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探寻攻击行为的神经标志物：来自P300的证据

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摘　要

攻击行为正逐渐上升为一个突出的公共卫生问题，是否能够寻找到攻击性行为的神经标志物，成为了心理学家和神经科学家的共同关注目标。P300被认为可作为独立指标有效预测攻击性行为。本文分别介绍了P300在临床群体、犯罪群体和非临床暴力风险群体的攻击性行为测量中的应用，评估了研究结果的一致性，并从P300指标的多角度分析及与其他ERP成分的结合、对犯罪群体进行进一步的类型细分、P300的应用场景拓展(如监内暴力预测、暴力行为干预效果评估和正常人攻击风险测量)等三个方面对未来的研究方向进行了展望。

关键词

P300，攻击行为，临床群体，犯罪群体

Exploring the Neural Markers of Aggressive Behavior: Evidence from P300

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Abstract

Aggressive behavior is gradually emerging as a prominent public health problem. Finding neural markers for aggressive behavior has become a common focus for psychologists and neuroscientists. The P300 is considered to be an independent indicator that can effectively predict aggressive behavior. This article introduces the application of P300 in the measurement of aggressive be-

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havior in clinical, criminal and non-clinical violence risk groups, evaluates the consistency of research results, and looks forward to future research directions from three perspectives: multi-dimensional analysis of P300 predictors and combination with other ERP components, further subdivision of criminal groups, and expansion of the application scenarios of P300 (such as the prediction of violence in prison, the evaluation of the effectiveness of violence intervention and the measurement of the risk of aggression in normal people).

Keywords

P300, Aggressive Behavior, Clinical Groups, Criminal Groups

1. 引言

根据世界卫生组织 2014 年的报告，每年有超过 130 万人因暴力而丧生，占全球死亡率的 2.5%；到了 2021 年，这一数字快速攀升至 440 万，占全球死亡率的近 8%。在这一背景下，是否能够寻找到攻击性行为的神经标志物(Neural markers)，成为了心理学家和神经科学家的共同关注目标。神经标志物基于神经生理活动的测量，可以在不依赖主观报告的情况下进行客观地测量，具有高准确性的特点(Tsuchiya et al., 2015; Arzi et al., 2020)。

事件相关电位(Event-Related Potential, ERP)的波幅或潜伏期已被证实可以稳定地标识出攻击性和非攻击性个体(Patrick, 2008)。P300 作为 ERP 的一种成分，是指从接受刺激开始在大约 300ms 左右出现的正波电位(魏景汉，罗跃嘉，2010)。其优势在于，低成本、测试时间短、容易获得稳定结果，且操作简单(Herzog et al., 2021; Olichney et al., 2022; Sheffler et al., 2022; Li et al., 2013; Tao et al., 2022)。P300 被认为可作为独立指标(Blignaut & Vandenheever, 2022; Key et al., 2023; Arıkan et al., 2024; Salas et al., 2024)，有效预测攻击性行为(Gao & Raine, 2009; Venables et al., 2011; Yancey et al., 2013; Fanning et al., 2014; Zhang et al., 2017; Pasion et al., 2018; Delfin et al., 2022; Yu et al., 2022; Pasion et al., 2023; Wu et al., 2023)。本文将分别介绍 P300 在临床群体、犯罪群体和非临床暴力风险群体的攻击性行为测量中的应用，评估研究结果的一致性，并对未来的研究方向进行展望。

2. 攻击行为

攻击是行动者有意图伤害他人的行为或者倾向，且受害者有意避免这种伤害(Allen & Anderson, 2017)。攻击行为通常包括三大特征：1) 可观察的外显行为或倾向；2) 行动者具有主动伤害意图；3) 受害者有动机避免这种行为。其中暴力是以极端伤害为目标的攻击行为(Allen & Anderson, 2017; Bushman & Anderson, 2001; Klein Tuente et al., 2019)。

攻击行为可以划分为：特质性的攻击倾向(Tremblay & Belchevski, 2004)和状态性的攻击行为(Bushman & Anderson 2001)。前者是指个体稳定且持久的、倾向于伤害他人的认知、情绪和行为模式，这种倾向可以通过个体间的差异来量化(Paulhus et al., 2018)。后者则是指在特定情境下，个体故意进行的伤害行为，这种行为通常是他人所希望避免的。

攻击行为的脑电研究显示，攻击行为与多个 ERP 成分异常有关，这包括早期(P50)、中期(ERN, N2)

和晚期(P300)成分。其中 P300 波幅的减小与攻击行为的关系尤为密切，这可能是因为 P300 能更精确地反映了攻击行为的决策和执行过程(Gao & Raine, 2009)。

3. P300 与临床群体的攻击行为测量

这里的临床群体定义为：符合精神障碍诊断与统计手册第五版(The Diagnostic and Statistical Manual of Mental Disorders, DSM-5)中精神分裂症、物质使用障碍、反社会人格障碍、品行障碍等诊断标准；或者符合国际疾病分类第 10 版(International Classification of Diseases, 10th Revision, ICD-10)中精神与行为障碍分类中有关精神分裂症或急性精神分裂症样精神病性障碍的诊断标准。

3.1. 精神分裂症

精神分裂症患者产生攻击行为的原因主要包括精神病症状(Wu et al., 2018)、心理因素(Khosravani et al., 2024)和冲动性(Hoptman, 2015)。精神分裂症被认为在发生暴力行为时存在认知缺陷和消极情绪调节障碍(Richetto & Meyer, 2021)。Krakowski 等人(2016)发现，精神分裂症患者面对负面情绪刺激时，P300 成分的减小与其反应抑制能力的减弱有关。也有研究者认为，P300 潜伏期延长是精神分裂症患者发生暴力行为最突出的表现(Silverstein et al., 2015)，也是精神分裂症患者最显著的暴力指标(Bochkarev et al., 2020)。采用 Oddball 范式，李丹玉(2021)、唐敏和黄银秋(2022)、赵红岩等人(2022)、Wu 等人(2023)和赵丁等人(2024)均发现，P300 的潜伏期和波幅可以作为评估精神分裂症患者暴力风险的特异性神经电生理指标。高风险组的 P300 潜伏期较低风险组延长，且 P300 的波幅显著减小。有研究者认为，Oddball 范式中 P300 的异常可能反映了精神分裂症患者在处理信息时存在延迟，这种延迟进而影响了他们对周围环境的感知和对社会互动的理解，增加了误解和冲突的风险，最终导致暴力行为发生。

3.2. 反社会人格障碍

反社会人格，也称为反社会型人格障碍(Antisocial Personality Disorder, APD)，是一种心理障碍，其特征是漠视或侵犯他人的权利，表现为不遵守社会规范的行为模式(Black, 2015)。反社会人格的个体通常会表现出冲动性暴力行为(Bauer et al., 1994)。

大量研究揭示了反社会行为与 P300 波幅减小之间的关系。这些研究主要集中在反社会人格以及品行障碍(Conduct Disorder, CD)中。Bauer，O'Connor 和 Hesselbrock (1994)使用视觉 Oddball 范式发现，反社会人格组(相比于控制组)对目标刺激表现出更小的 P300，主要表现在额区。很多研究者也验证了上述发现，即 APD 成人在视觉 Oddball 任务中会出现 P300 波幅的减小(Bauer et al., 1994; O'Connor et al., 1994)。P300 的波幅与 APD 症状数量呈负相关关系，且可以回顾性评估 CD 症状(Costa et al., 2000)。CD 障碍的青少年在听觉(Bauer & Hesselbrock, 2003)和视觉(Bauer & Hesselbrock, 1999a; Iacono et al., 2002) Oddball 任务和 Stroop 任务(Bauer & Hesselbrock, 1999b)中均会表现出 P300 的减小。Patrick 等(2006)采用视觉 Oddball 范式发现，能够表征 APD、CD 和药物滥用失常的潜在外化因素均与 P300 波幅的减小相关联。

Gao 和 Raine (2009)的元分析表明，反社会行为通常与 P300 的波幅减小和潜伏期的延长相关，这一结果既可以出现在标准的 Oddball 范式中，也可以出现在非 Oddball 范式中(如 Stroop 范式)，但精神病患者出现的 P300 波幅效应只出现在 Oddball 范式中。冲动型反社会个体仅表现出 P300 波幅的减小，没有表现出潜伏期的延长。

3.3. 物质使用障碍

物质使用障碍(Substance use disorders, SUDs)也称为药物使用障碍，指的是患者持续使用某种物质，即使这种使用已经导致明显的问题和病态的行为方式(Degenhardt et al., 2018; Peterson et al., 2021)。

Iacono，Carlson，Malone，& McGue (2002)指出，P300 波幅的减小与多种障碍(包括注意力缺陷多动障碍、对立违抗性障碍、品行障碍、反社会人格、酒精成瘾、尼古丁依赖、药物滥用等)有关，也与父母的风险指数有关；个体 17 岁时的 P300 减小可以预测其 20 岁时的物质使用障碍情况。Branchey 等人(1988)发现，有攻击性行为记录的酗酒和禁欲药物滥用的男性被试均表现出 P300 波幅的减小，其中存在暴力犯罪监禁史的个体，其 P300 的波幅最低。Elsheikh (2020)发现，SUDs 个体的 P300 波幅较小、潜伏期较短，表明他们的注意力异常(比如思考过程过快、但反应的准确性却较差)。这可能反映了 SUDs 个体在面对挑衅或压力时更容易做出冲动和攻击性的反应。Bel-Bahar et al. (2022)在其元分析中指出，Oddball 任务中的 P300 可以作为评估 SUDs 治疗效果的神经标志物。

酒精依赖是物质使用障碍的一种形式。有研究发现，酒精依赖个体更容易参与暴力攻击行为，酒精依赖的男性发生暴力攻击行为的概率大约在 20%~50%之间(Stoddard et al., 2015)。徐佳兵，杨岭和周旭辉(2018)采用听觉 Oddball 任务发现，与正常对照组相比，伴有和不伴有攻击行为的酒精依赖组的 P300 的潜伏期延长、波幅减小；其中伴有攻击行为的酒精依赖组表现出了更为明显的 P200 和 P300 波幅减小。研究者认为，酒精依赖者可能由于去抑制功能、酒精近视(即，酒后注意力缩窄且易冲动)、敌意归因偏差、执行功能等障碍而引发冲动性攻击行为。Brislin 等人(2023)基于酒精使用障碍遗传学研究(COGA)的数据发现，在欧洲血统的青年群体中，P300 波幅与自我报告的酒精和大麻使用等外化行为指标呈负相关。

综上所述，P300 在多个临床群体中表现出异常，这包括精神分裂症、酒精依赖、药物依赖、反社会人格、儿童行为障碍以及注意缺陷多动障碍等(Iacono et al., 2002)。这意味着 P300 可能反映了这些群体的共同特征，有研究者认为这是冲动控制问题(Krueger et al., 2002)，而冲动控制恰好是攻击行为的基础，尤其是冲动性攻击。这些群体的外化性问题多表现出 P300 波幅的减小。有研究表明，P300 波幅的减小不仅与特定障碍相关，而且反映了更广泛的外化倾向风险(Patrick et al., 2006; Krueger et al., 2021; Pasion et al., 2023)。

4. P300 与犯罪群体的攻击行为测量

暴力犯罪行为是指“以实施暴力行为为基本特征的犯罪行为，如伤害、杀人、抢劫等犯罪行为”(张维，2015)。早期的 EEG 研究较为一致的发现，暴力犯罪者会表现出慢波脑活动的增强，尤其是 delta 频段(Convit et al., 1991)，EEG 的慢波活动可以有效预测其未来的反社会行为(Scarpa & Raine, 1997)。研究者认为，这一结果可能反映了暴力犯罪者的皮层不成熟所导致的冲动抑制能力受损，这种皮层唤醒不足会导致个体倾向于寻找补偿性刺激(Convit et al., 1991; Scarpa & Raine, 1997)从而发生暴力行为。ERP 的研究显示，在遭遇挑衅后，暴力犯罪者在表现出更强攻击性的同时，也显示出前额叶激活的不对称性(即左侧前额叶的活动强度大于右前额叶)，这是行为趋近系统得到激活的重要标志(Harmon-Jones & Sigelman, 2001)。

近年来 P300 成为测量暴力犯罪者的攻击行为的主要指标。研究发现暴力犯罪者在 Oddball 任务中表现出 P300 的减小，且暴力犯罪的数量与 P300 波幅呈现显著的负相关性(Bernat et al., 2007)。Barratt 等人(1997)对比了非攻击性对照组和通过访谈被归类为冲动性或工具性攻击的男性囚犯之间的 P300 波幅的差异。结果发现，冲动性攻击犯表现出最低波幅的 P300。P300 波幅与愤怒和冲动的自我报告呈负相关关系。毋嫘等人(2022)使用视频诱发愤怒情绪，利用双选择 Oddball 范式对冲动性暴力犯的行为抑制能力进行了考察。结果发现，冲动性暴力犯在愤怒状态下的 P300 波幅显著大于中性状态，表明其在愤怒状态下行为抑制的困难。在 Delfin 等人(2020)的研究中，精神障碍型暴力罪犯在自我报告的行为抑制特质量表上得分较高，并显示出 NoGo-P300 波幅的减小和潜伏期的延长，这可能反映了在行为监控和评估过程中的神经效率降低。Delfin 等人(2022)通过 Go/NoGo 任务，对比了 P300 和 N200 成分与暴力精神障碍罪犯的攻

击性和反社会行为的关系。结果表明，NoGo 条件下的 P300 的潜伏期延长与攻击性和反社会行为的增加有关。Yu 等人(2022)等使用情感停止信号任务发现，暴力犯罪者在处理负面情绪刺激时，P300 波幅显著减小，这表明负面情绪刺激可能增加了他们的认知负荷并影响随后的认知处理过程。Xian 等人(2024)发现，抑郁症患者中犯有暴力罪行的个体在完成 Go/NoGo 任务时 P300 的潜伏期延长、前额叶和中央脑区的 P300 波幅减小，但顶叶区域 P300 波幅增加。

但也有研究发现，预谋犯罪者(相比于控制组)并未表现出听觉 P300 的波幅差异(Žukov et al., 2009)，Barratt 等人(1997)就曾指出预谋攻击与 P300 无关。这意味着，P300 在犯罪群体中可能成为预测攻击行为的潜在神经生理学指标，但是否适用于所有类型的暴力犯罪者，还有待深入地考察与验证。

5. P300 与非临床暴力风险群体的攻击行为测量

非临床暴力风险人群是指，虽然未经临床诊断确定，但是拥有较高的攻击特质或者倾向的群体，这包括高攻击性、高冲动性、高心理变态和高愤怒特质个体等。

5.1. 高攻击性人群

根据 Kunaharan，Halpin，Sitharthan，& Walla (2019)的研究，P300 波形的变化可能与个体的攻击性行为有关。该研究发现，在加工带有暴力内容的图像时，自我报告攻击性较高的个体(相比较低的个体)在前额、中央和顶叶区域的 P300 波形表现出显著差异。特别是在前额区域，高攻击组在处理暴力图像时 P300 的波幅减小。Crago 等人(2019)将图片刺激的内容扩展为社会面孔，结果发现，身体攻击性较高的个体在处理愤怒面孔时，P300 波幅表现出不分化的特点。即，相比于攻击性较低的个体，攻击性较高的个体在加工愤怒和中性面孔时，P300 波幅的差异消失。这些研究均表明，高攻击个体在处理愤怒线索和愤怒面孔时注意力存在困难。Sun 等人(2020)使用愤怒和快乐面孔的 Go/NoGo 任务，结果发现，在愤怒和快乐条件下，反应性冲动攻击组的青少年(相比于控制组)表现出更小的 NoGo P300 效应，特别在愤怒条件下，控制组的 NoGo 条件 P300 波幅显著大于 Go 条件。相关分析的结果表明，个体的反应性攻击分数与 P300 的 Go/NoGo 波幅差异呈负相关关系。该结果表明，反应性冲动攻击组的青少年对愤怒情绪的反应抑制缺陷主要发生在晚期抑制阶段。之后，Sun 等(2023)进一步使用愤怒和恐惧面孔的 Go/NoGo 任务，结果发现，对于恐惧面孔，高反应性攻击组(相比于控制组)表现出更短的反应时、更小的 NoGo P300 和 ERN 波幅。该研究进一步表明，高反应性攻击青少年在情绪刺激的认知评价和反应抑制过程中可能存在特殊困难，特别是在面对潜在的威胁性刺激时。Teti Mayer 等人(2021)则发现在不同(正向和负向)反馈情境下，P300 波幅的变化可能反映了个体对潜在后果的认知评估。这可能是因为高水平反应性攻击的青少年经常暴露于威胁情境中(Wilkowski & Robinson, 2012)，对于环境因素的敏感性较高。

5.2. 高冲动性人群

冲动性通常被定义为缺乏充分思考的行为(Verdejo-García et al., 2008)，可以通过多种方法进行测量，包括自我报告量表、行为以及神经生理测量(Luijten et al., 2011)。冲动行为被认为是反应抑制缺陷和错误加工的共同作用，会引发一系列的不顾及自己和他人消极后果的有害行为(Verdejo-García et al., 2008)。

研究表明，高冲动人群在早期冲突监测和晚期反应抑制方面均表现出异常(Hecht & Latzman, 2018; Lievaart et al., 2016; Zhang et al., 2017)。攻击性个体在 Oddball 任务中常表现出 P300 波幅减小，这种现象在冲动性攻击群体中更为明显(Barratt et al., 1997; Branchey et al., 1988; Gerstle et al., 1998)。Ruchsow 等人(2008)使用 Flanker-Go/NoGo 范式发现，高冲动个体相较于低冲动个体，NoGo 条件下的 P300 波幅显著减小；Surguy 和 Bond (2006)发现，高攻击个体在额区对攻击词的反应减小，表现出 P300 波幅减小。然

而，在停止信号任务中，自我报告高冲动的个体却表现出更大的 Stop P300 波幅(Lansbergen et al., 2007)。

青春期是冲动性易发的高峰期(Pérez Fuentes et al., 2016)，同时也在面对社交挫败时表现出反应性攻击行为的易感时期(Coppens et al., 2014)。Harmon-Jones 等人(1997)发现，青少年的攻击行为和态度均与 P300 的波幅呈负相关。Gerstle，Mathias 和 Stanford (1998)选取了面试评估为带有攻击性的大学生，发现这些被试的攻击性与听觉 Oddball 任务中 P300 波幅的减小相关。这一结果在之后的改进范式(标准的和三个刺激的视觉 Oddball 范式)中均得到了验证(Mathias & Stanford, 1999)。

目前比较一致的结论是，那些表现出冲动性攻击行为的个体在 Oddball 任务中往往伴随着 P300 波幅的减小(Gerstle et al., 1998; Barratt et al., 1997; Branchey et al., 1988)。

5.3. 高心理变态人群

心理变态(Psychopathy)是一个多面向的人格障碍，包含了一系列独特的情感、人际和行为偏差特征(Cleckley, 1951)。其特点通常包括冲动性、冷漠、欺诈行为、反社会行为等，并有三种不同的表现类型：去抑制、大胆和刻薄(Patrick et al., 2009)。

有研究者发现，心理变态中与刻薄特质相关的冷酷无情特质(Callous-unemotional, CU)在青少年中能够预测 P300 波幅的减小，这可能意味着这些个体在抑制控制和情绪调节方面存在困难(Prata et al., 2019)。与此同时，Ribes-Guardiola 等人(2020)通过使用 Go/NoGo 和 Flanker 任务评估了心理变态特质个体与大脑执行监控功能的关系。结果显示，心理变态中的抑制不足特质与大脑电生理活动(ERPs)在执行监控任务时的表现存在显著关联。即抑制不足与 P300 呈负相关，意味着抑制能力较差的个体在处理动机显著事件的后期阶段时，大脑活动减少。Tillem 等人(2021)发现，心理变态特质较高的个体在进行双任务时，会出现注意力瓶颈和 P300 波幅减小现象，这与他们在现实世界中的冲动和反社会行为有关联，这可能也解释了抑制不足可能是由注意力造成的。Wang 等人(2020)发现在受到挑衅后，高心理变态特征水平的个体更倾向于对无辜的他人施加高强度的惩罚，其决策阶段的 P300 波幅显著减小。这一结果再次表明，P300 波幅的这种变化可能与个体在社交互动中的攻击性倾向有关。

5.4. 其他人群

除了上述人群，研究者还关注了高风险环境下的青少年。Pincham 等人(2019)使用修改后的泰勒攻击范式(Taylor Aggression Paradigm, TAP)，评估了心理社会干预对处于高风险环境中的青少年的影响。这些青少年可能面临贫困、社区暴力和创伤等问题，并表现出一系列认知和行为挑战，尤其是行为问题和反社会、外化行为。研究结果显示，长期参与干预的青少年在接收到赢的反馈时，其 P300 波幅更大，表明他们在处理积极反馈时的大脑活动更为积极。相反，短期或未充分参与干预的青少年显示出较小的 P300 波幅，这可能指示了他们在生理上对奖励信息的低敏感性。这种低敏感性可能与青少年的反社会行为有关，因为先前的研究(Finger et al., 2011)已经发现反社会行为的青少年在处理奖励信息时存在缺陷。

此外，Irak 等人(2021)的研究发现，经常玩暴力视频游戏的个体在处理暴力相关词汇时，P300 波幅增大，这可能反映了对这类刺激的注意力和情感反应的增强。这些发现进一步支持了 P300 作为评估个体对攻击性刺激敏感性的神经生理指标的潜力。Peng 等人(2021)使用“Chicken Game”(一种社会困境游戏)，探究了对手的合作行为如何影响玩家的行为和大脑的神经动态，发现参与者在面对攻击性行为时，其 P300 波幅显著增大，这表明攻击行为作为一种出乎意料的负面刺激，能够引起更强烈的神经反应。P300 波幅的增大可能反映了个体对这种期望违背的敏感性。Sun 等人(2023)的研究进一步探讨了竞技电子游戏对玩家认知敏感性的影响。他们发现，参与竞技游戏的个体在接触到攻击性词汇时，P300 波幅显著增大，表明竞技游戏环境可能增强了玩家对攻击性刺激的认知反应。此外，该研究发现 P300 波幅的增大在竞技模

式下与更高的攻击性行为呈正相关。

6. 未来展望

综上所述，P300 作为 ERP 的一种内源性成分，P300 的波幅减小和潜伏期延长是潜在的攻击性行为的神经预测指标，该结果比较稳定，且受年龄、性别、刺激类别、负面情绪和物质滥用等其他变量的影响不显著(Bernat et al., 2020)，具有一定的跨群体一致性(如图 1 所示)。

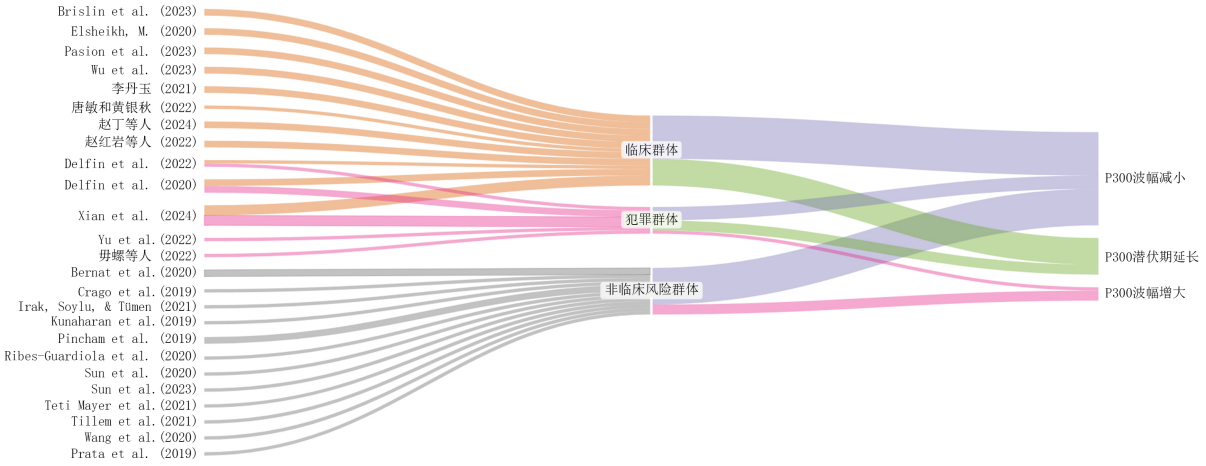

Figure 1. Literature summary chart: p300 and aggressive behavior measurements in different groups (2019~2024)
图 1. 文献归纳图：P300 与不同群体的攻击行为测量(2019~2024)

但现有的研究也还存在一些可以拓展的方面，具体如下：

1) P300 指标的多角度分析及与其他 ERP 成分的结合：P300 除了波幅和潜伏期，还可以关注试次间变异性(Inter-trial variability, ITV)等指标(Bauer, 2021)或者探索 P300 的更多不同子成分，特别是与冲动性相关的 P3a 成分(Koelsch, 2009)和与情绪调节相关的 P3b 成分(Shackman & Pollak, 2014)，以揭示它们与攻击性行为背后机制的联系，并评估这些成分在预测攻击性行为方面的潜力。此外，P300 还可以结合其他 ERP 成分进行联合预测。早期成分如 P50 的波幅减小被认为与攻击行为相关(Lijffijt et al., 2012)；中期成分如错误相关负波(ERN)反映了错误信息监控的失败，可能与攻击的产生有关(Olvet & Hajcak, 2008)；在使用 TAP 任务的研究中，高挑衅条件下的额叶负性增强与 N2 成分相关(Krämer et al., 2008)。此外，LPP 与情绪反应相关，而 FRN 与反馈处理相关，这些成分的变化均有助于揭示攻击行为背后的神经机制(Krämer et al., 2008; Yi et al., 2012)。

2) 进一步验证 P300 在不同样本群体中的有效性。目前的犯罪群体中研究对象主要为男性，女性被试较少，未能充分反映男女群体间的性别差异(张卓，2022)；且暴力犯罪主要是从犯罪学领域来划分，主要区分了冲动性暴力犯和预谋性暴力犯(李昕雨，2023)，而较少关注心理学和神经生物学的角度划分，因此未来对不同类型罪犯评估时，应该结合生物学和行为指标对其不同攻击性行为做出区分(刘宇平等，2019)，以确定 P300 在不同类型犯罪群体中的有效性。

3) P300 的应用场景可进一步拓展：研究数据表明，暴力行为在监狱中的发生率是社区的三倍甚至更多，囚犯发生暴力行为的比例也大约是社区匹配子样本的两倍(Teplin et al., 2005)。如果可以将 P300 更精确地用于识别潜在的暴力风险，并据此制定有效的干预措施，以减少监狱内的暴力事件，这不仅有助于维护监狱秩序，也对囚犯的改造和社会的长期安全具有重要意义。另外，Oddball 任务中的 P300 可以作为有效的证据，推进 EEG 标记在精神病学领域的应用，例如作为治愈预后、预测、诊断和监测的生物标

记，使得治疗更加个性化和有效(García-Gutiérrez et al., 2020; Lahnakoski et al., 2022; Niculescu & Le-Niculescu, 2022; Wan et al., 2010)。最后，P300 在正常人群中识别那些具有较高暴力风险特质或倾向的个体，这对未来暴力犯罪的预防与早期干预有着重要的意义，开发基于 P300 的正常人群中区分个体差异的监测工具也是未来的重要方向之一(Fido et al., 2017)。

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