce Cognitive Burden in the Information-Rich Driving Environment.* Center for Connected and Automated Transportation Paper 4.

Billot, P., Andrieu, P., Biondi, A., Vieillard, S., Moulin, T., & Millot, J. (2017). Cerebral Bases of Emotion Regulation toward Odours: A First Approach. *Behavioural Brain Research, 317,* 37-45. https://doi.org/10.1016/j.bbr.2016.09.027

Braun, M., Mainz, A., Chadowitz, R., Pfleging, B., & Alt, F. (2019a). At Your Service: Designing Voice Assistant Personalities to Improve Automotive User Interfaces. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-11). ACM. https://doi.org/10.1145/3290605.3300270

Braun, M., Schubert, J., Pfleging, B., & Alt, F. (2019b). Improving Driver Emotions with Affective Strategies. *Multimodal Technologies and Interaction, 3,* Article 21. https://doi.org/10.3390/mti3010021

Braun, M., Weber, F., & Alt, F. (2021). Affective Automotive User Interfaces-Reviewing the State of Driver Affect Research and Emotion Regulation in the Car. *ACM Computing Surveys, 54,* 1-26. https://doi.org/10.1145/3460938

Chamorro-Premuzic, T., & Furnham, A. (2007). Personality and Music: Can Traits Explain How People Use Music in Everyday Life? *British Journal of Psychology, 98,* 175-185. https://doi.org/10.1348/000712606x111177

David, A., Smet, K. A. G., & Whitehead, L. (2019). Methods for Assessing Quantity and Quality of Illumination. *Annual Review of Vision Science, 5,* 479-502. https://doi.org/10.1146/annurev-vision-091718-015018

Deffenbacher, J. L. (2016). A Review of Interventions for the Reduction of Driving Anger. *Transportation Research Part F: Traffic Psychology and Behaviour, 42,* 411-421. https://doi.org/10.1016/j.trf.2015.10.024

Deffenbacher, J. L., Kemper, C. C., & Richards, T. L. (2007). The Driving Anger Expression Inventory: A Validity Study with Community College Student Drivers. *Journal of Psychopathology and Behavioral Assessment, 29,* 220-230. https://doi.org/10.1007/s10862-007-9049-x

FakhrHosseini, S. M., & Jeon, M. (2019). How Do Angry Drivers Respond to Emotional Music? A Comprehensive Perspective on Assessing Emotion. *Journal on Multimodal User Interfaces, 13,* 137-150. https://doi.org/10.1007/s12193-019-00300-3

Gandhi, A., Adhvaryu, K., Poria, S., Cambria, E., & Hussain, A. (2023). Multimodal Sentiment Analysis: A Systematic Review of History, Datasets, Multimodal Fusion Methods, Applications, Challenges and Future Directions. *Information Fusion, 91,* 424-444. https://doi.org/10.1016/j.inffus.2022.09.025

Ge, Y., Zhang, Q., Zhao, W., Zhang, K., & Qu, W. (2017). Effects of Trait Anger, Driving Anger, and Driving Experience on Dangerous Driving Behavior: A Moderated Mediation Analysis. *Aggressive Behavior, 43,* 544-552. https://doi.org/10.1002/ab.21712

Hu, J., Huang, Y., Hu, X., & Xu, Y. (2023). The Acoustically Emotion-Aware Conversational Agent with Speech Emotion Recognition and Empathetic Responses. *IEEE Transactions on Affective Computing, 14,* 17-30. https://doi.org/10.1109/taffc.2022.3205919

Hu, T., Xie, X., Han, X., & Ma, X. (2012). How Do Passengers Influence Drivers' Propensities for Angry Driving? Different Effects of Supervisors versus Friends. *Accident Analysis & Prevention, 49,* 429-438. https://doi.org/10.1016/j.aap.2012.03.015

Innocenti, L., Nicolò, A., Massaroni, C., Minganti, C., Schena, E., & Sacchetti, M. (2022). How to Investigate the Effect of Music on Breathing during Exercise: Methodology and Tools. *Sensors, 22,* Article 2351. https://doi.org/10.3390/s22062351

Katiyar, D. N., Shukla, D. A., & Chawla, D. N. (2024). AI in Autonomous Vehicles: Opportunities, Challenges, and Regulatory Implications. *Educational Administration Theory and Practices, 30,* 6255-6264. https://doi.org/10.53555/kuey.v30i4.2373

Kenrick, D. T., & MacFarlane, S. W. (1986). Ambient Temperature and Horn Honking: A Field Study of the Heat/Aggression Relationship. *Environment and Behavior, 18,* 179-191. https://doi.org/10.1177/0013916586182002

Kim, H., Kim, S., Kim, H., Ji, Y., & Im, C. (2022). Modulation of Driver's Emotional States by Manipulating In-Vehicle Environment: Validation with Biosignals Recorded in an Actual Car Environment. *IEEE Transactions on Affective Computing, 13,* 1783-1792. https://doi.org/10.1109/taffc.2022.3206222

Kim, T., Kim, Y., Jeon, H., Choi, C., & Suk, H. (2021). Emotional Response to In-Car Dynamic Lighting. *International Journal of Automotive Technology, 22,* 1035-1043. https://doi.org/10.1007/s12239-021-0093-4

Lahat, D., Adali, T., & Jutten, C. (2015). Multimodal Data Fusion: An Overview of Methods, Challenges, and Prospects. *Proceedings of the IEEE, 103,* 1449-1477. https://doi.org/10.1109/jproc.2015.2460697

Larsen, R. J. (2000). Toward a Science of Mood Regulation. *Psychological Inquiry, 11,* 129-141. https://doi.org/10.1207/s15327965pli1103_01

Li, S., Zhang, T., Zhang, W., Liu, N., & Lyu, G. (2020). Effects of Speech-Based Intervention with Positive Comments on Reduction of Driver's Anger State and Perceived Workload, and Improvement of Driving Performance. *Applied Ergonomics, 86,* Article ID: 103098. https://doi.org/10.1016/j.apergo.2020.103098

Li, T., Wang, L., Liu, J., Yuan, J., & Liu, P. (2022a). Sharing the Roads: Robot Drivers (vs. Human Drivers) Might Provoke Greater Driving Anger When They Perform Identical Annoying Driving Behaviors. *International Journal of Human—Computer Interaction, 38,* 309-323. https://doi.org/10.1080/10447318.2021.1938392

Li, W., Zhang, B., Wang, P., Sun, C., Zeng, G., Tang, Q. et al. (2022b). Visual-Attribute-Based Emotion Regulation of Angry Driving Behaviors. *IEEE Intelligent Transportation Systems Magazine, 14,* 10-28. https://doi.org/10.1109/mits.2021.3050890

Meschtscherjakov, A., Tscheligi, M., Fröhlich, P., McCall, R., Riener, A., & Palanque, P. (2017). Mobile Interaction with and in Autonomous Vehicles. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services* (pp. 1-6). ACM. https://doi.org/10.1145/3098279.3119837

Nakagawa, Y., & Park, K. (2014). Psychological Effect of Passenger Presence on Drivers and Its Dimensions: Scale Development and Validation. *Transportation Research Part F: Traffic Psychology and Behaviour, 25,* 86-97. https://doi.org/10.1016/j.trf.2014.04.018

Navarro, J., Gaujoux, V., Claude Ouimet, M., Ferreri, L., & Reynaud, E. (2023). How Does Background Music Affect Drivers' Behaviours, Emotions and Mood behind the Wheel? *Transportation Research Part F: Traffic Psychology and Behaviour, 98,* 47-60. https://doi.org/10.1016/j.trf.2023.08.003

Nicol, J. R., Perrotta, S., Caliciuri, S., & Wachowiak, M. P. (2013). Emotion-Specific Modulation of Early Visual Perception. *Cognition & Emotion, 27,* 1478-1485. https://doi.org/10.1080/02699931.2013.793654

Ota, K., Fujiwara, K., & Hiraoka, T. (2024). Frustration Control during Driving Using Auditory False Heart Rate Feedback. *Transportation Research Part F: Traffic Psychology and Behaviour, 101,* 375-386. https://doi.org/10.1016/j.trf.2024.01.014

Ouyang, D., Li, G., Li, Q., Sui, X., Qu, X., & Guo, G. (2023). Effect of Music Intervention Strategies on Mitigating Drivers' Negative Emotion in Post-Congestion Driving. In *2023 IEEE Intelligent Vehicles Symposium (IV)* (pp. 1-6). IEEE. https://doi.org/10.1109/iv55152.2023.10186669

Reza Namazi, H. (2017). Fractal-Based Analysis of the Influence of Music on Human Respiration. *Fractals, 25,* Article ID: 1750059. https://doi.org/10.1142/s0218348x17500591

Schaefer, H. (2017). Music-Evoked Emotions—Current Studies. *Frontiers in Neuroscience, 11,* Article 600. https://doi.org/10.3389/fnins.2017.00600

Schmidt, E., & Bullinger, A. C. (2019). Mitigating Passive Fatigue during Monotonous Drives with Thermal Stimuli: Insights into the Effect of Different Stimulation Durations. *Accident Analysis & Prevention, 126,* 115-121. https://doi.org/10.1016/j.aap.2017.12.005

Schmidt, E., Decke, R., Rasshofer, R., & Bullinger, A. C. (2017). Psychophysiological Responses to Short-Term Cooling during a Simulated Monotonous Driving Task. *Applied Ergonomics, 62,* 9-18. https://doi.org/10.1016/j.apergo.2017.01.017

Shang, Z., Wang, Y., & Bi, T. (2021). How Does Fearful Emotion Affect Visual Attention? *Frontiers in Psychology, 11,* Article 584412. https://doi.org/10.3389/fpsyg.2020.584412

Shao, R., Man, I. S. C., & Lee, T. M. C. (2024). The Effect of Slow-Paced Breathing on Cardiovascular and Emotion Functions: A Meta-Analysis and Systematic Review. *Mindfulness, 15,* 1-18. https://doi.org/10.1007/s12671-023-02294-2

Sharma, A., Lin, I. W., Miner, A. S., Atkins, D. C., & Althoff, T. (2023). Human-AI Collaboration Enables More Empathic Conversations in Text-Based Peer-To-Peer Mental Health Support. *Nature Machine Intelligence, 5,* 46-57. https://doi.org/10.1038/s42256-022-00593-2

Shinar, D. (1998). Aggressive Driving: The Contribution of the Drivers and the Situation. *Transportation Research Part F: Traffic Psychology and Behaviour, 1,* 137-160. https://doi.org/10.1016/s1369-8478(99)00002-9

Smart, R. G., & Mann, R. E. (2002). Is Road Rage a Serious Traffic Problem? *Traffic Injury Prevention, 3,* 183-189. https://doi.org/10.1080/15389580213643

Sorella, S., Vellani, V., Siugzdaite, R., Feraco, P., & Grecucci, A. (2022). Structural and Functional Brain Networks of Individual Differences in Trait Anger and Anger Control: An Unsupervised Machine Learning Study. *European Journal of Neuroscience, 55,* 510-527. https://doi.org/10.1111/ejn.15537

Spiridon, E., & Fairclough, S. H. (2017). The Effects of Ambient Blue Light on Anger Levels: Applications in the Design of Un-Manned Aircraft GCS. *Systems Engineering, 5,* 53-69.

Sweller, J. (1988). Cognitive Load during Problem Solving: Effects on Learning. *Cognitive Science, 12,* 257-285. https://doi.org/10.1207/s15516709cog1202_4

Valdez, P., & Mehrabian, A. (1994). Effects of Color on Emotions. *Journal of Experimental Psychology: General, 123,* 394-409. https://doi.org/10.1037//0096-3445.123.4.394

Wang, J., Lu, J., Xu, Z., & Wang, X. (2022a). When Lights Can Breathe: Investigating the Influences of Breathing Lights on Users' Emotion. *International Journal of Environmental Research and Public Health, 19,* Article 13205. https://doi.org/10.3390/ijerph192013205

Wang, Y., Song, W., Tao, W., Liotta, A., Yang, D., Li, X. et al. (2022b). A Systematic Review on Affective Computing: Emotion Models, Databases, and Recent Advances. *Information Fusion, 83,* 19-52. https://doi.org/10.1016/j.inffus.2022.03.009

Wang, Y., Zheng, J., Zhang, W., Chen, X., & Wu, M. (2024). Inducing Driving Anger with Multi-Stage Road Events in Simulator Environment. *Transportation Research Part F: Traffic Psychology and Behaviour, 101,* 403-422. https://doi.org/10.1016/j.trf.2024.02.001

Wells-Parker, E., Ceminsky, J., Hallberg, V., Snow, R. W., Dunaway, G., Guiling, S. et al. (2002). An Exploratory Study of the Relationship between Road Rage and Crash Experience in a Representative Sample of US Drivers. *Accident Analysis & Prevention, 34,* 271-278. https://doi.org/10.1016/s0001-4575(01)00021-5

Wu, L., Xue, J., Li, W., Wang, K., Zhang, X., & Guo, G. (2022). Toward Decreasing the Driving Risk: Speech-Based Driver's Anger Regulation in Smart Cockpit. *IEEE Journal of Radio Frequency Identification, 6,* 764-768. https://doi.org/10.1109/jrfid.2022.3208199

Xie, X., Cai, J., Fang, H., Tang, X., & Yamanaka, T. (2022). Effects of Colored Lights on an Individual's Affective Impressions in the Observation Process. *Frontiers in Psychology, 13,* Article 938636. https://doi.org/10.3389/fpsyg.2022.938636

Xiong, Z., Weng, X., & Wei, Y. (2022). Research on the Influence of Visual Factors on Emotion Regulation Interaction. *Frontiers in Psychology, 12,* Article 772642. https://doi.org/10.3389/fpsyg.2021.772642

Yalçın, Ö. N., & DiPaola, S. (2020). Modeling Empathy: Building a Link between Affective and Cognitive Processes. *Artificial Intelligence Review, 53,* 2983-3006. https://doi.org/10.1007/s10462-019-09753-0

Ye, S., Chen, Q., & Tang, Y. (2023). Anger Expressions of Bus Drivers and Passengers during Conflicts on the Bus. *Transportation Research Record: Journal of the Transportation Research Board, 2677,* 782-794. https://doi.org/10.1177/03611981231170008

Yoo, Y., Lee, J., Kim, N., Yang, M., Lee, S., & Kim, J. (2023). An Empirical Study on the Effect of a Driving Companion Bot on Anger Coping Behaviors. *Behaviour & Information Technology, 42,* 329-344. https://doi.org/10.1080/0144929x.2021.2019831

Yoo, Y., Yang, M., Lee, S., Baek, H., & Kim, J. (2022). The Effect of the Dominance of an In-Vehicle Agent's Voice on Driver Situation Awareness, Emotion Regulation, and Trust: A Simulated Lab Study of Manual and Automated Driving. *Transportation Research Part F: Traffic Psychology and Behaviour, 86,* 33-47. https://doi.org/10.1016/j.trf.2022.01.009

]Yu, K., Du, D., Yu, D., Zhi, J., Wang, Y., & Jing, C. (2024). Effects of a Color Gradient and Emoji in AR-HUD Warning Interfaces in Autonomous Vehicles on Takeover Performance and Driver Emotions. *Traffic Injury Prevention, 25,* 714-723. https://doi.org/10.1080/15389588.2024.2337120

Zhang, L., Wang, Y., He, K., Zhang, H., Xing, B., Liu, X. et al. (2023). The Power of Humorous Audio: Exploring Emotion Regulation in Traffic Congestion through EEG-Based Study. *EURASIP Journal on Audio, Speech, and Music Processing, 2023,* Article No. 34. https://doi.org/10.1186/s13636-023-00302-w

Zhang, Q., Ge, Y., & Qu, W. (2024). The Effect of Relaxing Music on Driving Anger and Performance in a Simulated Car-following Task. *Human Factors and Ergonomics in Manufacturing & Service Industries, 34,* 386-395. https://doi.org/10.1002/hfm.21031

Zhang, T., & Chan, A. H. S. (2016). The Association between Driving Anger and Driving Outcomes: A Meta-Analysis of Evidence from the Past Twenty Years. *Accident Analysis & Prevention, 90,* 50-62. https://doi.org/10.1016/j.aap.2016.02.009

Zhao, Y., Jiang, K., Yu, Z., & Huang, Z. (2024). Emotion-Matched In-Vehicle Assistants: An Exploration in Regulating Drivers' Incidental Emotions and Enhancing Takeover Performance and Situational Awareness. *Cognition, Technology & Work, 26,* 225-245. https://doi.org/10.1007/s10111-024-00756-8

Zimasa, T., Jamson, S., & Henson, B. (2017). Are Happy Drivers Safer Drivers? Evidence from Hazard Response Times and Eye Tracking Data. *Transportation Research Part F: Traffic Psychology and Behaviour, 46,* 14-23. https://doi.org/10.1016/j.trf.2016.12.005