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Cannabis and Driving Ability

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Abstract

The aim of this review is to discuss recent evidence on cannabis and driving ability. In particular, the review examines experimental research on the acute effects of tetrahydrocannabinol (THC) on driving-related neurobehavioral skills and driving performance based on simulator and road course studies. The evidence indicates that certain driving abilities are significantly, albeit modestly, impaired in individuals experiencing the acute effects of THC. Treatment effects are moderated by dose, delivery method, recency of use, and tolerance development, with inconclusive evidence concerning the moderating influence of cannabidiol (CBD). Emerging research priorities include linking neurobehavioral deficits to specific decrements in driving performance, estimating the real-world implications of experimental driving impairment research, understanding how tolerance differentially affects driving impairment in different subgroups, and developing more evidence on CBD's potential role in mitigating THC-induced impairment.

1.1 Introduction

Road traffic crashes (RTCs) are a major cause of death and injury worldwide, and they are the leading cause of death among children and young adults aged 5-29 [1]. Cannabis is one of the most prevalent psychoactive substances detected in RTC-involved drivers [2]. Several recent meta-analyses estimate that cannabis intoxication and recent use produces a low to moderate increased crash risk, with reported odds ratios (ORs) ranging from 1.28 – 2.49 [3-7]. As more US states and countries liberalize legal access to cannabis, attitudes and behaviors surrounding cannabis-involved driving and associated RTC risk factors are drawing increased scrutiny from researchers and policymakers [8-10]. Against this backdrop, this review examines recent experimental research on the acute effects of cannabis on driving-related neurobehavioral skills and driving performance. This review does not focus on chronic cannabis use, which has also been shown to impair driving ability [11-13].

2.1 Cannabis use and driving skills

Driving is a complex task requiring coordinated cognitive, visual, and motor abilities to be performed safely. Cannabis-induced impairments in driving performance therefore present a major threat to roadway safety. This section summarizes recent experimental evidence and systematic reviews concerning the acute effects of cannabis on driving ability, assessed across a range of neurobehavioral tasks relevant to driving and simulated or on-road driving performance metrics.

2.1.1 Experimental neurobehavioral research

Recent systematic reviews of experimental studies examining the acute neurobehavioral effects of tetrahydrocannabinol (THC), the main psychoactive compound in cannabis, consistently document significant impairments in memory, attention and concentration, psychomotor function, and executive functions such as problem-solving and impulse control [14-18]. The most recent and comprehensive of these reviews, McCartney et al.'s [15] meta-analysis of 80 primary studies, summarizes the experimental evidence across 11 cognitive performance domains, documenting a significant increase in peak-THC impairments of small to moderate size across nine functional areas (working memory, divided attention, sustained attention, information processing, tracking performance, fine motor coordination, reaction time, conflict control, and fluid intelligence). Conversely, the authors found no evidence that THC produces acute impairments in perception (sensory discrimination and time perception), but they cautioned against drawing a firm conclusion given the small number of included studies assessing perceptual impairments. Indeed, recent research by Ortiz-Peregrina and colleagues [19,20] that was not included in McCartney et al.'s [15] meta-analysis finds that THC produces significant deterioration in visual acuity, contrast sensitivity, depth perception, focusing ability, and straylight or glare response. More research is needed on the heterogeneous and potentially compounding neurobehavioral responses to THC, including the effects on visual disturbances under nighttime conditions when neurobehavioral demands are likely to be greater.

2.1.2 Experimental driving simulator and on-road research

Although neurobehavioral impairments can be indicative of poor driving skills, experimental simulator and road course studies provide more direct evidence of the acute effects of cannabis on driving performance. McCartney et al. [15] also meta-analyzed this body of research, synthesizing evidence across seven driving performance domains. Their analysis documents a significant increase in peak-THC impairments of small to moderate size for 'standard deviation of lane position' (SDLP; considered the gold standard outcome in driving safety research), other measures of lane weave, and reaction time. No significant effects were observed for either differences or variances in speed and car-following headway. These summary findings are generally consistent with two other recent reviews by Alvarez et al. [21], who narratively summarized 13 studies investigating cannabis impairment in young drivers, and Simmons (SM Simmons, PhD thesis, University of Calgary, 2020), who performed a meta-analysis of 81 studies investigating the effects of cannabis and alcohol on driving performance. A key divergence is that both Alvarez et al. [21] and Simmons conclude that drivers experiencing the acute effects of THC reduce average driving speeds, likely as a compensatory response to perceived impairment, whereas McCartney et al. [15] was unable to draw this statistical inference despite an effect that trended in the same direction. In summary, drivers under the influence of THC weave more and are slower to react to stimuli (such as a roadside pedestrian). While it is also likely that drivers reduce their average speed to compensate for other performance deficiencies, additional confirmatory research is needed.

3.1 Moderators of acute THC effects on driving ability

Recent research indicates that certain neurobehavioral competencies and specific driving skills are significantly, albeit modestly, impaired in individuals experiencing the acute effects of THC. This section reviews recent research on key moderators of this association.

3.1.1 Dose, delivery method, and recency of use

THC produces a dose-dependent effect on driving-related neurobehavioral outcomes [22]. More generally, McCartney et al.'s [15] meta-regression analysis demonstrates a significant dose-response association between THC and driving impairment across multiple performance domains. Consistent with research showing vaporization to be a highly efficient THC delivery method [23], McCartney et al. [15] also document a significantly greater effect of vaporized versus smoked cannabis on impairment. Although the bioavailability of THC varies by dose and route of administration [23], there appears to be little correlation between biological THC concentrations and impairment of neurobehavioral skills and driving performance indicators [24,25]. Indeed, detectable levels of THC in blood and oral fluid do not reliably discriminate recent cannabis use, especially among frequent users [26]. A key implication is that *per se* driving laws, which make it illegal to drive with THC blood concentrations above specified thresholds (e.g., 5 ng/mL), cannot accurately identify impaired drivers [24]. Perhaps the most reliable determinant of cannabis-induced impairment is time since exposure. The majority of THC's psychoactive effects occur within the first 2 hours of use, with any residual impairment subsiding during the subacute phase at 3-5 hours post-administration [10,23,27,28]. The actual cannabis impairment window will vary by factors such as the performance domain assessed, dose, route of administration, and individual characteristics. Meta-regression models reported by McCartney et al. [15], for instance, predict that meaningful impairment in SDLP among occasional users will last about 5 hours after smoking 10 mg THC but about 8 hours after vaporizing 20 mg THC. In light of such variability, new technologies and roadside protocols for detecting cannabis-impaired driving that do not rely on THC bioavailability markers offer promising avenues for future research [29-31].

3.1.2 Tolerance development

Outside of treatment effects related to dose, mode, and timing, the development of cannabis tolerance can attenuate certain acute cognitive and driving performance deficits. Stronger evidence exists for the pharmacodynamic model of tolerance, in which acute effects are blunted by neuroadaptive responses to repeated cannabis exposure, than for the behavioral model, in which functional performance is maintained through volitional control and learned compensatory strategies [32,33]. In either case, tolerance development is more likely to occur among high-dose cannabis users who partake daily at high frequency [33]. A recent driving simulator study of medically authorized daily cannabis users, for instance, showed a significant reduction in overall vehicle speed after subjects smoked a typical dose, but found no statistical differences in lateral control or braking latency [34]. As another example, Karoly et al. [30] found significant acute psychomotor impairments following use of high-potency cannabis among frequent users, although no significant differences were observed across other cognitive domains including attention and decision-making. Thus, tolerance development tends to be partial and manifest differently across performance domains, even among experienced users [32]. Developing coherent public policies on safe driving following cannabis use will need to address response heterogeneity as it relates to cannabis tolerance by accounting for the occasional recreational user as much as the medically authorized user who maintains a fixed dosing regimen [35,36].

3.1.3 Cannabinoid ratios and interactions

Most research on cannabis-impaired driving focuses on THC, but cannabis contains hundreds of other compounds that may affect driving ability. Recent impairment research has focused on the potential mitigating effects of cannabidiol (CBD), which is a major nonpsychoactive compound in cannabis. CBD, it is widely argued, attenuates certain adverse effects of THC, although the empirical evidence for this claim is decidedly mixed [37,38]. Recent cognitive and driving experiments examining the interactive effects of vaporized CBD and THC show that both THC-dominant and THC/CBD-equivalent cannabis impaired neurobehavioral and driving performance, whereas CBD-dominant and placebo cannabis did not [39-41]. Importantly, these findings may not extend to clinical populations, especially those who use pharmaceutical formulations of cannabis. A systematic review by Celius and Vila [42], for example, finds that Sativex, the THC/CBD-equivalent oromucosal spray, does not impair driving ability among multiple sclerosis (MS) patients, and may even improve performance due to enhanced cognition and reductions in spasticity. Thus, although CBD may moderate certain acute effects of THC such as anxiety [37,38], it does not appear to reliably protect against THC-induced driving impairments. Still, there is some evidence that CBD may reduce driving impairment in certain clinical populations, but more research is needed [15,42].

4.1 Emerging research priorities and challenges

This review elicits a number of research priorities and challenges. First, the neurobehavioral impairment research on THC is highly varied, and the systematic reviews summarizing this literature inconsistently categorize the primary study effects into different cognitive domains and subdomains [14-18]. Future review work in this area would therefore benefit from more consistent domain categorization of the neurobehavioral effects of THC [e.g., 43]. Moreover, road safety research would benefit from establishing clearer linkages between observed neurobehavioral deficits and functional decrements in driving performance [40], as some researchers are already doing [20].

Second, although cannabis significantly impairs driving ability, the magnitude of these impairments tends to be small. In McCartney et al.'s [15] meta-analysis, significant THC impairments observed across 10 of 12 performance domains were considered small, with two effects reaching into the moderate range. There is some debate, then, about the extent to which these observed deficits meaningfully compromise roadway safety (MA White and NR Burns, unpublished). According to this critique, researchers need to more effectively grapple with the issue of "tolerable crash risks" for THC, similar to the limits currently in place for alcohol (e.g., BAC < 0.8). Given the incongruence between THC blood concentrations and measures of driving ability, valid approaches to determining cannabis-induced impairment for public health guidance and legal liability purposes are desperately needed. Research seeking to reliably and cost-effectively identify cannabis-impaired drivers should be prioritized [e.g., 29,30,31]. Because driving ability reaches across multiple performance domains, development of a summary 'index of cannabis-impaired driving' would also be a fruitful research endeavor.

Third, much of the experimental research on cannabis-related driving impairment excludes regular or daily cannabis users [e.g., 27,39]. Given tolerance development, selection effects associated with a primary focus on infrequent and occasional users are likely to be severe in much of the existing cannabis impairment research. More research is therefore needed that examines cannabis-related driving impairment in heterogeneous user populations, including clinical populations with daily regimented cannabis use [34]. Further, given that clinical populations may be more likely to use products with different THC:CBD formulations, more research is warranted on how different cannabinoid dose combinations affect driving performance.

5.1 Conclusions and policy implications

This review of the experimental literature on the acute effects of cannabis on driving ability confirms that THC significantly impairs certain neurobehavioral competencies and driving skills, although the impairments tend to be modest and reversible. These effects are also contingent upon treatment-related factors, including dose, route of administration, and recency of use. Tolerance development mitigates impairment of certain driving skills, but not consistently or equally across performance domains. CBD is a component of cannabis that may ameliorate specific negative effects of THC (e.g., anxiety), but it does not appear to fully moderate the performance deficits induced by THC, except possibly in certain clinical populations.

Several research priorities were noted for the field, including linking neurobehavioral deficits to specific decrements in driving performance, translating implications of experimental research findings on driving impairment to real-world conditions, understanding how THC tolerance affects impairment across different subgroups, and developing additional knowledge of CBD's role in mitigating the acute impairing effects of THC on driving ability.

Lastly, a number of policy implications can be derived from this review. First, because THC dose and recency of use are clearly associated with the level of impairment, policies that require clear labelling of cannabinoid content of regulated products, coupled with public service campaigns about minimum "wait" times after consuming cannabis, may assist individuals with making responsible use decisions around driving [e.g., 44]. Current research also indicates that biological THC concentrations are not strongly correlated with impairment, so *per se* laws that criminalize driving above specific thresholds do not appear to be justified as stand-alone policy [24].

Conflict of interest statement

Nothing declared.

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