


REVIEW

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Attitudes toward driving after cannabis use: a systematic review

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Abstract

Background Driving after cannabis use (DACU) is associated with increased risk of motor vehicle collisions. As cannabis legalization expands, DACU is emerging as a major public safety concern. Attitudes have a significant impact on behavioural decision making. As such, understanding the degree to which people have favorable or unfavorable evaluations of DACU is an important first step for informing prevention efforts. This systematic review summarizes existing evidence on attitudes toward DACU, their association with actual or intended DACU, and changes in attitudes following legalization of recreational cannabis.

Methods Four electronic databases (MEDLINE, EMBASE, PsycINFO, and TRID) were searched for studies that reported attitudes or changes in attitudes toward DACU published between their inception dates and February 26 2024. A total of 1,099 records were retrieved. Studies were analyzed using an inductive thematic synthesis approach.

Results Seventy studies from seven countries originating predominantly from the United States and Canada met inclusion criteria. Thematic analysis identified six themes. (I) Attitudes toward the safety and acceptability of DACU are mixed; participants in 35 studies predominantly expressed negative attitudes toward DACU (e.g., DACU is dangerous, affects driving ability, and increases crash risk). However, 20 studies reported opposing views. (II) Attitudes toward DACU vary by age, sex/gender, and cannabis use frequency; youth, men, and frequent cannabis users tended to view DACU more favorably than older participants, women, and occasional or non-users. (III) Attitudes toward DACU are associated with past DACU and intention to DACU. (IV) DACU is viewed more favorably than driving after drinking alcohol. (V) The relationship between legal status of recreational cannabis and attitudes toward DACU is unclear. (VI) Perceived risk of apprehension for DACU is low to moderate.

Conclusions This review found that perceptions of DACU are primarily negative but mixed. Findings suggest that attitudes toward DACU are important targets for interventions to reduce this behaviour.

Keywords Cannabis, Marijuana, Impaired driving, Attitudes, Beliefs, Risk perceptions

Introduction

As legalization of recreational cannabis expands worldwide, driving after using cannabis (DACU) becomes an increasingly relevant public safety concern. The

prevalence of DACU has been increasing in Canada (Brubacher et al. 2022) and the United States (US), (Fink et al. 2020) with annual prevalence estimates from roadside surveys ranging from 4–10% in 2012–2022 (Beasley and Beirness 2012; Beirness 2018; Beirness 2022; Beirness et al. 2017; Johnson et al. 2012). Cannabis is frequently implicated in serious and fatal motor-vehicle collisions (MVCs), with odds ratios for collision risk ranging from 1.36 (95% CI: 1.15–1.61) (Rogeborg and Elvik 2016) to 1.92 (95% CI: 1.35–2.73), (Asbridge et al. 2012) although differences in study design make it difficult to

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ascertain the exact prevalence of MVCs attributable to cannabis. A growing body of epidemiological and experimental research shows that cannabis use leads to decrements in driving performance (Rogeberg and Elvik 2016; Asbridge et al. 2012; Li et al. 2012; Li et al. 2017; Hartman and Huestis 2013). In driver simulator and on-road studies, tetrahydrocannabinol (THC) impairs driving skills including lateral control, steering control, speed maintenance, and reaction time in both occasional and heavy users (Hartman and Huestis 2013; Arkell et al. 2020a; Bosker et al. 2012; Downey et al. 2013; Hartman et al. 2015; McCartney et al. 2021; Micallef et al. 2018; Ramaekers et al. 2000; Ronen et al. 2008; Brands et al. 2019).

To reduce the prevalence of DACU, it is necessary to evaluate factors that predict decisions to engage in this behaviour. If these factors can be modified, it may be possible to develop prevention programs to reduce the incidence of cannabis-related MVCs. Drug-driving prevention research has largely focused on cognitive predictors of intention to drive impaired, such as perceived risk (Earle et al. 2020; Ward et al. 2018; Ward et al. 2017; McCarthy et al. 2007; Malhotra et al. 2017). Broadly, prevention strategies aim to change traffic safety culture by increasing perceptions of dangerousness and severity of associated consequences (Shults et al. 2001). These efforts are based on behavioural theories such as the Theory of Reasoned Action, (Fishbein and Ajzen 1975) which explain and predict voluntary behaviour as a function of attitudes, subjective norms, and intentions. Specifically, attitudes (i.e., beliefs about a behaviour and evaluations of behavioural outcomes) and subjective norms (i.e., beliefs about the extent to which others encourage performance of a behaviour) jointly determine intentional performance of a behaviour. The Theory of Planned Behaviour (Ajzen 1991) adds control beliefs (i.e., perceived ability to perform or avoid a behaviour) as an antecedent of behavioural intention. These theories figure prominently in health promotion strategies (Godin and Kok 1996; Hausenblas et al. 1997; Hackman and Knowlden 2014). Following this line of reasoning, positive attitudes toward DACU play an important role in motivating intentions to engage in DACU. Indeed, safety perceptions have been shown to predict actual DACU (Aston et al. 2016; Arterberry et al. 2017; Borodovsky et al. 2020). Concerningly, existing cross-sectional research has shown that a large proportion of people believe they can safely DACU, and that some even report that cannabis makes them better drivers (Greene 2018; Swift et al. 2010).

Identifying individual factors associated with intention to DACU can further inform prevention strategies. For example, campaigns might be directed toward frequent cannabis users, who tend to report greater willingness

and intention to DACU (Allen et al. 2016; Otto et al. 2016) relative to occasional and non-users. Situational factors can also predict DACU and provide interventional opportunities. For instance, some evidence suggests that the prevalence of moderately injured drivers with a blood THC level of 2ng/ml or more increased after legalization of recreational cannabis and introduction of cannabis retail markets, (Brubacher et al. 2022) while other evidence from drug use surveys suggests DACU has not increased (Government of Canada 2018).

Despite the growing body of research on this topic, a systematic review of attitudes toward DACU has not been conducted, to our knowledge. This review aims to characterize attitudes toward DACU. Attitudes are the degree to which people have positive or negative evaluations of a behaviour (e.g., DACU is dangerous or unacceptable) and entail consideration of the expected consequences (e.g., DACU is likely to lead to an MVC). This systematic review aims to provide a broad, comprehensive overview of quantitative, qualitative, and mixed-methods research related to DACU attitudes using an inductive thematic synthesis approach. Thematic analysis is useful for identifying, interpreting, and synthesizing key features across various types of data, allowing for a nuanced account of DACU attitudes.

Methods

Search strategy and data sources

This systematic review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement (Page et al. 2021). Studies were identified by searching four electronic databases: MEDLINE (Ovid), EMBASE (Ovid), PsycINFO (EBSCOhost), and Transport Research International Documentation. All databases were initially searched from their inception dates until May 31 2022 and the search was later updated to include studies published up to February 26, 2024. Key terms relating to cannabis use (e.g., cannabis OR marijuana OR THC), attitudes (e.g., attitude* OR belie* OR opinion*), and driving (e.g., driv* OR motor vehicle OR DACU) were combined. The keyword search terms were adapted for each database (see Additional File 1). All articles were uploaded to Covidence, (Covidence 2023) an online platform that streamlines the production of systematic reviews and allows for asynchronous collaboration among reviewers. Two reviewers (B.B. and Y.Y.) independently screened all studies by title and abstract. Full text of the retained studies was independently reviewed by two reviewers (B.B. and D.A.). Disagreements in both stages were resolved by consensus or involving a fourth reviewer (J.B.). The protocol was pre-registered on PROSPERO (CRD42022337260).

Eligibility criteria

Studies that met the following criteria were included: (i) report attitudes or changes in attitudes toward cannabis use and driving, (ii) report qualitative, quantitative, or mixed methods empirical research, (iii) use primary research data, (iv) English-language, and (v) full-text available. Studies reporting secondary research data were excluded but used to identify the original study. Studies that met the following criteria were excluded: (i) attitudes or changes in attitudes toward cannabis use and driving not reported, (ii) narrative non-research reports (e.g., commentaries, position statements), (iii) not in English, (iv) full text not available. Both academic and gray literature (e.g., reports, policy literature) were included. As this review aimed to synthesize all available data on attitudes toward DACU, no studies were excluded based on study design or sample characteristics. Where two or more studies used the same data-set, the report with the largest sample size was retained.

Data extraction and quality assessment

Data from eligible studies were collected in a pre-developed data extraction form by two reviewers (B.B. and D.A.) using Microsoft Excel. Extracted data included: (i) title, (ii) author(s), (iii) year of publication, (iv) location from which subjects were sampled, (v) aim(s) and hypothesis(es), (vi) sample characteristics, including sample size, age, sex/gender, cannabis use history, and inclusion/exclusion criteria, (vii) data collection date(s), (viii) study design/data collection method(s), (ix) outcome measures, (x) data analysis method(s), (xi) control for confounding variables, and (xii) key findings. Both reviewers performed extraction for 10 studies and cross-checked the extracted data to assess agreement. Each reviewer then extracted data for approximately half of the remaining 60 studies.

Methodological quality and risk of bias was assessed by two reviewers (B.B. and D.A.) using the Standard Quality Assessment Criteria for Evaluating Primary Research Papers (SQAC) (Kmet et al. 2004). The SQAC comprises separate checklists for quantitative and qualitative studies; both checklists were used to assess mixed-method studies. A conservative inclusion threshold of 75% was used (Kmet et al. 2004) (no studies were excluded on this basis). Additional File 2 provides a summary of the included studies.

Data synthesis

An inductive thematic synthesis approach (Ryan et al. 2018) was used to identify, analyze, and report patterns across findings from included studies. First, two reviewers (B.B. and D.A.) read the original texts, adding to a bank of free codes as necessary. Decisions to combine,

rename, or eliminate these initial codes were reached through discussion. This process yielded 48 initial codes (see Additional File 3). Each code was entered as a row in a table and populated with data from relevant studies. Studies reporting any finding related to the code were added to the table, including those reporting non-significant results. Reviewers then grouped initial codes into a hierarchical structure by identifying similarities between the codes. Analytic themes were generated by synthesizing extracted findings in relation to the research question. Both reviewers reviewed themes and assigned theme names.

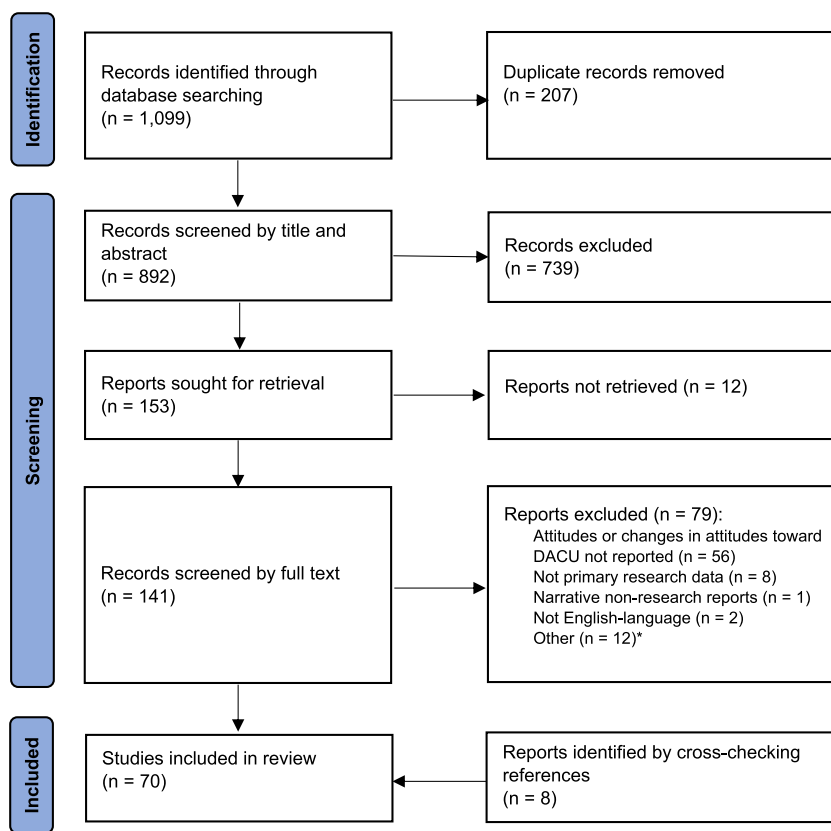
Results

Description of included studies

A total of 1,099 non-duplicate records were screened by title and abstract, resulting in 141 records retrieved for full text review. Seventy-nine records were excluded for reasons shown in Fig. 1 and eight records were added by cross-checking references from the 62 included studies. Data were extracted from a final set of 70 studies. Inter-rater reliability was substantial for the abstract and title screening ($\kappa=0.60, 0.59$) and full text review ($\kappa=0.62, 0.79$) during the initial and updated searches, respectively. (McHugh 2012).

The 70 included articles dated from 1981 to 2024, with only three studies published before 2000. The synthesis of findings involved over 126,930 participants. Twenty-seven studies sampled youth, young adults (<35 years old) or students. Twenty-four samples were restricted to people who had used cannabis (including two studies with medical cannabis users). Twenty-six studies were restricted to participants who drove (at least once in the past year) or held a driving license. Five studies drew from samples of drug users ($n=3$), police detainees ($n=1$), or participants in a remedial program for impaired drivers ($n=1$).

Male and female subjects were equally represented (49% male), although seven studies did not provide sex or gender demographics. Most studies sampled subjects from the US (37 studies) or Canada (17 studies); the remaining studies included subjects from Australia ($n=11$), the United Kingdom ($n=4$), New Zealand ($n=2$), Spain ($n=2$), and Israel ($n=1$). This count totals more than 70 because three studies used international samples. Data was collected primarily through online, in-person, and telephone surveys or questions ($n=54$), in-person or telephone interviews ($n=15$), and focus groups ($n=6$). These counts total more than 70 because five studies used multiple data collection formats. Three pairs of studies were suspected of having fully (Allen et al. 2016; Davis et al. 2016) or partially (Wadsworth and Hammond 2018; Wadsworth and Hammond 2019; Mills



*data used in included report (n=6), attitudes towards DACU asked using double-barreled question

(n=3), ongoing study (n=2), duplicate (n=1)

Fig. 1 PRISMA screening process with reasons for exclusion

et al. 2023; Mills and Freeman 2023) overlapping sample frames; all were retained because they reported different analyses. Table 1 summarizes the included studies.

Study findings

Analysis of the studies identified six themes (Table 2).

Attitudes toward the safety and acceptability DACU are mixed

Sixty studies from the US (n=29, 1981–2024), Canada (n=13, 2006–2023), Australia (n=11, 2000–2023), England (n=2, 2003–2005), New Zealand (n=2, 2009–2017), Spain (n=2, 2016–2022), and Canada, the US, and England (n=1, 2019) reported beliefs about the effect of cannabis on driving safety, driving ability, and crash risk. In 35 studies, participants predominantly expressed negative attitudes toward DACU or did not endorse statements such as ‘DACU is safe’. Specifically, DACU was considered to be a dangerous, unsafe, or risky behavior that increases collision risk and cannabis

was thought to negatively affect driving ability. DACU was also considered to be unacceptable and unenjoyable (Jones et al. 2006; Earle et al. 2020; Ward et al. 2018; Ward et al. 2017; Malhotra et al. 2017; Arterberry et al. 2017; Swift et al. 2010; Allen et al. 2016; Otto et al. 2016; Davis et al. 2016; EKOS Research Associates Inc. 2017; Corporate Research Associates 2018; Benedetti et al. 2021; AAA Foundation for Traffic Safety 2018; Cavazos-Rehg et al. 2018; Duckworth and Lee 2019; Eichelberger 2016; Fischer et al. 2006; Ginsburg et al. 2008; Goodman et al. 2020; Grilly 1981; Hammond 2009; Jonah 2013; Kohn et al. 2014; Lenné et al. 2001; Lensch et al. 2020; McDonald et al. 2021; McKiernan and Fleming 2017; Pino et al. 2016; Porath-Waller 2008; Terry and Wright 2005; Wechsler et al. 1984; Eichelberger 2023; Ortiz-Peregrina et al. 2022; Wickens et al. 2023). These studies were largely from the US (n=20) and Canada (n=9), and eight were from Australia (n=3), Spain (n=2), New Zealand (n=2), and England (n=1). Conversely, participants predominantly

Table 1 Characteristics of included studies

Characteristic	Number of studies
Study population	
Youth/young adults/students	27
Cannabis users	24
Drivers	26
Special population	5
Country	
US	37
Canada	17
Australia	11
United Kingdom	4
New Zealand	2
Spain	2
Israel	1
Data collection method	
Surveys	54
Interview	15
Focus group	6

reported positive attitudes toward DACU in 18 studies. Namely, participants expressed that DACU is safe, does not increase collision risk, does not impair driving ability, or is acceptable (Fischer et al. 2014; Aston et al. 2016; Greene 2018; Mills et al. 2023; Mills and Freeman 2023; Adams et al. 2008; Aitken et al. 2000; Arterberry et al. 2013; Berg et al. 2018; Colonna et al. 2021; Cuttler et al. 2018; Danton et al. 2003; Huynh et al. 2022; Teeters et al. 2021; Townsend et al. 1996; Barrie et al. 2011; Hultgren et al. 2023a; Miller et al. 2024). Two studies found that participants who used cannabis for therapeutic reasons did not think it impaired their driving (Arkell et al. 2020b; Arkell et al. 2023a). These studies were largely from the US ($n=9$), Australia ($n=7$) and four were from Canada ($n=3$) and England ($n=1$). Participants in five studies expressed neutral or mixed views (Wadsworth and Hammond 2018; Wadsworth and Hammond 2019; Eichelberger 2019; Matthews et al. 2014; Wickens et al. 2019). Interestingly, negative attitudes toward DACU were more common among studies conducted with non-medical users residing in areas with legalized recreational cannabis. This observation is supported by a US study that found that the belief that DACU is unsafe is more common in states with legalized sale of recreational cannabis ($aPR=1.10$), (Lensch et al. 2020) although evidence is mixed (see theme V).

Across studies that asked about the impact of DACU on driving, subsets of participants in nine studies identified driving-relevant skills that may be negatively impacted by cannabis use. These included slowed reaction time, impaired attention or concentration, distorted visual perception, and paranoia (EKOS Research Associates Inc. 2017; Lenné et al. 2001; McKiernan and Fleming 2017; Terry and Wright 2005; Aitken et al. 2000; Colonna et al. 2021; Arkell et al. 2023a; Wickens et al. 2019; MacDonald et al. 2008). Such beliefs may be protective, as subjects who avoided or decided against DACU cited safety concern as a primary reason (Malhotra et al. 2017; Swift et al. 2010; Hammond 2009). However, subsets of participants in 16 of these studies reported that using cannabis actually improves or has positive effects on drivers (Greene 2018; Swift et al. 2010; Otto et al. 2016; EKOS Research Associates Inc. 2017; Cavazos-Rehg et al. 2018; Lenné et al. 2001; McKiernan and Fleming 2017; Terry and Wright 2005; Adams et al. 2008; Colonna et al. 2021; Danton et al. 2003; Barrie et al. 2011; Miller et al. 2024; Arkell et al. 2020b; Wickens et al. 2019; MacDonald et al. 2008). This belief may be attributed to the notion that cannabis makes drivers more cautious, relaxed, alert, or calm, or makes them drive slowly (Swift et al. 2010; Otto et al. 2016; EKOS Research Associates Inc. 2017; McKiernan and Fleming 2017; Terry and Wright 2005; Danton et al. 2003; Arkell et al. 2020b; Wickens et al. 2019; MacDonald et al. 2008; Barrie et al. 2011). Indeed, Otto et al. found that those who had a positive attitude toward DACU were more likely to believe that they would be more alert, calm, and cautious if they drove after using cannabis (Otto et al. 2016). The amount of cannabis consumed, tolerance, frequency of use, and time waited before driving were thought to moderate the effect of cannabis on driving ability (Greene 2018; McKiernan and Fleming 2017; Porath-Waller 2008; Danton et al. 2003; Wickens et al. 2019). Five studies identified gaps between personal and others' attitudes toward DACU; participants were more likely to indicate that they were less impaired when DACU and less likely to have an accident, intend to drive, or hold positive attitudes toward DACU than others (Ward et al. 2017; Swift et al. 2010; Fischer et al. 2006; Grilly 1981; Wickens et al. 2019).

Attitudes toward DACU can differ by age, sex/gender, and cannabis use frequency

Age

Nineteen studies from the US ($n=12$, 2016–2023), Canada ($n=6$, 2013–2023), and Australia ($n=1$, 2020) reported differences in attitudes toward DACU by age. Younger participants were more likely than older participants to perceive DACU as an acceptable, safe, or unconcerning behavior that does not negatively affect driving

Table 2 Summary of themes

Theme	Summary
Attitudes toward the safety and acceptability DACU are mixed	Sixty studies ($n > 110,289$ participants; NR in one study) supported this theme. Participants in 35 studies ($n = 67,761$), predominantly expressed negative attitudes toward DACU. Participants in 20 studies ($n > 23,077$, NR in one study) expressed the opposite. Participants in 5 studies ($n = 19,451$) expressed neutral or mixed views. Subsets of participants in 16 studies ($n > 8,039$, NR in one study) reported that cannabis can improve or have positive effects on driving ability.
Attitudes toward DACU can differ by age, sex/gender, and cannabis use frequency	Age. Nineteen studies ($n = 40,006$) supported this theme. Youth were more likely to hold positive attitudes toward DACU than older participants across ten studies ($n = 30,603$). One study found the reverse ($n = 1,773$) and eight studies found that older age was unrelated to attitudes ($n = 7,630$). Sex/gender. Twenty-six studies ($n = 46,694$) supported this theme. Men were more likely to hold positive attitudes toward DACU than women across 13 studies ($n = 33,376$). Two studies reported the reverse ($n = 3,416$), two reported mixed results ($n = 2,842$), and nine found no differences by gender ($n = 7,060$). Cannabis use frequency. Twenty-four studies ($n = 26,637$) supported this theme. Frequent users had more positive attitudes toward DACU, reported greater intention to DACU, more frequent past DACU, and lower likelihood of legal consequences than those who used cannabis less frequently across 23 studies ($n = 26,378$). One study reported no such relationship ($n = 259$).
Attitudes toward DACU are associated with past DACU and intention to DACU	Twenty-six studies ($n = 28,775$) supported this theme. Positive attitudes toward DACU were associated with actual DACU and greater intention and willingness to DACU.
DACU is viewed more favorably than driving after drinking alcohol	Thirty-seven studies ($n > 56,159$, NR in one study) supported this theme. Attitudes toward DACU were more positive than attitudes toward driving after drinking alcohol in 31 studies ($n > 49,420$, NR in one study). Five studies reported contradictory results ($n = 6,672$). There was consensus that driving under the combined influence of cannabis and alcohol was riskier than DACU alone across six studies ($n = 1,305$).
The relationship between legal status of recreational cannabis and attitudes toward DACU is unclear	Fifteen studies ($n = 56,127$) supported this theme. Opinions toward the DACU safety and related laws differed across five studies ($n = 37,477$). Five studies ($n = 12,566$) did not identify any clear differences. Five studies ($n = 6,084$) reported various effects of legalization (e.g., anticipated post-legalization rise in DACU prevalence).
Perceived risk of apprehension for DACU is low to moderate	Thirty-one studies ($n = 69,503$) supported this theme. Perceived risk of apprehension and/or penalty for DACU was low to moderate, especially relative to driving after alcohol, in 25 studies ($n = 54,433$). One study had contradictory results ($n = 416$). Fourteen studies discussed the effect of and support for preventive policies, penalties, and detection efforts ($n = 26,941$).

ability or increase MVC risk (EKOS Research Associates Inc. 2017; Corporate Research Associates 2018; Benedetti et al. 2021; AAA Foundation for Traffic Safety 2018; Eichelberger 2016; Jonah 2013; Eichelberger 2023). Youth also reported greater willingness and intention to DACU than older participants (Ward et al. 2018; Davis et al. 2016). One US study found that older participants rated medical, but not recreational, cannabis use as having a more negative impact on driving ability (Auguste and Zambrano 2023). Eight studies found that older age was unrelated to attitudes toward DACU after use of cannabis (Aston et al. 2016; Allen et al. 2016; Duckworth and Lee 2019; Goodman et al. 2020; McDonald et al. 2021;

Wickens et al. 2023; Arkell et al. 2020b; Eichelberger 2019) and one reported that older age was associated with believing that DACU is safe (Cutler et al. 2018).

It is important to note that safety beliefs varied among other studies studies conducted with samples of youth. While teenagers and youth predominantly report that DACU is dangerous and cannabis negatively affects driving ability, some youth report that cannabis use could actually improve driving ability (Greene 2018; EKOS Research Associates Inc. 2017; Lenné et al. 2001; Porath-Waller 2008; Danton et al. 2003). As in drivers of all ages, youth believed effects depended on the amount of cannabis consumed, tolerance, and time waited before driving

(Greene 2018; McKiernan and Fleming 2017; Porath-Waller 2008; Danton et al. 2003).

Sex and gender

'Sex' and 'gender' is presented as one concept because the reviewed literature used these terms interchangeably. Twenty-six studies from the US ($n=13$, 2007–2023), Canada ($n=7$, 2008–2023), Australia ($n=5$, 2001–2023) and Spain ($n=1$, 2016) reported sex and gender differences in attitudes toward DACU. Compared to women, men were more likely to report that DACU is acceptable and safe and less likely to agree DACU is impairing, risky, or concerning (Earle et al. 2020; McCarthy et al. 2007; Corporate Research Associates 2018; Benedetti et al. 2021; Duckworth and Lee 2019; Eichelberger 2016; Jonah 2013; McDonald et al. 2021; Pino et al. 2016; Porath-Waller 2008; Arterberry et al. 2013; Brown et al. 2022). Men also believed that DACU is less dangerous than driving after drinking alcohol, (EKOS Research Associates Inc. 2017) reported less support for per-se cannabis laws, (Benedetti et al. 2021) greater intention to DACU, (Earle et al. 2020) and were less likely to believe that drivers who DACU would be stopped or charged by police (Allen et al. 2016; Corporate Research Associates 2018; Jonah 2013). However, these findings were not consistent across all studies. Eight studies found no association between gender and perceived safety of DACU, cannabis-related crash risk or impact of cannabis on driving ability, (Aston et al. 2016; Swift et al. 2010; Allen et al. 2016; Goodman et al. 2020; Eichelberger 2023; Wickens et al. 2023; Arkell et al. 2020b; Auguste and Zambrano 2023) likelihood of future DACU, (Jones et al. 2006) or likelihood of being stopped or charged by police (Goodman et al. 2020). Two studies reported mixed results depending on attitudinal probes or time of survey (Mills et al. 2023; Eichelberger 2019). Further, three studies found that men were more likely than women to admit that cannabis use impairs driving ability, (Lenné et al. 2001) less likely to approve of DACU, (AAA Foundation for Traffic Safety 2018) and more aware that DACU and driving after alcohol use could have the same legal penalties (Corporate Research Associates 2018).

Cannabis use frequency

Twenty-four studies from the US ($n=12$, 1981–2023), Canada ($n=8$, 2006–2022), Australia ($n=2$, 2010–2020), New Zealand ($n=1$, 2017) and Spain ($n=1$, 2016) considered differences in attitudes toward DACU by cannabis use frequency. Participants who used cannabis more frequently were less likely to believe that driving ability is impaired by cannabis, that higher intoxication levels are safe for DACU, that DACU is dangerous, unsafe, risky, unacceptable, concerning or problematic, (McCarthy

et al. 2007; Malhotra et al. 2017; Arterberry et al. 2017; Borodovsky et al. 2020; Swift et al. 2010; Allen et al. 2016; Otto et al. 2016; EKOS Research Associates Inc. 2017; Goodman et al. 2020; Grilly 1981; McDonald et al. 2021; Pino et al. 2016; Wechsler et al. 1984; Eichelberger 2023; Arterberry et al. 2013; Berg et al. 2018; Colonna et al. 2021; Cuttler et al. 2018; Huynh et al. 2022; Arkell et al. 2020b; Wickens et al. 2019; Auguste and Zambrano 2023) than those who used cannabis less frequently (including non-users). Frequent users also reported greater willingness and intention to DACU in the future (Allen et al. 2016; Otto et al. 2016; Fischer et al. 2006) than less frequent users. Only one study found no association between cannabis use frequency and believing that DACU increases collision risk (Wickens et al. 2023).

Attitudes toward DACU are associated with past DACU and intention to DACU

Twenty-six studies from the US ($n=16$, 2007–2023), Canada ($n=5$, 2008–2021), and Australia ($n=5$, 2010–2023) examined associations between attitudes toward DACU and actual or intended DACU. In the US, participants with a history of DACU had more favorable attitudes toward DACU than those who reported never or less frequent DACU (Ward et al. 2018; McCarthy et al. 2007; Aston et al. 2016; Arterberry et al. 2017; Otto et al. 2016; Davis et al. 2016; Cavazos-Rehg et al. 2018; Eichelberger 2016; Arterberry et al. 2013; Berg et al. 2018; Cuttler et al. 2018; Scott et al. 2021). For example, positive attitudes were associated with reporting past DACU (RR=1.59) (Ward et al. 2018) while negative attitudes were associated with lower odds of driving five or more times within one hour of using cannabis (OR=0.26) (Davis et al. 2016). Those who had ever engaged in DACU also believed that DACU was more prevalent and acceptable (Ward et al. 2018; McCarthy et al. 2007; Otto et al. 2016; Hultgren et al. 2023a) than those who had not. Greater intoxication levels perceived as safe for DACU also corresponded to more frequent DACU; for each unit increase in intoxication level perceived as safe for driving (0; sober/need to be sober to 10; so high that you throw up/vomit), the odds of past-month DACU increased 18–68% (MOR=1.18–1.68) (Borodovsky et al. 2020). Interestingly, a third (30%) of participants who perceived their driving to be impaired by cannabis also reported DACU (Cuttler et al. 2018). Positive attitudes toward DACU also predicted greater willingness and intention to DACU in the future, which were in turn associated with engagement in DACU (Earle et al. 2020; Ward et al. 2018; Ward et al. 2018; Ward et al. 2017; Otto et al. 2016; Otto et al. 2016; Scott et al. 2021).

Studies conducted in Canada reported similar findings; having a history of DACU was associated with more positive attitudes toward DACU (Fischer et al. 2014; Goodman et al. 2020; McDonald et al. 2021; Colonna et al. 2021). Positive attitudes toward DACU also predicted greater willingness and intention to DACU in the future (Porath-Waller 2008). Similarly, in five studies conducted in Australia, participants who reported past or intended DACU were more likely to believe cannabis does not impair driving ability (OR=3.53) or increase crash risk, and believing that cannabis increases accident risk discourages frequent engagement in DACU (OR=0.4) (Swift et al. 2010; Mills et al. 2023; Mills and Freeman 2023; Arkell et al. 2023a; Matthews et al. 2014). Overall, the available evidence is consistent across the three countries and recreational or medical legal status of cannabis. However, it is worth noting that one international study found that US youth were more likely than Canadian or English youth to report DACU but less likely to report that DACU is risky (Wadsworth and Hammond 2019).

DACU is viewed more favorably than driving after drinking alcohol

Thirty-seven studies from Canada ($n=12$, 2006–2023), the US ($n=14$, 1981–2023), US and Israel ($n=1$, 2024), Australia ($n=5$, 2000–2014), England/United Kingdom (UK) ($n=3$, 2000–2005), and New Zealand ($n=2$, 2009–2017), examined perceptions of DACU relative to driving after drinking alcohol (and in some cases illicit drugs such as heroin or ecstasy). DACU was considered to be relatively less dangerous, impairing, risky, or problematic across 31 studies from Canada, (Corporate Research Associates 2018; Fischer et al. 2006; Jonah 2013; McKiernan and Fleming 2017; Wickens et al. 2023; Colonna et al. 2021; Wickens et al. 2019; MacDonald et al. 2008) the US, (McCarthy et al. 2007; Greene 2018; Allen et al. 2016; Davis et al. 2016; AAA Foundation for Traffic Safety 2018; Cavazos-Rehg et al. 2018; Duckworth and Lee 2019; Eichelberger 2016; Ginsburg et al. 2008; Grilly 1981; Kohn et al. 2014; Lensch et al. 2020; Eichelberger 2023; Hultgren et al. 2023b) Australia, (Swift et al. 2010; Aitken et al. 2000; Barrie et al. 2011; Matthews et al. 2014) England/UK, (Terry and Wright 2005; Danton et al. 2003; Albery et al. 2000) New Zealand, (Hammond 2009) and Israel/US (LoParco et al. 2024). One US study found that the amount of alcohol consumed moderated relative attitudes (DACU was considered less dangerous than driving after five, but not fewer, drinks) (McCarthy et al. 2007). This sentiment appears to be common among samples of youth in Canada and the US, (McCarthy et al. 2007; Greene 2018; Grilly 1981; McKiernan and Fleming 2017; Colonna et al. 2021) as supported by three studies which reported differences by age (EKOS Research Associates

Inc. 2017; Corporate Research Associates 2018; McDonald et al. 2021). Men and recent or frequent cannabis users were also more likely to hold this belief (EKOS Research Associates Inc. 2017; McDonald et al. 2021). Some researchers suggest that this difference may be partially explained by limited exposure to the dangers cannabis impaired driving (McKiernan and Fleming 2017) or lack of thought given to DACU (Danton et al. 2003). In contrast, messages about the dangers of alcohol-impaired driving are ubiquitous in these countries. Indeed, the need for information around how cannabis affects driving was expressed in four studies (Greene 2018; EKOS Research Associates Inc. 2017; Hammond 2009; Colonna et al. 2021). Due to these demographic differences, such messaging may be directed at youth and cannabis users.

DACU was considered to be as dangerous or more dangerous than driving after drinking alcohol in five studies on all (Malhotra et al. 2017; EKOS Research Associates Inc. 2017; McDonald et al. 2021; Woods-Fry et al. 2020) or some measures (Porath-Waller 2008). These studies were varied in regard to legal status of recreational or medical cannabis. Driving under the combined influence of cannabis and alcohol was universally thought to be riskier than DACU alone across studies from Canada, the US, and Australia (Greene 2018; Swift et al. 2010; Fischer et al. 2006; Lenné et al. 2001; Porath-Waller 2008; Aitken et al. 2000).

The relationship between legal status of recreational cannabis and attitudes toward DACU is unclear

Fifteen studies from the US ($n=10$, 2016–2024) and Canada ($n=5$, 2017–2021) compared attitudes toward DACU in participants surveyed before versus after legalization of recreational cannabis ($n=4$) or in participants residing in US states with versus without legalized recreational cannabis ($n=7$), reported anticipated changes in DACU following legalization ($n=2$), or discussed the impact of legalization on risk perception ($n=2$). In the US, where recreational cannabis was legalized at the state level, drivers were more likely to view DACU as problematic after legalization (Eichelberger 2016). Residents in states with established recreational cannabis retail markets were more likely to believe that DACU is risky than residents in states without established retail markets (Lensch et al. 2020). Residents in states without legalized recreational cannabis thought DACU was less safe, (Brown et al. 2022) expressed less support for per-se laws for legal blood-THC concentration limits, (Benedetti et al. 2021) and were less likely to endorse anti-legalization arguments related to potential increases in MVCs relative to those in states without (McGinty et al. 2017). Still, some of this research found no difference in attitude

by state legal status (Otto et al. 2016; Wadsworth and Hammond 2018; Benedetti et al. 2021; LoParco et al. 2024). Otto et al. (Otto et al. 2016) did not find any association between legal status and DACU intention, willingness, control beliefs, norms, and DACU behaviour. Pre-post legalization comparisons of US data suggest that there were no changes in perceived safety of DACU, (Cutler et al. 2018) perceived risk of impairment due to DACU, or perceived likelihood of arrest after legalization (Eichelberger 2019).

Five studies were conducted in Canada where recreational cannabis was legalized in October 2018. Prior to legalization, most participants believed that DACU prevalence would rise after recreational cannabis use became legal, (EKOS Research Associates Inc. 2017; Colonna et al. 2021) although most did not intend to DACU themselves (Corporate Research Associates 2018). Concerningly, participants in a remedial program for impaired drivers understood legalization to mean that DACU is a low-risk activity (Wickens et al. 2019). The belief that cannabis is less impairing than alcohol increased from pre- to two years post legalization (Woods-Fry et al. 2020).

Additionally, another study compared safety attitudes in youth from Canada, England, and the US (Wadsworth and Hammond 2019). At the time of study (2017) recreational cannabis use was prohibited in England, all but four US states, and Canada (although Canada had announced plans for legalization in 2018). Youth in England were significantly more likely to endorse that DACU increases the risk of accident by 'a lot' than youth in Canada or the US, while US youth were significantly less likely than Canadian youth. Overall, the available evidence from studies conducted between 2016 and 2024 suggests that legalization does not prompt positive attitudes toward DACU.

Perceived risk of apprehension for DACU is low to moderate

Thirty-one studies from the US ($n=11$ 1998–2021), US and Israel ($n=1$, 2024), Canada ($n=9$, 2013–2023), Australia ($n=7$, 2001–2023), England ($n=2$, 2003–2005), and Canada, the US, and England ($n=1$, 2019) reported on perceived risk of apprehension for DACU. With the exception of one US study, (Ward et al. 2017) participants in the US, (Ward et al. 2018; Greene 2018; Allen et al. 2016; Wadsworth and Hammond 2018; Wadsworth and Hammond 2019; AAA Foundation for Traffic Safety 2018; Eichelberger 2016; Townsend et al. 1996; Eichelberger 2019) Canada, (Wadsworth and Hammond 2019; EKOS Research Associates Inc. 2017; Corporate Research Associates 2018; Goodman et al. 2020; Jonah 2013; McKiernan and Fleming 2017; Colonna et al. 2021; Huynh et al.

2022) Australia, (Jones et al. 2006; Mills et al. 2023; Lenné et al. 2001; Matthews et al. 2014) and England (Wadsworth and Hammond 2019; Danton et al. 2003) perceived low to moderate risk of apprehension and/or penalty for DACU. Perceptions of apprehension and/or penalty for driving after drinking alcohol were higher than for DACU (AAA Foundation for Traffic Safety 2018; Eichelberger 2016; Goodman et al. 2020; Jonah 2013; Lenné et al. 2001; McDonald et al. 2021; Terry and Wright 2005; Wickens et al. 2023; Matthews et al. 2014; LoParco et al. 2024). When asked about the likelihood of being stopped by police while DACU, one to two-thirds (38–69%) of participants in seven studies agreed that they would probably not be stopped (Ward et al. 2018; Allen et al. 2016; Wadsworth and Hammond 2018; Wadsworth and Hammond 2019; Corporate Research Associates 2018; AAA Foundation for Traffic Safety 2018; Goodman et al. 2020). Participants in four Canadian and US studies acknowledged that determining cannabis-related impairment would be difficult for law enforcement (EKOS Research Associates Inc. 2017; McKiernan and Fleming 2017; Colonna et al. 2021; LoParco et al. 2024). Perceived likelihood of being caught for DACU was low among samples of youth in five studies, (Greene 2018; Lenné et al. 2001; Colonna et al. 2021; Danton et al. 2003; Townsend et al. 1996) although two studies reported greater concerns among younger participants (EKOS Research Associates Inc. 2017) or no relationship between age and perceived likelihood of legal consequences (Jonah 2013).

Support for various preventive policy options, including per-se laws for legal blood-THC limits and stricter penalties for offences, was expressed in studies from Canada (EKOS Research Associates Inc. 2017; Jonah 2013; Colonna et al. 2021) and the US (Benedetti et al. 2021; AAA Foundation for Traffic Safety 2018). Participants in all countries agreed that increasing the likelihood of detection (e.g., through random testing) and punishment would have a deterrent effect on DACU, (Swift et al. 2010; Corporate Research Associates 2018; Terry and Wright 2005) although the majority in one Australian study disagreed because they thought they would 'pass roadside performance tests anyway' (Lenné et al. 2001). A small majority of Australian medical cannabis users (56–65%) indicated that random drug testing deters them from DACU (Arkell et al. 2020b; Arkell et al. 2023a). However, evidence in support of such strategies is mixed. In two studies from the US and Australia, cannabis users with a history of DACU reported less worry about being charged for DACU (OR=1.17) (Berg et al. 2018) and more willingness to drive if there was no chance of detection and punishment (Jones et al. 2006). Another study found no association between perceived risk of arrest and DACU (Eichelberger 2019). Studies were heterogeneous

in terms of legal status of recreational and medical cannabis at the time the research was done and legal status appears unrelated to support for preventive policies. However, legal status and drug-driving laws vary widely across US states, and no additional US studies contrasted perceived apprehension risk on this basis.

Discussion

This review examined attitudes toward DACU based on results from 70 studies. In 35 studies, attitudes toward DACU were predominantly negative (e.g., DACU is dangerous, affects driving ability, and increases crash risk). However, positive attitudes were predominantly expressed in 20 studies. Surprisingly, subsets of participants in 16 studies reported that cannabis actually improves or positively affects driving ability. Youth, men, and frequent cannabis users tended to view DACU more favorably than older participants, women, and occasional or non-users. There appear to be gaps in beliefs regarding personal v.s., others' attitudes toward DACU; participants believed that, relative to others, they held less favorable attitudes toward DACU, had less intention to DACU, and would be less impaired or likely to have an accident when DACU.

Despite a dearth of longitudinal studies linking current attitudes to future engagement in DACU, 26 studies in this review showed associations between attitudes and past DACU, intended DACU, or willingness to DACU. This evidence aligns with theoretical models that connect evaluations of behavior to actual behavioural engagement, including the theories of Planned Behaviour, Reasoned Action, (Fishbein and Ajzen 1975) and the Prototype Willingness Model (Gerrard et al. 2008). Broadly, these models assert that future behaviours are predicted by a system of cascading beliefs whereby attitudes shape intention and/or willingness to perform a behavior, which in turn predicts behavioural engagement. Dispelling misunderstandings about DACU safety may therefore decrease its incidence. Current evidence supports drug-driving interventions aimed at changing attitudes and improving knowledge about associated risks (Razaghizad et al. 2021).

DACU is generally viewed more favorably than driving after alcohol use and this perception may make DACU more likely. As such, it may be tempting to develop public safety campaigns against DACU that frame the two activities as equally dangerous. However, this may not be advisable as experimental and epidemiological evidence has consistently demonstrated that driving after alcohol use is more dangerous than DACU. In driver simulator studies, cannabis has been shown to affect driving performance to an extent similar to blood alcohol concentration of 0.04–0.06% (Simmons et al. 2022). The risk of

MVC is higher among drinking drivers than in those who used cannabis (Sewell et al. 2009; Drummer et al. 2020; Brubacher et al. 2019) and alcohol-related collisions are more likely to result in serious injury than cannabis-related collisions (Brubacher et al. 2023). Preliminary evidence suggests that use of THC-containing cannabis has a negligible impact on driving performance when used for medical purposes (Arkell et al. 2023b; Arkell et al. 2021; Manning et al. 2024). Nonetheless, cannabis use does pose an MVC risk, and it is concerning that many people are unaware of this risk. Public education is needed to correct misconceptions about DACU safety, without emphasizing its risk relative to alcohol. Reassuringly, our results show that most people believe co-consumption of alcohol and cannabis is more detrimental to driving performance than consumption of either substance alone. This aligns with evidence from experimental driving studies (Simmons et al. 2022).

Legalization of recreational cannabis appeared to have an inconsistent effect on perceptions of DACU. One explanation is that legal changes influence cultural norms gradually, as most studies were conducted shortly before and after legalization. Further, differences in country and state-level dialogue on the risks of DACU around the time of legalization may have obfuscated the impact of legalization on attitudes.

Results of this analysis show that perceived risk of apprehension for DACU is low. In accordance with Deterrence Theory, enforcement agencies and policy makers seek to increase perception of certain, swift and severe punishment for illegal driving behavior (Bates et al. 2012; Davey and Freeman 2011; Hasan et al. 2022). Problematically, populations who tend to exhibit relatively positive attitudes toward DACU, including younger drivers and recent cannabis users are less likely to believe they will be caught by police. One reviewed study found that perceived likelihood of legal consequences is inversely associated with willingness to DACU among recent cannabis users (Jones et al. 2006). As such, policies that facilitate detection (e.g., roadside oral fluid testing) are encouraged, especially when directed at at-risk populations.

Currently, country-level impaired driving laws and detection approaches vary. Australia has a zero-tolerance policy, Canada has a zero-tolerance policy for young, novice, and commercial drivers but introduced per-se limits of THC in blood of ≥ 2 and 5ng/mL for other drivers in 2018, (Department of Justice Canada 2021) and the US has a mix of zero-tolerance, per-se, under the influence, and permissible inference laws (Conference and of State Legislatures. Marijuana-Impaired Driving 2023). Canada, Australia, and some US states permit oral fluid roadside testing, but uptake is variable. The state of

Victoria has operated a high-visibility random oral fluid screening program since 2004, which has resulted in behavioural change, presumably because public awareness increased perceived likelihood of detection (Boorman and Owens 2009; Cameron et al. 2022). In contrast, in Canada and US states with authorization to collect oral fluid, police must have reasonable grounds to suspect DACU before they may demand a sample blood for testing. As THC blood levels drop rapidly after smoking cannabis, delays as police gather evidence may result in THC levels falling below per se limits before blood samples are obtained. Legal regimes that include visible enforcement along with well-publicized media campaigns can enhance deterrent effects by making drivers aware of policing efforts and legal penalties (Davey and Freeman 2011).

Educating drivers on the risks of DACU is strongly encouraged, but attitudinal change alone may not be sufficient to prevent this behavior. Even drivers who believe that cannabis impairs their ability to drive safely report driving within one hour of cannabis use (Cuttler et al. 2018). Behaviour is influenced by many factors including attitudes, norms, perceived behavioural control, and expectations. Five included studies found that DACU is predicted by perceived behavioural control (i.e., beliefs about ability to engage or not engage in DACU), descriptive norms (i.e., the extent to which DACU is believed to be common or normal), and injunctive norms (i.e., the extent to which others approve or disapprove of DACU) over and above attitudes (Earle et al. 2020; Ward et al. 2018; Otto et al. 2016; Scott et al. 2021). Consistent with these findings, several other studies report associations between perceived control, norms, and actual or intended DACU (McCarthy et al. 2007; Aston et al. 2016; Porath-Waller 2008; Aitken et al. 2000; Berg et al. 2018; Colonna et al. 2021; Huỳnh et al. 2022). Although not the focus of this review, these malleable social-cognitive antecedents of DACU behavior provide opportunities for intervention (Miller and Prentice 2016).

The studies included in this review largely focused on between-person differences in attitudes as predictors of DACU. However, individuals may decide to DACU on some occasions while deciding against it on others. Sometimes these decisions are made while under the influence of cannabis. Users who report feeling high are more likely to report that they can safely DACU than those who are not high (Allen et al. 2016). A similar pattern has been observed in regard to perceptions of danger and willingness to drive after drinking alcohol (Morris et al. 2014; Quinn and Fromme 2012). Given the importance of intoxication to one's ability to make safer decisions, research on event-level characteristics of DACU decision-making is encouraged. Similar

to the 'arrive alive' public service announcements for impaired driving campaigns, (CNW Group 2018) cannabis campaigns might encourage people to identify designated drivers and decide how they will be getting home after cannabis consumption before using.

Strengths and limitations

This review has several strengths. To our knowledge, this is the first systematic review of attitudes toward DACU. It is comprised of 70 studies from seven countries that sampled various populations, including recreational and medical cannabis users, youth, and drivers with a history of DACU. This review also has some limitations. Interpretation of the present findings may be limited due to substantial heterogeneity between studies (e.g., variation in study design, number of participants, use of different questions). Attitudes were assessed in a variety of ways (e.g., dangerousness of DACU, effects of cannabis on crash risk or driving performance). The terminology used in survey studies may have implied varying degrees of impairment. For example, 'driving under the influence of cannabis' or 'driving while impaired by cannabis' may have biased respondents to endorse the dangerousness of DACU. The use of neutral language, such as 'driving after using cannabis' is encouraged, although a time interval may need to be specified and additional probes about 'feeling the effects of cannabis' might be useful. The questions posed usually referred to driving after using cannabis without specifying time elapsed from using cannabis to driving, dose, THC/CBD composition, or route of administration, leaving these parameters to participants' interpretation. Consuming greater quantities of cannabis or cannabis with higher THC content may affect driving performance more dramatically, and the route of administration may affect the magnitude and duration of potential impairment (Burt et al. 2021). Further work could explore how attitudes toward DACU vary with dose, THC/CBD composition, route of administration, or time since use. Despite differences in methodology and outcomes measured, included studies converged on six broad themes that offer direction for intervention efforts.

Conclusions

The current review revealed that the majority of participants in most studies consider DACU to be unsafe. That said, more education is needed as a minority of people do not perceive DACU as dangerous and individuals with a history of DACU tended to express willingness to DACU in the future. As legalization of recreational cannabis expands, concerns about what constitutes safer consumption or

practices which mitigate harms to oneself and others will also likely increase. Because DACU has the potential to jeopardize the health and safety of not only the driver but also other road users, it will be crucial to consider attitudes toward DACU, how they vary across subpopulations, and how they can be changed to promote safer driving practices. This review has implications for campaigns to prevent DACU which include messaging to increase perception of risk and certainty of apprehension.

Supplementary Information

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Additional file 1. Search Strategy.

Additional file 2. Study Summary Table.

Additional file 3. Thematic synthesis codes.

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Authors' contributions

BB: Conceptualization, methodology, data curation, analysis, and writing. DA: data curation, writing. YY: Methodology. JB: Supervision, editing.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

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Competing interests

The authors declare that they have no competing interests.

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