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Evaluating cannabis exposure in survey items: Insights, strategies, and remaining challenges identified from cognitive interviewing

Claire A. Walsh^a, Cara A. Struble^d, Efrat Aharonovich^{a,b}, Dvora Shmulewitz^{a,b},
Jacob Borodovsky^d, Mohammad I. Habib^d, Alan Budney^d, Ofir Livne^{a,b}, Deborah S. Hasin^{a,b,c,*}

^a New York State Psychiatric Institute, 1051 Riverside Drive, New York, NY 10032, USA

^b Department of Psychiatry, Columbia University Irving Medical Center, 1051 Riverside Drive, New York, NY 10032, USA

^c Department of Epidemiology, Columbia University Mailman School of Public Health, 722W 168th St, New York, NY 10032, USA

^d Center for Technology and Behavioral Health, Dartmouth Geisel School of Medicine, One Medical Center Drive, Lebanon, NH 03756, USA

HIGHLIGHTS

- Recall difficulty on survey items varied with participant's use frequency.
- Difficulties emerged in reporting quantity of cannabis used over the past 7 days.
- Few issues were found with comprehension of items key to reporting THC exposure.
- Responses revealed several cannabis products previously unaddressed in the survey.
- Survey items were modified to address points of ambiguity identified in interviews.

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ABSTRACT

Background: The diversity in characteristics of cannabis products and behavior patterns make evaluation of cannabis exposure in population-based, self-report surveys challenging. Accurate identification of cannabis exposure and related outcomes necessitates a thorough understanding of participants' interpretations of survey questions assessing cannabis consumption behaviors.

Objectives: The current study utilized cognitive interviewing to gain insight on participants' interpretation of items in a self-reported survey instrument used to estimate the quantity of THC consumed in population samples.

Methods: Cognitive interviewing was used to evaluate survey items assessing cannabis use frequency, routes of administration, quantity, potency, and perceived "typical patterns" of use. Ten participants ≥ 18 years ($n = 4$ cisgender-men; $n = 3$ cisgender-women; $n = 3$ non-binary/transgender) who had used cannabis plant material or concentrates in the past week were recruited to take a self-administered questionnaire and subsequently answer a series of scripted probes regarding survey items.

Results: While most items presented no issues with comprehension, participants identified several areas of ambiguity in question or response item wording or in visual cues included in the survey. Generally, participants with irregular use patterns (i.e., non-daily use) reported more difficulty recalling the time or quantity of cannabis use. Findings resulted in several changes to the updated survey, including updated reference images and new quantity/frequency of use items specific to the route of administration.

Conclusion: Incorporating cognitive interviewing into cannabis measurement development among a sample of knowledgeable cannabis consumers led to improvements in assessing cannabis exposure in population surveys, which may otherwise have been missed.

* Corresponding author at: Department of Psychiatry, Columbia University Irving Medical Center, 1051 Riverside Drive, New York, NY 10032, USA.

E-mail address: dsh2@cumc.columbia.edu (D.S. Hasin).

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1. Introduction

Cannabis is one of the most widely used drugs in the United States (U.S.), with nearly 50 million individuals aged 12 or older reporting past-year use in 2020 (Substance Abuse and Mental Health Services Administration, 2021). Cannabis is currently legal for medical and/or recreational use in 36 states and the District of Columbia (D.C.), comprising 69.4% of the U.S. population (United States Census Bureau, 2021). Rapid legalization of cannabis has introduced a variety of new cannabis products to a quickly expanding industry. Specifically, legalization of cannabis has contributed to greater availability of these novel products as dispensaries and delivery services become increasingly accessible in legal states (Borodovsky et al., 2016; Rocky Mountain High Intensity Drug Trafficking Area, 2019). The rise in popularity of new cannabis products and routes of administration (e.g., electronic vaping devices) contributes to greater heterogeneity in use patterns. Because the pharmacokinetics of delta-9-tetrahydrocannabinol (THC) absorption may vary as a function of route of administration (McGilveray, 2005), older measures of substance use behaviors may fail to capture the nuances of THC exposure in increasingly popular products, necessitating updated, reliable, and valid measures of assessing modern patterns of cannabis use.

To aid in the development of lower-risk use guidelines (Fischer et al., 2017) and to keep pace with increased variability in cannabis use patterns and associated outcomes, public health experts have recently called for increased standardization of dosing for cannabis products in the form of a standard unit of THC, the psychoactive component found in cannabis (Freeman and Lorenzetti, 2020; Volkow and Weiss, 2020). Reliable estimates of the number of milligrams of THC (mg/THC) that an individual consumes are critical to accurately define the likelihood of benefits or adverse consequences associated with different levels of cannabis use. Developing measures to provide meaningful information requires comprehensive instruments that quantify mg/THC consumed that can be efficiently administered to general population samples. To date, such instruments and standardized measures are lacking (Lee et al., 2019; Lorenzetti et al., 2022).

Past studies have utilized other metrics of cannabis consumption such as product weight (Tomko et al., 2018). Additionally, while several tools for identifying problematic cannabis use are available to researchers and clinicians, such tools overwhelmingly rely on use frequency to screen for use that may result in adverse consequences (Adamson and Sellman, 2003; Gossop et al., 1995; Legleye et al., 2012). However, a challenge in estimating cannabis consumption is the heterogeneity of the patterns of use of the drug, such that quantity, potency, route of administration, and product type are all dimensions that impact total mg/THC consumed, the key metric for assessing adverse outcomes associated with the drug (Asbridge et al., 2014; Casajuana et al., 2016; Gray et al., 2009). Therefore, instruments that solely rely on cannabis use frequency or product weight may be inadequate. Other self-report measures of cannabis consumption have been developed that include items assessing cannabis exposure across various domains, for example, the measures in the International Cannabis Policy Study (ICPS) (Goodman et al., 2019; Hammond et al., 2022). In the ICPS, cognitive interviewing was conducted to pretest survey items on patterns of cannabis use and related behaviors (Hammond et al., 2020). Several areas needing clarification were identified, including unclear or ambiguous item wording and items that were misinterpreted by survey participants (Goodman et al., 2019). This information was used to improve and adjust the ICPS measures (Goodman et al., 2019).

To address the challenges of developing accurate self-report cannabis measures, our research group is developing a low-burden, online, personalized self-report questionnaire, the Cannabis Exposure Inventory (CEI). The CEI is intended to assess cannabis use behaviors across six key domains: frequency of use, quantity used, product type, routes of administration, potency (% THC in cannabis products), and assessments of the individual's "typical" pattern of use (Borodovsky et al., 2023;

Budney et al., 2023). The CEI includes novel survey items developed by our research team as well as items used in previous assessments of cannabis consumption (Borodovsky et al., 2020; Cuttler and Spradlin, 2017; Hammond et al., 2022; Leos-Toro et al., 2018). For example, novel survey items include detailed queries of frequency of cannabis use over the past 7 days that are assessed in 4 time-of-day quadrants.

Given the heterogeneity of cannabis products, participants must adequately understand cannabis consumption survey items and be able to provide a response that is in alignment with the researcher's intent of the questions. In instrument development, cognitive interviewing is a qualitative research method designed to evaluate how individuals mentally process and respond to various types of information. Cognitive interviewing evaluates survey items using "verbal probing" techniques (Goodman et al., 2019; Hinds et al., 2016; Willis, 2009). These involve the administration of scripted queries that evaluate aspects of survey items after participants complete the entire questionnaire (Willis, 2005). We conducted a cognitive interviewing study of 24 CEI items that were important to the survey but about which we had questions regarding participant comprehension and understanding. We report on the understanding participants assign to those survey items and how these responses informed revisions to the CEI.

2. Material and methods

2.1. Overview & questionnaire

The CEI included 67 items assessing demographics, frequency of cannabis use within the past 30 and past 7 days, products used, routes of administration, quantity used, estimated potency (%THC), and whether the past 7-day period represented participants' typical pattern of use. Participants who endorsed using cannabis plant material (smoking or vaping) and/or concentrates (dabbing or vaping) were asked to select how they would like to report on the amount of cannabis consumed in the past 7 days, either in: (1) in the number of hits/puffs/tokes per day; (2) grams per day; or (3) joints per day. Potency or quantity of oral cannabis products (i.e., edibles or tinctures) was not assessed. All participants who used cannabis plant material or concentrates >2 days per week were asked if they had used about the "same total amount" of cannabis on each day. Those who reported using the same amount indicated the number of hits, grams, or joints they *typically* used, in four time-of-day quadrants (morning, afternoon, evening, night) (Fig. 1). Those who used different amounts of cannabis each day were asked to report the number of hits, grams, or joints they consumed in the four quadrants either on each day they used (for those who used on only 1–2 days), or on the days they consumed the greatest and least total amount of cannabis (for those who used on >2 days).

2.2. Cognitive interviewing development

Participants responded to all relevant items of the CEI. Twenty-four of those items on cannabis consumption frequency, quantity, and potency were evaluated on three main components: language of the questions, language of the response options, and images provided to increase response accuracy. Target items were identified by the research team responsible for development of the CEI instrument. Items relevant to cannabis consumption behaviors needed to estimate total milligrams of THC consumed per week were identified. General items of cannabis characteristics (i.e., age of onset) were included in the survey but omitted for the cognitive interview. Scripted, retrospective verbal probes for selected survey items were developed using Tourangeau's model of cognitive processing (Tourangeau, 1984), which encompasses four domains of successful interpretation of a given survey item: (1) question comprehension, (2) recall of relevant information, (3) judgement of how to respond appropriately, and (4) selection of the appropriate response (Tourangeau, 1984). Additionally, 13 items included a fifth probe category, specific to the clarity of reference images. Due to

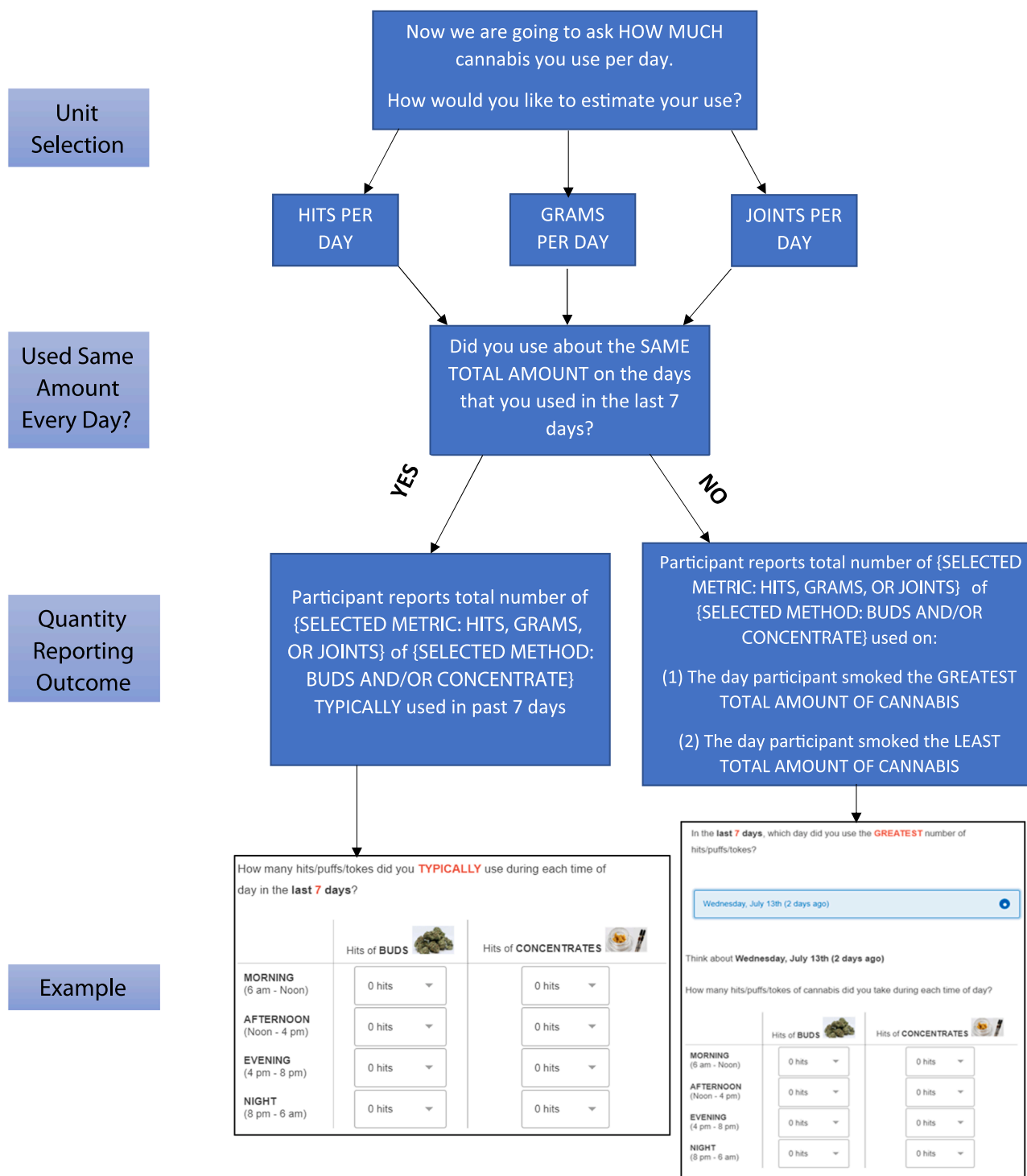


Fig. 1. Survey branching logic for personalization of quantity reporting.

skip logic programmed into the survey, participants were queried only about items they were shown in the survey and were not queried on irrelevant items based on their self-reported consumption pattern. A sample item tested in the cognitive interview, the matching cognitive domains and probes, and responses are displayed in Table 1.

2.3. Recruitment procedures

Participants (N = 10) were U.S. adults age ≥18 years. Recruitment occurred using targeted Facebook advertisements with cannabis-focused

keywords from October 2021 to January 2022 (Fig. 2). The advertisement URL directed participants to a brief eligibility survey that described the study and collected demographics and information regarding cannabis use habits. To be eligible, participants needed to confirm their age, report at least one day of smoking or vaping cannabis plant material and/or concentrates within the past 7 days and provide at least one method of contact (phone number or e-mail address). Information collected in the eligibility survey was reviewed by a study coordinator to identify a diverse group of potential participants in terms of race/ethnicity, gender and route of administration (smoking/vaping

Table 1
Sample CEI item tested via cognitive interviewing.

Item tested	Cognitive domain	Interview probe	Example response								
Check the TIME OF DAY for each day you used cannabis (even if you took just one hit/puff/toke). Leave blank if you did not use. <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <p style="text-align: center;">Tuesday, May 11th (2 days ago)</p> <p style="text-align: center;">Check all that apply</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 2px;">MORNING (6 am - Noon)</td> <td style="width: 50%; text-align: center; padding: 2px;"><input checked="" type="checkbox"/></td> </tr> <tr> <td style="padding: 2px;">AFTERNOON (Noon - 4 pm)</td> <td style="text-align: center; padding: 2px;"><input type="checkbox"/></td> </tr> <tr> <td style="padding: 2px;">EVENING (4 pm - 8 pm)</td> <td style="text-align: center; padding: 2px;"><input type="checkbox"/></td> </tr> <tr> <td style="padding: 2px;">NIGHT (8 pm - 6 am)</td> <td style="text-align: center; padding: 2px;"><input type="checkbox"/></td> </tr> </table> </div>	MORNING (6 am - Noon)	<input checked="" type="checkbox"/>	AFTERNOON (Noon - 4 pm)	<input type="checkbox"/>	EVENING (4 pm - 8 pm)	<input type="checkbox"/>	NIGHT (8 pm - 6 am)	<input type="checkbox"/>	Comprehension	"In your own words, what are we asking you to do here?"	"Tell you around what time we were smoking or when we are consuming cannabis"
MORNING (6 am - Noon)	<input checked="" type="checkbox"/>										
AFTERNOON (Noon - 4 pm)	<input type="checkbox"/>										
EVENING (4 pm - 8 pm)	<input type="checkbox"/>										
NIGHT (8 pm - 6 am)	<input type="checkbox"/>										
	Recall	"How easy or hard was it for you to remember the time of day for each day you used cannabis?"	"It was easier for some than others. On the first one there it was just asking for yesterday, it was easy because yesterday was yesterday, but when you're looking back for the whole week and trying to think about the times, it was a bit more hard."								
	Judgement	"How did you decide on which time(s) to choose? When you read [time frame], what were you thinking of?"	"I was just thinking of, well it says noon to four, so I usually do it between ... one and two for myself."								
	Response	"How easy or hard was it to find your answer in these time frames?"	"Yeah, at first, when I just read the morning afternoon evening that could vary between so many different people that I was wondering what time, but it says a time, right under it. So that did definitely help."								
	Clarity of display	"Was it clear that you could choose more than one response?"	"It easy to find the answer and easy to choose within the time frames"								

cannabis plant material and/or concentrates). Eligible participants who filled enrollment criteria (race, ethnicity, gender, sex, methods of use) were contacted in the order they completed the screening process. Once our target sample size and enrollment quotas were fulfilled, we suspended contacting future participants regardless of eligibility. The study coordinator confirmed appointments with potential participants and sent a Zoom[®] videoconferencing link to use for the cognitive interview. Appointment reminders were sent via the preferred method of contact 24 h before the interview.

2.4. Cognitive interviewing procedures

Two members of the research team conducted the interviews, a doctoral-level interviewer with prior experience in cognitive interviewing and a graduate student who received training from the first interviewer. The doctoral level interviewer completed one interview; the graduate student completed nine. Audio recordings were reviewed for quality assurance by a second doctoral-level clinical psychologist who did not complete interviews. Each participant used their smartphone or computer to meet with their interviewer during the virtual Zoom session. All participants provided written informed consent. Participants were instructed to be in a private area and to keep their webcam and microphone enabled for the entire interview. The interviewer used the Zoom "chat" function to send hyperlinks to the study materials to participants. Sessions took 18 to 37 min to complete. Study procedures were approved by the Dartmouth Committee for the Protection of Human Subjects. Following completion of the interview, participants received a \$50 Amazon gift code.

The interview session included (1) consent procedures, (2) completion of the CEI survey, and (3) the cognitive interview. After the interviewer obtained informed consent, the participant was sent a link to the online CEI survey hosted on the Qualtrics online survey platform and completed the survey independently. Next, the interviewer screen shared a PDF copy of the CEI survey items and the participant's responses so that relevant items could be viewed throughout the cognitive interview. The interviewer displayed each CI item and asked relevant

probes on the following domains: Item/term clarity (e.g., interpretation/understanding of survey language and images), recall knowledge (e.g., ability to recall quantities consumed with a given timeframe), and response options (if participants felt the response set provided in the item was appropriate, meaning that the response options enabled them to answer accurately). Participants were also asked more global questions to reflect on the overall survey (i.e., if there were any cannabis products they felt were missing from the survey, if they felt they were giving the same responses to different questions, and what type of electronic device they used to complete the survey).

2.5. Qualitative data coding

With consent to record video and audio, interviews were digitally recorded using the Zoom platform. Video files were immediately destroyed following the interview, and audio-only files were preserved. De-identified audio files were transcribed with captioning software via the Panopto Video Platform (Panopto Inc. Panopto, 2023). Each transcription was reviewed for accuracy by a doctoral-level psychologist and an undergraduate research assistant, neither of whom were involved in conducting interviews. For each item, two separate members of the research team mapped responses to each probe onto each of the five cognitive domains relevant to that item (comprehension, recall, judgement, response, and clarity of images/display), and determined (1) if the participant experienced any difficulty or confusion and (2) if the participant's response indicated a discrepancy between the *researcher's intention* of the question and the *participant's interpretation* of the question. Responses indicating difficulty or a lack of understanding of the intent were flagged.

3. Results

Sample characteristics are listed in Table 2. The average age was 39.0 years (SD=14.17, range=18–67), and 40% self-identified as cisgender-men, 30% as cisgender-women, and 30% as transgender or non-binary. Seventy percent completed some college; 50% used

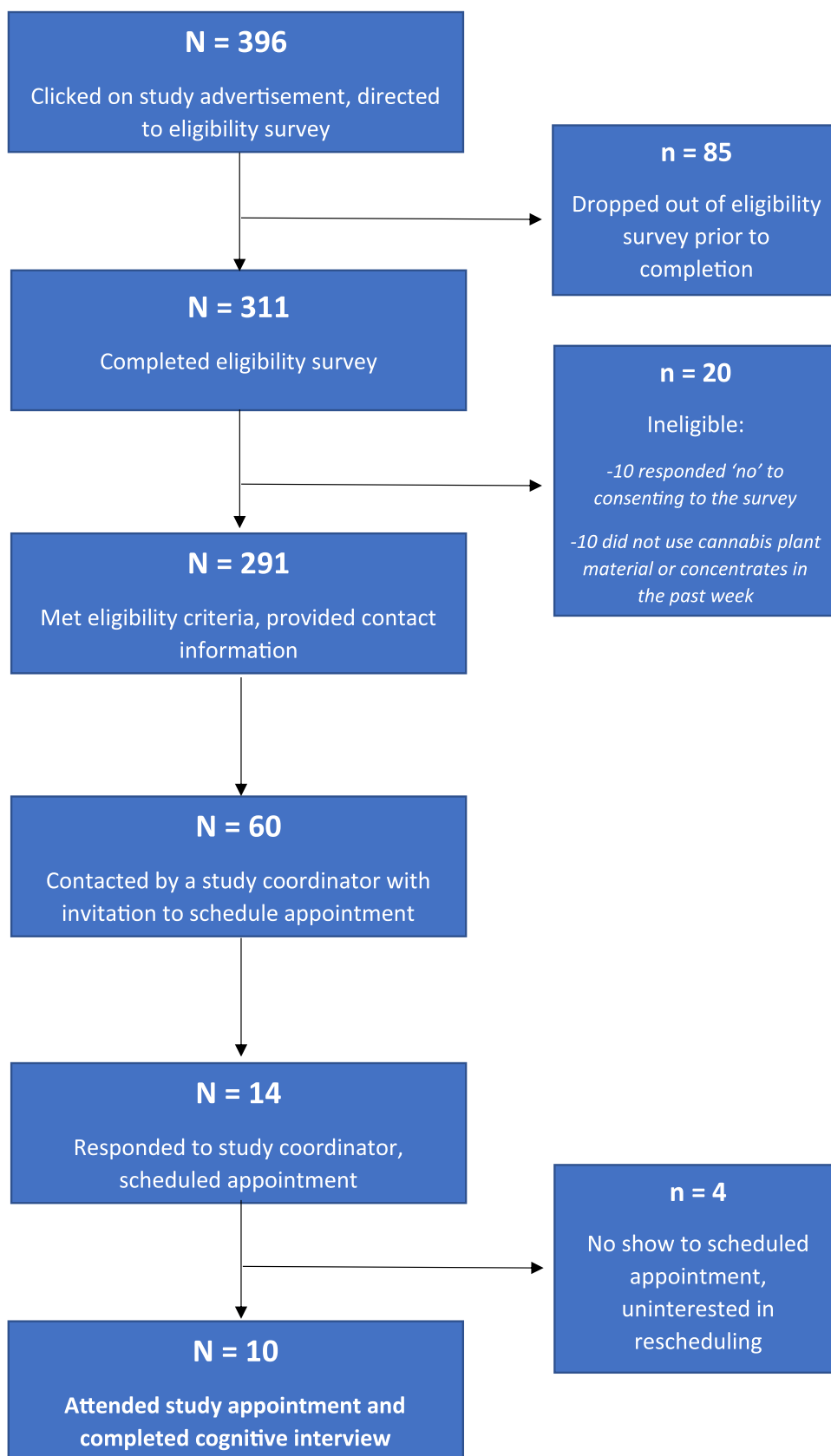


Fig. 2. Number of participants screened, eligible, contacted, and interviewed.

Table 2
Sample demographics and cannabis use characteristics.

Characteristic	n (%)
Gender	
Cisgender man	4 (40)
Cisgender woman	3 (30)
Transgender man	2 (20)
Non-binary	1 (10)
Race/Ethnicity	
White	7 (70)
Hispanic/Latinx	2 (20)
African American	1 (10)
Education	
Associates Degree or Trade School	4 (40)
High School/GED	3 (30)
Bachelor's degree or higher	3 (30)
State (MCL ¹ /RCL ²)	
MCL Only	4 (40)
RCL	3 (30)
No CL ³	3 (30)
Days Used Cannabis - Past 30 Days	
Daily (30 days)	5 (50)
Near daily (20 – 29 days)	2 (20)
Often (10 – 19 days)	2 (20)
Infrequently (<9 days)	1 (10)
Methods Used – Past 7 Days	
Smoking plant material	9 (90)
Vaping concentrates	5 (50)
Edibles	3 (30)
Vaping plant material	2 (20)
Liquid (tinctures/drops)	2 (20)
Dabbing concentrates	1 (10)
Capsules	0 (0)

¹ Medical cannabis law: Cannabis approved for medical use only at the time of the survey.

² Recreational cannabis law: Cannabis approved for both medical and recreational use at the time of the survey.

³ No cannabis law: Cannabis not legal for medical or recreational use at the time of the survey.

cannabis daily, 90% smoked plant material and 50% vaped cannabis concentrates.

Comprehension problems, issues with the survey display, and ambiguity in response sets of survey items resulted in 5 major revisions to the survey (Table 3).

3.1. Cannabis use: ever; past 30 days; past 7 days

All participants reported that they found it easy to answer if they had ever used cannabis, how many days they used in the past 30 days, and if they used in the past 7 days. To estimate the number of days of use during the past 30 days, 5 participants relied on their everyday use pattern and responded 30, and 5 referenced their typical weekly routines to generalize to the past 30 days.

When selecting which of the past 7 days cannabis was used, daily smokers ($n = 5$) easily selected every day. Three non-daily consumers endorsed recalling each day and remembering use on that specific day. Two non-daily consumers found it difficult to remember which days they used due to a break in their routine (“On my normal days where I have structure, it’s a little easier to remember or to be pretty confident about”), or due to general tendencies to not keep track of the date (“Well, easier in some ways and harder in other ways for me to remember it this way... when I go through my days, I typically don’t function as much with the date.”).

Of the nicknames for cannabis (“marijuana, weed, pot, herb, grass, ganja, kush, loud, buds, edibles, tinctures, oils, dabs, wax, shatter, crumble, or budder”), 4 participants did not recognize “loud”, “budder”, and “crumble”.

3.2. Time of day

Those with a regular pattern of use ($n = 7$) found it easy to report the time of day they used cannabis. Three participants used at different times each day and did not keep track of the time; these had difficulty recalling when they used (“It was fairly hard to remember, mainly because it’s not something that I consistently measure, it’s just something that’s part of my life. The only thing that really helped me with figuring out what time of day it would be is what time I wake up.”). Two of these participants reported it was helpful to have specific times (e.g., “6AM-Noon”) in the response options rather than descriptions (e.g., “in the morning”). Recall generally became more difficult as more time had passed since the day in question.

3.3. Methods of cannabis used

All participants understood that “methods” referred to the route of administration. Two participants noted that THC-infused drinks were not listed as an edible. All participants found the photos helpful as a tool for supporting their recognition of various cannabis products. (“Yes, helpful because actually, at first I kind of missed or misread the first one and then looked at it and was like, “Oh, wait”, and I think it was the actual picture that helped me to kind of go back and read it again”).

3.4. Quantity reporting preferences

Seven participants reported in hits per day and three in grams per day. One participant had difficulty responding because their use quantity depends on the delivery method, and two participants suggested additional units (“drops”, “edibles”, or “bowls”).

Nine participants were asked if they had used the same amount on each day of use (1 used cannabis on only one day). Participants identified that “same total amount” referred to “an average” or “overall” amount of cannabis they used on each use day, consistent with the intent of the CEI. All participants reported that it was “easy” to remember if they had used the same amount each day by indicating that they had 90% – 100% confidence in their responses.

3.5. Quantity used – past 7 days

When queried on the amount of cannabis participants had used in the past 7 days in hits, grams, or joints, those who reported in hits per day ($n = 7$) and grams per day ($n = 3$) had similar reasoning about reporting quantity. Those who used the same amount each day ($n = 5$) had a “routine” which made it easy for them to recall quantity used during different times of the day. Three of the 5 participants who did not use the same amount each day reported that recall was challenging, either because their use patterns varied based on the route of administration ($n = 2$), or because they had never attempted to conceptualize or quantify use in this way ($N = 1$).

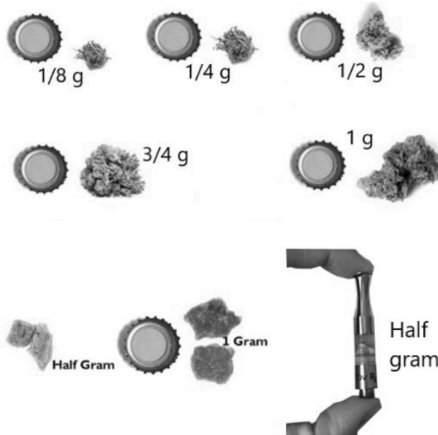
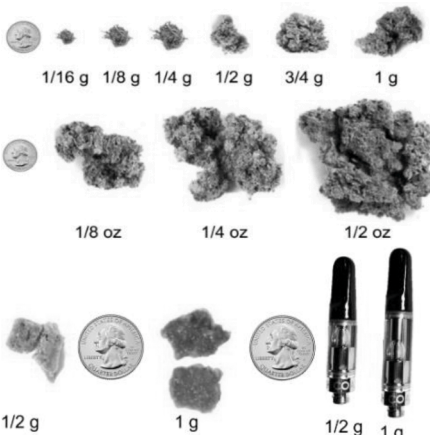


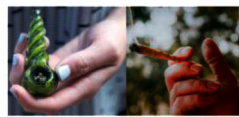
3.6. Quantity reference images

Two reference images of dried plant material and concentrate (Table 3), adapted from another survey (Leos-Toro et al., 2018), were included to assist estimating size in responses about weight in grams. Both included images of bottle caps; two participants did not recognize what the bottle caps were. Three participants suggested American currency (“coins” or “quarters”) instead. Additionally, in the image of plant material, one participant suggested larger amounts (>1 gram).

3.7. Potency

All participants understood that potency referred to the “strength” or “amount of THC” in their cannabis products. Most participants were able to report the potency of plant material or concentrates used, with

Table 3
Revisions made to survey items using participant feedback.

Original item	Discussion	Issue	Revised item
	<p>Interviewee: "Well, I didn't know what those round things were. Quarters would be pretty good." - Interviewee: "It would be helpful if it had a little bit of a like bigger denominations since there is more space"</p> <p>Interviewer: "Is there something other than a bottle cap that you think might be helpful as a reference?" Interviewee: "A penny. Well, actually, I would say like a quarter or a nickel".</p>	<p>Unsuccessful comprehension of item due to display; suggestion to improve clarity of display</p> <p>Unclear item display</p>	
<p><input type="checkbox"/> EDIBLES (brownies, gummies, etc...)</p> 	<p>Interviewer: "Was there anything that you use that was missing from this list?" Interviewee: "The drinks, I think it says under edibles, not referring to the drinks. I've had THC infused beverages." - Interviewee: "I know people will take like sometimes like shots or something that have THC in them. So, I don't know if that's listed"</p> <p>Interviewer: "It just varies depending on your method that you use for delivery"</p>	<p>Response set was missing a popular cannabis product</p>	<p><input type="checkbox"/> EDIBLES (drinks, brownies, gummies, chocolate bars etc...)</p> 
<p>Now we are going to ask HOW MUCH cannabis you use per day.</p> <p>How would you like to estimate your use each day? (choose one)</p> <p><input type="radio"/> in number of HITS / PUFFS / TOKES per day</p> <p><input type="radio"/> in number of GRAMS per day</p> <p><input type="radio"/> in number of JOINTS per day</p>	<p>Interviewer: "Were you also factoring in your Delta 8 use, or did you think about it separately from regular cannabis?" Interviewee: "Yeah, I would consider it the same... I mean, I think it's still weed, so like it's just like a variant that's like legalized, I guess."</p>	<p>Response options not specific to methods used, contributing to ambiguity in response</p>	<p>Now we are going to ask HOW MUCH BUD you SMOKED per day.</p>  <p>How would you like to estimate your use each day? (choose one)</p> <p><input type="radio"/> in number of HITS / PUFFS / TOKES per day</p> <p><input type="radio"/> in number of GRAMS per day</p> <p><input type="radio"/> in number of JOINTS / BLUNTS per day</p>
<p>When this survey asks about "cannabis", we are referring to THC products (not CBD-only). Have you ever used cannabis (aka "marijuana", "weed", "pot", "herb", "grass", "ganja", "kush", "loud") that contains THC including cannabis leaf and buds, edibles, tinctures, or concentrates (oils or dabs like wax, shatter, crumble, budder)?</p>	<p>Interviewer: "Were you also factoring in your Delta 8 use, or did you think about it separately from regular cannabis?" Interviewee: "Yeah, I would consider it the same... I mean, I think it's still weed, so like it's just like a variant that's like legalized, I guess."</p>	<p>Ambiguity in what constitutes definition of "THC" in survey questions</p>	<p>When this survey asks about "cannabis" (marijuana), we are referring to Delta 9-THC and Delta 8-THC products (not CBD-only products). Have you ever used cannabis (aka "marijuana", "weed", "pot", "herb", "grass", "ganja", "kush", "loud") that contains THC? This include cannabis:</p> <ul style="list-style-type: none"> • leaf and buds • concentrates (oils or dabs like wax, shatter, crumble, budder) • edibles • tinctures

confidence in their estimates ranging from 80%–100%. Those who were 100% confident had checked the product label for % THC. Three participants could not report potency. Their reasons included: (1) not being told the potency when purchasing and lack of a product label, (2) they had disposed of the packaging without checking potency information, or (3) somebody else had bought the product.

3.8. Typical use

Nine participants reported that "the last 7 days were typical" and one reported, "I typically use less". When probed on how participants decided on what constitutes "typical use", differences emerged in the specific behaviors considered for their "typical pattern." Four participants mentioned frequency of use, three mentioned quantities consumed (i.e., the response was specific to the amount of cannabis consumed; "do I use essentially the same amount of it on a regular basis or do I have some days that I might have more or less."), and three mentioned route

of administration ("A typical pattern would be, did I use the same sorts of products every day... And that would be to use, dabs, vape concentrate and flower.").

3.9. Follow-up probes

Eight participants completed the CEI on smartphones, and two on personal computers. The only technical issue faced was an outdated internet browser used by one participant. Two participants suggested adding more questions on reasons for cannabis use, particularly for recreational versus medical reasons. One participant included their delta-8 THC use along with their use of "regular" cannabis (delta-9 THC).

4. Discussion

This study's in-depth approach aims to improve the accuracy of

estimates of mg/THC consumed by improving the validity of a novel instrument. Assessing cannabis use quantities in general population samples poses several challenges, but measures for this purpose are necessary to determine the benefits and risks of cannabis use and subsequent efforts for harm reduction. We conducted cognitive interviewing on the first iteration of a self-report instrument designed to quantify cannabis use across several domains: frequency, route of administration, quantity, and potency. The cognitive interviews revealed important strengths as well as items to modify within the survey. Findings indicated high levels of comprehension of survey content, including unanimous comprehension of key cannabis-related terminology (i.e., “methods”, “potency”). However, some participants had trouble with recall and estimation of use frequency and quantity, informing several changes to the survey.

Participants identified several sources of ambiguity. In contrast to another cognitive interviewing study of a cannabis consumption measure (Goodman et al., 2019), some participants did not recognize bottle caps in the images, which were intended to provide a frame of reference on amount of cannabis used. Perhaps the lack of recognition stems from a lack of context (i.e., a bottle cap not accompanied by a bottle) or image quality. These results underscore the importance of using commonly recognizable objects (e.g., quarters for U.S. participants) and high-quality images to serve as visual cues in surveys.

Cannabis consumption patterns can be assessed using different timeframes. Participants generally found it “easy” to report lifetime use and the number of days used in the past 30 days (usually by generalizing from past-week use). Some difficulties emerged with selecting (1) specific days of use days in the past 7 days and (2) the times of day cannabis was used. Daily users and those with a routine pattern could easily report on use days, and the times of day used. Infrequent users (i.e., used one day in the past 7 days) also had an easy time reporting when they used, likely because a less frequent event may be memorable. However, participants who were frequent but nondaily users or who had variations in their use patterns experienced more difficulty with recall. This finding is consistent with results from cognitive interviewing of a nicotine use survey (Hinds et al., 2016) suggesting that recall of irregular but frequent behaviors may be subject to more error in estimation compared to behaviors that follow a specific pattern (Conrad et al., 1998).

Confidence in reporting accuracy for the quantity of cannabis used was related to whether the same total amount of cannabis was used on each day the respondent used cannabis. Greater recall difficulty was reported by participants who did not use the same total amount of cannabis on each use day. These findings, similar to findings about recalling time of use, suggest that greater variation in use patterns may lead to more difficulty in recalling quantity used. However, items assessing past 7-day use patterns were retained in the final survey, since most participants were able to provide their response without experiencing recall difficulty. Surveys that seek to obtain accurate estimates from less frequent users might consider additional prompts to assist with recall. Future studies employing test-retest reliability of user frequency and quantity items will yield information regarding the performance and consistency of these items.

Knowledge of the potency of the cannabis products consumed varied. All participants who were confident that they knew the percentage of THC in the cannabis they used were able to reference the product packaging, indicating the importance of product labeling. However, two participants had disposed of the product label without checking it for information about potency. Generally, greater awareness of product potency is expected from cannabis users with access to labeled packaging, and the inclusion of items assessing potency together with the source of their information on potency will assist in understanding the potential accuracy of item responses. Future surveys may also consider querying respondents on how cannabis was obtained (i.e., from a legal dispensary, or illicitly) to control for potentially greater error or in reporting on use of black-market products. The variation in knowledge surrounding % THC also confirms the importance of including a

confidence metric when assessing potency.

Finally, differences emerged in interpretation of the phrase “typical use pattern”. When considering whether past 7-day cannabis use was generalizable to a longer period of use behaviors, most participants considered either their frequency or quantity of use. This finding suggests that among consistent consumers, a shorter timeframe, such as the past week is informative about longer timeframes. For these participants, surveys may benefit from questioning substance use behaviors over a short timeframe and querying if this pattern can be generalized over longer timeframes to enhance recall. However, a different approach may be needed for atypical or infrequent users.

Cognitive interviews informed several changes that were made to the survey. First, because participants noted that THC infused drinks were missing as a route of administration category, the edibles group was updated to include “drinks”, as in other studies (McClements, 2020; Zipursky et al., 2020). Following feedback about the importance of photos as visual cues, this item was also updated to include more photos of edibles (THC-infused beverages and chocolate bar). Second, because responses indicated that their reporting of the quantity of cannabis used during the past week depended on the route of administration, the quantity reporting preference item (hits, grams, or joints) was updated so that participants could select their quantity reporting preference separately for each route of administration. Similarly, the survey was updated to allow respondents to answer if the same amount was used each day separately for every method of cannabis used in the past 7 days. Third, display issues emerged in both quantity reference photos containing bottle caps. To address comprehension problems, both images were updated to replace the bottle caps with quarters as a size reference. Additionally, the quantity reference image of plant material was updated to include larger reference sizes up to half an ounce. Fourth, when describing what constitutes their “typical pattern” participants brought up various domains of their use behaviors (i.e., frequency, quantity, and route of administration). To remove ambiguity, updated questions defined use pattern to include frequency and amount. Finally, because one participant brought up the inclusion of delta-8 THC use in their survey responses, the first question in the survey was updated to distinguish delta-8 and delta-9 in the definition of cannabis.

Study strengths are noted. First, 24 targeted CEI items were subjected to rigorous assessment of comprehension, recall, judgment, response, and the display of the item. This in-depth method of item evaluation based on recommended procedures (Willis, 2005) enabled identification of potentially unclear aspects of the instrument and provided information about the mental processing used by participants while responding to the survey. Additionally, feedback identified several cannabis products which were not previously considered (i.e., THC-infused beverages and delta-8 products) that may have gone unaddressed without detailed verbal probing. Also, the current study yields rich information concerning participant’s perception of a variety of questions assessing substance use behaviors. As such, the qualitative information collected for this study is not only informing development of the CEI, but also adds to more general knowledge of how participants build their responses about their cannabis use behavior patterns, which can potentially contribute useful information for other surveys assessing cannabis consumption and health behaviors.

Study limitations are noted. First, while ten participants is a standard sample size for cognitive interviewing studies (Willis, 2005), the small sample did not allow for assessment of differences by key sociodemographic groups (e.g., gender, age, race/ethnicity) or other potentially important characteristics. Notably, none of the participants reported quantity of use in joints, leaving those items untested. Further, half the sample were daily users, and most were frequent users, providing little information on how less frequent users comprehend items or recall detailed information about their cannabis habits. Next, while participants were instructed to not consume cannabis for the duration of the interview, we could not account for recall bias related to intoxication-induced impairment. Additionally, because interviews

were conducted remotely, biological confirmation of cannabis use behaviors through saliva or urine toxicology reports was not assessed. The current study limited recruitment to those who used cannabis plant material (via smoking or vaping) or concentrates (via vaping or dabbing). As such, items specific to other routes of administration, such as edible or tincture use, were not probed. Additional cognitive interviews should address these issues to identify potential problems.

5. Conclusion

The current study describes the information gleaned from cognitive interviewing about survey items from a novel instrument used to obtain estimates of daily mg/THC use among persons who use cannabis. As the expansion of retail outlets in legal states contributes to increased accessibility to a variety of product types and routes of administration, accurate, user-friendly tools to provide information on cannabis consumption are crucial to determining the risks and benefits of cannabis exposure at different levels. Cognitive interviewing allowed us to understand the mental processing behind responses to various survey items on cannabis consumption and take steps to refine these items to improve estimation accuracy. While further iterations of testing are needed, the current study represents an important step towards developing low-burden measures of cannabis consumption that can be used in general population samples. Furthermore, findings revealed aspects that were clear, and aspects of perceived difficulty, providing information that can be used to advance development of other surveys that include items about substance use patterns.

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Claire A. Walsh: Writing – original draft, Writing – review & editing, Conceptualization, Methodology. **Cara A. Struble:** Project administration, Methodology, Investigation, Data curation, Writing – review & editing. **Efrat Aharonovich:** Supervision, Methodology, Investigation, Data curation, Writing – review & editing. **Dvora Shmulewitz:** Writing – review & editing. **Jacob Borodovsky:** Methodology, Writing – review & editing. **Mohammad I. Habib:** Data curation, Writing – review & editing. **Alan Budney:** Funding acquisition, Conceptualization, Writing – review & editing. **Ofir Livne:** Writing – review & editing. **Deborah S. Hasin:** Supervision, Funding acquisition, Conceptualization, Writing – review & editing.

Declaration of Competing Interest

Alan Budney has served as a scientific consultant for Canopy Growth, Inc. and Jazz Pharmaceuticals.

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