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Estimated drug use based on direct questioning and open-ended questions: responses in the 2006 National Survey on Drug Use and Health

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Abstract

Substance use surveys may use open-ended items to supplement questions about specific drugs and obtain more exhaustive information on illicit drug use. However these questions are likely to underestimate the prevalence of use of specific drugs. Little is known about the extent of such underestimation or the groups most prone to under-reporting. Using data from the 2006 National Survey on Drug Use and Health (NSDUH), a civilian, non-institutionalized population survey of persons aged 12 or older in the United States, we compared drug use estimates based on open-ended questions with estimates from a new set of direct questions that occurred later in the interview. For these drugs, estimates of lifetime drug use based on open-ended questions often were at least seven times lower than those based on direct questions. Among adults identified in direct questions as substance users, lower educational levels were consistently associated with non-reporting of use in the open-ended questions. Given NSDUH's large annual sample size (~67 000 interviews), combining data across future survey years could increase our understanding of characteristics associated with non-reporting of use in open-ended questions and allow drug use trends to be extrapolated to survey years in which only open-ended question data are available. *Copyright © 2010 John Wiley & Sons, Ltd.*

Introduction

Research estimating the general population prevalence of illicit drug use, including use of illegal drugs or non-medical use of prescription drugs, usually relies on respondent self-reports (e.g. Johnston *et al.*, 2007; SAMHSA, 2007a). Self-administered survey questions have been found to yield higher estimates of illicit drug use and other sensitive behaviours than those produced from data collection modes that require respondents to

report their answers to an interviewer (Aquilino and LoSciuto, 1990; Epstein *et al.*, 2001; Tourangeau and Smith, 1996; Turner *et al.*, 1992).

Furthermore, even a well-designed survey cannot include specific questions about all possible drugs that a respondent might use. To capture information on the use of a more exhaustive set of drugs than are actually listed by name, surveys such as the National Survey on Drug Use and Health (NSDUH) ask respondents about their use of 'any other' drug in a given category of interest (e.g. hallucinogens); respondents are then asked to specify the names of additional drugs in that category that they have used (RTI International, 2005). Such open-ended questions allow researchers to generate estimates of use of drugs in the category as a whole and to identify commonly reported 'other' drugs that might warrant specific questions in later surveys.

When survey respondents answer questions, they go through a cognitive process of interpreting the questions, retrieving the relevant information, using the information they have retrieved to make a judgment, and reporting their answers (Holbrook *et al.*, 2006; Tourangeau and Rasinski, 1988; Tourangeau *et al.*, 2000). Respondents who are asked open-ended questions about their use of other drugs need to interpret what the drug categories mean, retrieve information about other drugs they have used, and determine which other drugs are relevant to the question. Open-ended items also require respondents to translate their answers into a written or typed response.

Thus, open-ended questions about use of other drugs are likely to underestimate the prevalence of use of specific other drugs, even if respondents are willing to answer truthfully. Although this is common wisdom (Kroutil *et al.*, 2006; Wu *et al.*, 2007), little is known about the magnitude of any such underestimation and important correlates of underestimation. For example, age (Holbrook *et al.*, 2006), education (Means *et al.*, 1989), the most recent use of a specific drug (Baddeley, 1979; Hser, 1997; Tourangeau *et al.*, 2000), or the frequency of use of a drug (Hser *et al.*, 1992) could affect reporting of drug use in open-ended questions.

Previous NSDUH methodological research found that adults with less than a high school education were less likely than other adults to enter answers to self-administered open-ended questions (Allred *et al.*, 1997). However, the difference could not be traced to difficulties in typing the answers. There also was little direct evidence that individuals changed their answers to avoid answering open-ended items (Caspar and Couper, 1997).

The 2006 NSDUH offered an opportunity to compare drug use estimates based on open-ended and direct questions. Drug questions early in the survey interview included open-ended items that asked respondents to specify the names of other hallucinogens, stimulants, or sedatives they had used in their lifetime. In a later section of the 2006 interview, respondents were asked direct questions about the stimulant Adderall®, the sedative Ambien®, and hallucinogens: ketamine, the tryptamine hallucinogens DMT (dimethyltryptamine), AMT (alpha-methyltryptamine), or 5-MeO-DIPT (5-methoxy-diisopropyltryptamine), and *Salvia divinorum*. Items about these drugs were added to the 2006 survey because of increasing numbers of mentions of these drugs in response to the open-ended questions.

Because respondents were asked the direct questions for these drugs after they had been asked the open-ended questions, their answers to the direct questions were unlikely to influence how they answered the open-ended questions. Thus, we could quantify the differences between lifetime estimates based on the data from the earlier open-ended questions and estimates based on the direct questions, and to examine factors associated with reporting or non-reporting of use of a drug in response to an open-ended item.

NSDUH is an advantageous survey with which to conduct such an analysis because its large annual sample size enhances the likelihood of encountering reports of these drugs in the open-ended questions. The sample size also facilitates use of multivariate models to identify significant predictors.

We hypothesized that age, educational attainment, recent drug use, socio-economic status (SES), general substance use history, mental conditions such as depression, and interview privacy could affect reporting of drug use in open-ended questions. A history of use of a large number of illicit drugs might facilitate the volunteering of information about use of other drugs in open-ended questions. Conditions such as depression could interfere with the cognitive tasks or burden associated with open-ended drug questions. Complete privacy of interviews was hypothesized to be conducive to more extensive typing of open-ended answers about drug use. NSDUH includes items that can be used to construct measures for each of these characteristics.

Methods

Sample design and data collection

Characteristics of the NSDUH sample design and data collection procedures are described in detail elsewhere (SAMHSA, 2007a). The target population for NSDUH is the civilian, non-institutionalized population aged 12 or

older in the United States, excluding homeless persons who do not use shelters. NSDUH uses a multistage probability sampling design within every State and the District of Columbia to select census blocks, dwelling units, and zero, one, or two eligible persons within a dwelling unit.

The interview averages about an hour and includes interviewer-administered and self-administered questions; questions about drug use and other sensitive behaviours are self-administered. The interview consists of a constant set of core questions critical for basic trend measurement and supplemental questions in the remainder of the interview. Respondents in 2006 were paid $30 for completing the interview.

Nationally, 137 057 addresses were screened for the 2006 survey, and 67 802 completed interviews were obtained from January through December 2006. Weighted response rates for household screening and for interviewing were 90.6% and 74.2%, respectively.

Data processing and coding

Interviewers transmitted the completed interview data via telephone lines to the survey contractor, RTI International (a trade name of Research Triangle Institute), in North Carolina. No personal identifying information was captured in respondents' interview records. Coding of the open-ended drug items was accomplished through a combination of computer-assisted procedures and additional coding and review by analysts (Kroutil and Handley, 2008).

Transmitted cases were retained as final only if respondents provided data on lifetime use of cigarettes and at least nine other substances in the core section of the interview. Missing or ambiguous data (e.g. undefined period of most recent use) in key demographic and drug use variables were statistically imputed (SAMHSA, 2007a). Final analysis weights were developed that took into account the selection probabilities and also were adjusted for non-response, post-stratified to known population control totals, and adjusted when necessary to control for extreme weights (SAMHSA, 2007a).

Measures

This study used standard NSDUH definitions for demographic characteristics, county type, and participation in government assistance programmes (SAMHSA, 2007a). Questions and definitions for major depressive episode (MDE) in the past year were based on the definition in the 4th edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV) (American Psychiatric Association, 1994). NSDUH did not permit missing values for questions about age and gender. Measures of adult education and health insurance coverage were based on statistically imputed data when missing or unknown.

Respondents were defined as users in the open-ended drug questions if they specified use of the drug of interest in the relevant module (e.g. Adderall® specified as some stimulant). Respondents were assumed to be non-users if they did not specify use of the drug of interest.

For measures based on direct questions, respondents were classified as users if they answered the relevant question about lifetime use affirmatively (e.g. for non-medical use of Adderall®). Because missing data were not statistically imputed for these variables, respondents with missing data for lifetime use or non-use of a given drug were classified as non-users.

Dependent variables for logistic regression models were defined as non-reporting of lifetime use of the drug of interest in the relevant open-ended questions, given that respondents had reported lifetime use in the corresponding direct question; dependent variables were defined in terms of non-reporting of use because of larger numbers of respondents who reported lifetime use in the direct questions but not in the open-ended ones. Dependent variables were dichotomous (coded as zero if lifetime use was reported in both the open-ended and direct questions; coded as one if use was reported in the direct question but not in the corresponding open-ended ones). Non-users based on the direct question were coded as missing and were excluded from the models.

Measures of past year use of the drug of interest, the number of other illicit drugs used in the lifetime, and interviewer reports of the privacy of the interview also were defined. Past year use of the drug of interest was derived from a direct question about the most recent use of each of the drugs in this study. The measure of the number of other illicit drugs was based on the count of affirmative lifetime answers for marijuana, any form of cocaine, heroin, six specific hallucinogens, 10 specific inhalants, 21 specific pain relievers, 16 specific tranquilizers, 15 specific stimulants, and 11 specific sedatives. For hallucinogens through sedatives, we did not include reports of use of 'some other drug' in that category in order to exclude mentions of the drugs in the open-ended questions.

Privacy was based on a five-point scale of interviewers' perceptions recorded after the interview had concluded. Our final privacy measure was dichotomous (i.e. completely private versus otherwise).

Analysis

Analyses consisted of computing weighted population prevalence estimates, ratios between weighted prevalence estimates, and estimation of study relationships using logistic regression models. Analyses and tests of statistical significance were performed using SUDAAN® to take into account the sample design (RTI International, 2004). Standard NSDUH criteria were implemented to identify unreliable estimates, which were not reported (SAMHSA, 2007a). The *t* test was used to identify statistically significant differences between percentages.

Confidence intervals (CIs) of the ratios of prevalence estimates were constructed using Fieller's (1940) method. These CIs are asymmetric and assume that the numerator and denominator in the ratio are normally distributed. This assumption would not hold when proportions are too close to zero or one for a fixed sample size; in these latter situations, ratios and associated CIs were not presented.

Covariate-adjusted predictors of non-reporting of drug use (or non-medical use) in the open-ended questions were derived from logistic regression models. Models were run for persons aged 18 or older who reported lifetime use in a drug's direct question; models were restricted to adults to allow educational attainment to be included as a covariate term. We specified separate models for each drug. Logistic regression model results were presented as predicted marginals (PMs) (Graubard and Korn, 1999; RTI International, 2004), or estimates of the proportion of lifetime users (based on direct questions) who would fail to report use in the open-ended questions at each level of the covariate of interest. To protect against inflation of the Type I error rate, we conducted pairwise *t* tests of the PMs between levels of covariates only if the overall Wald *F* test statistic for that covariate was statistically significant ($p < 0.05$).

Results

Unweighted numbers of respondents

As might be expected, larger numbers of respondents reported use (or misuse) of Adderall®, Ambien®, ketamine, specific tryptamines, or *Salvia divinorum* in the direct questions than in the open-ended ones (Table 1); small numbers of respondents (no more than four) specified use or non-medical use of some drugs in the open-ended questions, but not when asked directly. More than 100 respondents each specified use of Adderall®, Ambien®, or *Salvia divinorum* in the relevant open-ended questions. Only small numbers of respondents who were Hispanic or who were in racial/ethnic groups other than White (not Hispanic) reported use in the open-ended questions, including no reports of lifetime use of the specific hallucinogens by black, non-Hispanic respondents.

Comparison of weighted estimates based on open-ended and direct questions

Comparison of weighted population estimates of lifetime drug use/misuse based on open-ended questions and direct questions for persons aged 12 or older and by age group indicated that all reliable estimates that were based on open-ended questions were significantly lower than the estimates based on direct questions (Table 2). The larger sample size for persons aged 12 or older yielded less variability in the ratios comparing open-ended and direct question estimates.

Lifetime estimates based on the direct questions were about seven times greater for Adderall®, the three specific tryptamine hallucinogens, and *Salvia divinorum* compared with estimates based on the open-ended questions. The direct questions on lifetime non-medical use of Ambien® yielded an estimate for this sedative that was about 10 times greater than the corresponding estimate based on the open-ended questions. A wider but more variable difference in estimates between the direct and open-ended questions was observed for ketamine (21.1 times greater for the direct question).

Table 3 compares weighted drug use estimates based on open-ended questions and direct questions for the population aged 18 or older by adult education. Again, all estimates based on open-ended questions were significantly lower than the corresponding estimates based on direct questions, though ratios between the two estimation methods often could not be estimated reliably for ketamine and the tryptamines.

For Ambien®, lifetime estimates of non-medical use based on a direct question were about 10 to 14 times greater than the corresponding estimates from open-ended questions for adults who had graduated from high school or had completed some college and were nearly seven times greater for college graduates. For Adderall® and *Salvia divinorum*, the lowest discrepancy between direct question and open-ended question estimates occurred among adults with some college education (five to six times greater for direct questions than for open-ended questions).

We also examined the weighted percentages of lifetime users who were past year users, based solely on direct questions (data not shown). More than 40% of persons aged 12 or older who were lifetime users (or non-medical

Table 1 Unweighted numbers of persons reporting lifetime use of selected drugs in open-ended and direct questions among National Survey on Drug Use and Health (NSDUH) respondents aged 12 or older, by selected demographic characteristics. Data from the 2006 NSDUH (unweighted sample size, $n = 67802$)

	Drug/source of information									
	Adderall®		Ambien®		Ketamine		AMT, DMT, or 5-MeO-DIPT		*Salvia divinorum*	
Characteristic	Open-ended questions[1]	Direct question[2]	Open-ended questions[1]	Direct question[2]	Open-ended questions[1]	Direct question[2]	Open-ended questions[1]	Direct question[2]	Open-ended questions[1]	Direct question[2]
Total	403	2617	117	1420	44	875	41	306	151	1049
Age in years										
12–17	79	636	13	271	2	63	2	44	31	216
18–25	301	1793	61	728	35	615	30	206	114	769
≥26	23	188	43	421	7	197	9	56	6	64
Gender										
Male	205	1374	45	651	30	521	36	206	126	798
Female	198	1243	72	769	14	354	5	100	25	251
Race/ethnicity										
Not Hispanic										
White	361	2262	99	1153	39	728	39	274	129	887
Black	4	63	1	67	0	14	0	2	0	14
Other or ≥2	16	141	10	72	1	49	1	14	11	68
Hispanic	22	151	7	128	4	84	1	16	11	80
Education[3]										
<High school	39	298	7	182	6	142	5	44	15	134
High school graduate	70	585	26	344	14	282	13	88	31	305
Some college	148	737	35	375	14	283	16	105	59	307
College graduate	67	361	36	248	8	105	5	25	15	87

[1] Based on reports of use (or non-medical use) of the drug of interest in the relevant open-ended questions. Counts include small numbers of respondents who specified non-medical use of Adderall® ($n = 4$), non-medical use of Ambien® ($n = 2$), use of the tryptamine hallucinogens DMT, AMT, or 5-MeO-DIPT ($n = 4$), or *Salvia divinorum* ($n = 3$) in the open-ended questions but not in the corresponding direct questions.

[2] Based on reports of use (or non-medical use) of the drug of interest in the relevant direct questions.

[3] Data for education are shown only for persons aged 18 or older.

Table 2 Comparison of lifetime drug use in open-ended and direct questions for selected drugs among persons aged 12 or older, by age group: Percentages and corresponding 95% confidence intervals (CIs). Data from the 2006 NSDUH (unweighted sample size, $n = 67\,802$)

	Source of lifetime estimate					
	Specified as 'other drug' in relevant open-ended questions		Direct question		Ratio of direct question/open-ended estimates	
Drug/age in years	Percentage	95% CI[1]	Percentage	95% CI[1]	Ratio	95% CI[1]
Adderall®[2]						
≥12 years	0.27	0.24, 0.32	1.91**	1.78, 2.04	7.0	6.1, 8.0
12–17	0.33	0.25, 0.43	2.75**	2.50, 3.03	8.4	6.4, 11.1
18–25	1.40	1.21, 1.62	8.47**	7.90, 9.07	6.0	5.3, 6.9
≥26	0.07	0.04, 0.12	0.65**	0.55, 0.78	9.3	5.4, 15.7
Ambien®[3]						
≥12 years	0.17	0.13, 0.23	1.81**	1.65, 1.98	10.4	7.9, 13.7
12–17	0.06	0.03, 0.10	1.23**	1.06, 1.44	21.8	10.7, 42.7
18–25	0.34	0.25, 0.47	3.62**	3.28, 4.01	10.6	7.7, 14.5
≥26	0.16	0.11, 0.23	1.57**	1.38, 1.78	9.8	6.7, 14.3
Ketamine[4]						
≥12 years	0.04	0.02, 0.08	0.93**	0.82, 1.05	21.1	10.2, 41.9
12–17	0.01	0.00, 0.03	0.33**	0.24, 0.45	–	–, –
18–25	0.18	0.12, 0.28	2.79**	2.51, 3.11	15.3	9.8, 23.8
≥26	0.02	0.01, 0.09	0.68**	0.56, 0.83	–	–, –
AMT, DMT, or 5-MeO-DIPT[4]						
≥12 years	0.04	0.03, 0.06	0.28**	0.23, 0.33	7.2	4.7, 10.8
12–17	–	–, –	0.18**	0.12, 0.27	NA	NA, NA
18–25	0.16	0.10, 0.25	0.94**	0.78, 1.13	5.9	3.9, 8.9
≥26	0.02	0.01, 0.05	0.18**	0.13, 0.24	7.8	2.7, 18.6
Salvia divinorum[4]						
≥12 years	0.10	0.08, 0.13	0.73**	0.66, 0.81	7.3	5.8, 9.2
12–17	0.16	0.10, 0.25	0.90**	0.75, 1.07	5.7	3.7, 9.0
18–25	0.50	0.39, 0.66	3.62**	3.27, 4.00	7.2	5.6, 9.2
≥26	0.02	0.01, 0.06	0.21**	0.15, 0.28	9.2	1.8, 28.7

Note: These estimates are based on different methods of assessing the same measures from the same respondents from the 2006 National Survey on Drug Use and Health (NSDUH). Due to the high within-subject correlation between these estimates and the large sample size, even a small difference between estimates may be statistically significant. NA, not applicable; –, low precision; no estimate/ratio reported.

* Difference between this estimate and the estimate based on the responses from the open-ended questions is statistically significant at the 0.05 level.

** Difference between this estimate and the estimate based on the responses from the open-ended questions is statistically significant at the 0.01 level.

[1] Ninety-five per cent CI of the estimate or ratio.

[2] Estimates for Adderall® from open-ended questions were based on reports of non-medical use of Adderall® or Adderall® XR as 'some other stimulant'.

[3] Estimates for Ambien® from open-ended questions were based on reports of non-medical use of Ambien® or Ambien® CR as 'some other sedative'.

[4] Estimates for ketamine, alpha-methyltryptamine (AMT), dimethyltryptamine (DMT), 5-methoxy-diisopropyltryptamine (5-MeO-DIPT), and *Salvia divinorum* from open-ended questions were based on reports of use of these drugs as 'some other hallucinogen'.

Table 3 Comparison of lifetime drug use in open-ended and direct questions for selected drugs among adults aged 18 or older, by education: percentages and corresponding 95% confidence intervals (CIs). Data from the 2006 NSDUH (unweighted sample size, $n = 67\,802$)

	Source of lifetime estimate					
	Specified as 'other drug' in relevant open-ended questions		Direct question		Ratio of direct question/open-ended estimates	
Drug/education	Percentage	95% CI[1]	Percentage	95% CI[1]	Ratio	95% CI[1]
Adderall®[2]						
≥18 years	0.27	0.23, 0.31	1.81**	1.67, 1.96	6.8	5.8, 7.9
<High school	0.19	0.13, 0.28	1.44**	1.22, 1.70	7.7	5.1, 11.4
High school graduate	0.15	0.10, 0.22	1.52**	1.34, 1.73	10.1	6.9, 14.7
Some college	0.49	0.38, 0.62	2.50**	2.21, 2.83	5.1	4.1, 6.4
College graduate	0.25	0.17, 0.35	1.73**	1.46, 2.05	7.1	4.9, 10.0
Ambien®[3]						
≥18 years	0.19	0.14, 0.25	1.87**	1.70, 2.06	10.0	7.5, 13.3
<High school	0.05	0.02, 0.11	1.35**	1.04, 1.75	29.3	5.3, 91.0
High school graduate	0.16	0.09, 0.28	1.54**	1.31, 1.81	9.6	5.2, 17.3
Some college	0.18	0.10, 0.31	2.37**	2.01, 2.81	13.6	7.2, 24.7
College graduate	0.31	0.20, 0.49	2.11**	1.76, 2.52	6.7	4.3, 10.4
Ketamine[4]						
≥18 years	0.05	0.03, 0.09	0.99**	0.87, 1.13	20.6	9.8, 41.4
<High school	0.02	0.01, 0.05	0.80**	0.60, 1.05	37.2	4.7, 124.0
High school graduate	0.03	0.01, 0.05	0.99**	0.78, 1.25	38.3	15.2, 83.8
Some college	0.07	0.04, 0.14	1.46**	1.20, 1.77	20.7	8.8, 44.4
College graduate	0.07	0.02, 0.30	0.70**	0.51, 0.94	–	–, –
AMT, DMT, or 5-MeO-DIPT[4]						
≥18 years	0.04	0.03, 0.07	0.29**	0.24, 0.35	6.7	4.4, 10.1
<High school	0.03	0.01, 0.09	0.24**	0.16, 0.38	–	–, –
High school graduate	0.04	0.02, 0.09	0.27**	0.20, 0.38	6.3	2.6, 13.7
Some college	0.06	0.03, 0.11	0.52**	0.39, 0.69	8.8	4.3, 16.4
College graduate	0.03	0.01, 0.12	0.13**	0.07, 0.23	–	–, –
Salvia divinorum[4]						
≥18 years	0.09	0.07, 0.12	0.71**	0.64, 0.80	7.6	5.9, 9.9
<High school	0.05	0.03, 0.10	0.75**	0.58, 0.98	14.8	6.2, 31.4
High school graduate	0.08	0.05, 0.14	0.72**	0.61, 0.84	8.6	5.0, 14.9
Some college	0.18	0.13, 0.26	1.04**	0.88, 1.23	5.8	4.2, 8.1
College graduate	0.05	0.02, 0.13	0.38**	0.28, 0.52	7.1	1.9, 19.8

Note: These estimates are based on different methods of assessing the same measures from the same respondents from the 2006 National Survey on Drug Use and Health (NSDUH). Due to the high within-subject correlation between these estimates and the large sample size, even a small difference between estimates may be statistically significant. NA, not applicable; –, low precision; no estimate/ratio reported.

*Difference between this estimate and the estimate based on the responses from the open-ended questions is statistically significant at the 0.05 level.

**Difference between this estimate and the estimate based on the responses from the open-ended questions is statistically significant at the 0.01 level.

[1] Ninety-five per cent CI of the estimate or ratio.

[2] Estimates for Adderall® from open-ended questions were based on reports of non-medical use of Adderall® or Adderall® XR as 'some other stimulant'.

[3] Estimates for Ambien® from open-ended questions were based on reports of non-medical use of Ambien® or Ambien® CR as 'some other sedative'.

[4] Estimates for ketamine, alpha-methyltryptamine (AMT), dimethyltryptamine (DMT), 5-methoxy-diisopropyltryptamine (5-MeO-DIPT), and *Salvia divinorum* from open-ended questions were based on reports of use of these drugs as 'some other hallucinogen'.

users) of Adderall®, Ambien®, and *Salvia divinorum* also were past year users. Only 15% of lifetime users of DMT, AMT, or 5-MeO-DIPT and 9% of lifetime users of ketamine who were aged 12 or older were past year users of these drugs.

Covariate-adjusted predictors of non-response in open-ended questions

Table 4 presents PMs for statistically significant covariates ($p < 0.05$) associated with non-reporting of drug use in open-ended questions. Data are not shown for the tryptamine model because none of the covariates in that model was significantly associated with non-reporting. The percentage of variation in non-reporting explained by these models ranged from 6% for the Adderall® model to 13% for the ketamine and *Salvia divinorum* models, based on the maximum rescaled R^2 of Nagelkerke (1991).

Overall, the PMs from the logistic regression models indicated high probabilities of non-reporting in the open-ended questions, even for statistically significant covariates. For Adderall®, Ambien®, and *Salvia divinorum*, non-reporting in the open-ended questions was predicted to be less likely among lifetime users (based on the direct questions) who completed certain higher levels of education compared with users who completed certain lower levels of education. For Adderall® and *Salvia divinorum*, adult users who had some college education were less likely to be non-reporters in the open-ended questions compared with those who were high school graduates (for Adderall®) or had not finished high school (for *Salvia divinorum*). For Ambien®, adult users who were college graduates were less likely than those who had not finished high school to be non-reporters in the open-ended sedative questions.

Lower levels of interview privacy were associated with higher levels of non-reporting of non-medical Adderall® use. In other significant effects, lifetime non-medical Adderall® users who were likely to have had an MDE in the past year were less likely than users without a past year MDE to be non-reporters of Adderall® use in the open-ended questions. For ketamine, lifetime users who had health insurance coverage were less likely to be non-reporters compared with users who had no coverage. For *Salvia divinorum*, non-reporting also was associated with gender (less likely among males), county type (less likely among users in small metropolitan areas versus those in large metropolitan areas), and household participation in government assistance programmes (less likely among users in households that were not receiving government benefits).

However, these subgroups of adults also tended to have higher prevalences of past year use of these drugs (for all adults based on direct questions). For example, adults who had completed some college were more likely than adults who had completed other levels of education to be past year non-medical users of Adderall® ($p < 0.0001$ for all pairwise comparisons; data not shown). Adults with a past year MDE also were nearly three times more likely than those without a past year MDE to be past year non-medical users of Adderall® (1.7% versus 0.6%; $p < 0.0001$), and the rate of past year non-medical Adderall® use among adults in interview settings that were rated as completely private was greater than the rate among adults in less than private settings (0.7% versus 0.6%; $p < 0.05$). Rates of past year use of *Salvia divinorum* were five times higher among adult males than among adult females (0.5% versus 0.1%; $p < 0.0001$).

Therefore, we investigated whether some of the statistically significant relationships that were noted earlier might be explained by past year use (based on direct questions). However, past year use was not associated with non-reporting of use in any of the models; this covariate also created singularity problems in the ketamine and tryptamine models and problems with degrees of freedom in the tryptamine model. The lack of significance for past year use also could not be explained by collinearity. Correlations (based on Pearson's r) between past year use and the other covariates in the models were small ($-0.15 < r < 0.14$). The largest correlation (between education and household receipt of benefits in the *Salvia divinorum* model) was less than 0.34.

Discussion

Substance use surveys may use open-ended questions to capture more exhaustive information about drugs that people are using (or misusing). Although open-ended questions can be useful tools for evaluating respondent understanding of drug use questions or developing new substance use questions, this study's findings underscore the limitations of open-ended questions for estimating the prevalence of use of specific drugs. We found considerable underestimation of drug use through open-ended questions compared with estimates based on direct questioning. Although it would seem evident that open-ended questions will underestimate the prevalence of behaviours of interest, this study quantifies the extent of the underestimation for a specific set of drugs. For the drugs that were investigated, most of the lifetime drug use estimates for persons aged 12 or older and for adults aged 18 or older that were based on open-ended questions were at

Table 4 Covariate-adjusted predicted marginals for non-reporting of selected drugs among adults aged 18 or older. Data from the 2006 NSDUH (unweighted sample size, $n = 67\,802$)

	Drug							
	Adderall®		Ambien®		Ketamine		*Salvia divinorum*	
Covariate	PM[1]	95% CI[1]	PM	95% CI[1]	PM	95% CI[1]	PM	95% CI[1]
Gender								
Male	–	–	–	–	–	–	0.860	0.818, 0.894
Female	–	–	–	–	–	–	0.935	0.879, 0.967
Education								
<High school	0.869	0.803, 0.915	0.964	0.909, 0.987	–	–	0.922	0.859, 0.958
High school graduate	0.904	0.863, 0.933	0.907	0.839, 0.947	–	–	0.911	0.860, 0.944
Some college	0.816	0.768, 0.857	0.926	0.873, 0.958	–	–	0.835	0.776, 0.881
College graduate	0.850	0.798, 0.890	0.858	0.791, 0.907	–	–	0.845	0.704, 0.925
County type								
Large metropolitan area	–	–	–	–	–	–	0.908	0.866, 0.938
Small metropolitan area	–	–	–	–	–	–	0.831	0.762, 0.882
Non-metropolitan area	–	–	–	–	–	–	0.831	0.712, 0.907
Participation in government assistance programmes[2]								
Yes	–	–	–	–	–	–	0.971	0.901, 0.992
No	–	–	–	–	–	–	0.864	0.826, 0.895
Health insurance coverage								
Any	–	–	–	–	0.936	0.889, 0.964	–	–
None	–	–	–	–	0.977	0.951, 0.989	–	–
Major depressive episode, past year								
Yes	0.747	0.648, 0.826	–	–	–	–	–	–
No	0.871	0.847, 0.891	–	–	–	–	–	–
Privacy of interview[3]								
Completely private	0.846	0.820, 0.869	–	–	–	–	–	–
Less than completely private	0.916	0.871, 0.946	–	–	–	–	–	–

Note: Dependent variables were based on persons who reported lifetime use/misuse in the direct question but did not specify use/misuse in the open-ended questions in the relevant drug module. Only statistically significant predictors ($p < 0.05$) are shown. Adult age group (18–25 and ≥26) and numbers of other illicit drugs that were used in the lifetime (0–9, 10–19, and ≥20) also were included as covariates in all models. –, Not a significant covariate in that drug's model (at $p < 0.05$).

[1] PM, predicted marginal; 95% CI, 95% confidence interval of the PM.

[2] Defined as one or more household family members having received any of the following during the prior calendar year: Supplemental Security Income (SSI), food stamps, cash assistance due to low income [e.g. Temporary Assistance for Needy Families (TANF), welfare, or public assistance], or non-cash assistance due to low income (e.g. help getting a job, placement in an education or job training programme, or help with transportation, child care, or housing).

[3] Based on interviewers' perceptions. Completely private = no one else present or listening to the interview; less than completely private = minor distractions or persons present or listening one third of the time or more.

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least seven times lower than the corresponding estimates based on direct questions.

This impact on prevalence estimates may be even more notable for estimates of the numbers of people who have ever used a drug. For example, the estimated 0.3% of people aged 12 or older who had ever used Adderall® non-medically based on open-ended questions (Table 2) translates to slightly fewer than 700 000 persons. The estimate of 1.9% based on the direct question translates to ~4.7 million persons.

These findings also do not suggest that analysts can get reasonable estimates of the likely population prevalence of a drug of interest from open-ended data simply by multiplying the estimated prevalence from open-ended questions by a factor of seven. For drugs such as ketamine, estimates based on open-ended questions could be lower than those based on direct questions by a factor of 20 or more. In addition, data from open-ended questions could more seriously underestimate the likely population prevalence among certain demographic subgroups. Thus, simple assumptions cannot be readily applied across the board to infer the likely prevalence of use of specific drugs based only on data from open-ended questions. However, clearer patterns may emerge if NSDUH data for these drugs are compared and averaged across multiple years.

In logistic regression models among adult lifetime users, education was the covariate that was most consistently associated with non-reporting of use in the open-ended questions and was generally in the expected direction, with lifetime users having lower levels of education tending to be more likely to be non-reporters in the open-ended questions compared with users who had completed more education. However, the likelihood of non-reporting did not show a pattern of steady declines with increasing levels of education.

Nevertheless, these findings are consistent with earlier NSDUH methodological research (Allred *et al.*, 1997), suggesting that adults with lower levels of education will be less likely than those with higher levels to enter answers to self-administered open-ended questions. Although we do not know the exact reasons for non-reporting in the open-ended questions (e.g. cognitive difficulties; problems with reading, spelling, or typing; increased comfort level with the nature of the questions), our findings substantiate the challenges that open-ended drug questions may present for substance users with lower education levels.

For ketamine and *Salvia divinorum*, the likelihood of non-reporting in the direct questions also was associated with potential indicators of lower SES (receipt of government assistance in the *Salvia divinorum* model and lack of health insurance in the ketamine model). The finding for ketamine also was independent of any relationship between younger adult age groups and lack of insurance coverage (DeNavas-Walt *et al.*, 2007).

An alternative explanation for some of the subgroups in which non-reporting in the open-ended questions was less likely is that past year use was more prevalent in these groups. Hence, use of these drugs may be more salient for these past year users. However, this hypothesis was not supported in any of the models that we ran with past year use as a covariate.

Nevertheless, our finding of no significant relationships between past year use and non-reporting in the open-ended questions does not rule out the possibility of confounding between covariates and outcome variables due to other factors that were not included in the models, including measures that were not captured in NSDUH. For example, the 2006 NSDUH did not collect information on the frequency of use of these specific drugs in the lifetime or past 12 months. Frequent users may be more likely than less frequent users of these drugs to recall their use when presented with open-ended questions. Thus, we cannot rule out the possibility that some of the relationships observed in the models may be explained by associations between frequent use and other characteristics, such as gender.

In addition, the relatively low proportions of variation explained by the covariates in the models suggest that NSDUH may not contain measures of important predictors of non-reporting of use in open-ended drug use questions. However, these low R^2 values are not atypical for models in which the outcome variables have a relatively low prevalence and only a limited number of covariates are included (Gfroerer *et al.*, 2003).

Further research to identify measures that explain more of the variation in non-reporting of drug use in open-ended questions may be helpful for survey researchers, social scientists, and epidemiologists in understanding the data obtained from these types of questions, such as whether these items tend to capture information from frequent users or persons who recently initiated use. However, including additional items in NSDUH, such as for frequency of use or first use, would need to be considered relative to the requirements for keeping the average respondent burden at approximately one hour.

Some findings from these models also warrant further investigation. In particular, the prediction that approximately one-fourth of adult non-medical Adderall® users with a past year MDE would be predicted to report

Adderall® use in the open-ended stimulant questions (versus ~13% of users without a past year MDE) could be related to the stimulant properties of this drug. Thus, further research might examine whether certain subgroups of people with MDE are misusing Adderall® or other similar prescription stimulants to self-medicate their depression.

The number of other drugs that respondents had ever used in their lifetime did not appear to be a significant predictor of non-reporting. Any increased likelihood of users of multiple drugs to report the use of other drugs in open-ended questions may be counterbalanced by the amount of stored information about other drug use that these respondents would need to retrieve and process to answer the open-ended questions, thereby interfering with their ability to provide information about their use of specific other drugs of interest (Baddeley, 1979; Tourangeau *et al.*, 2000).

Information on these correlates of non-reporting could be investigated further as NSDUH data become available for future years for these direct questions and open-ended items. Combining data from multiple survey years would increase the power of the models to identify additional significant covariates and allow the inclusion of additional covariates in the models, such as race/ethnicity, while still maintaining adequate degrees of freedom.

Additional data from future surveys also could have application in extrapolating the potential trends in prevalence for these drugs prior to the introduction of direct questions in the survey. With multiple data points for estimates based on both the open-ended and direct questions, it would be possible to assess whether the ratio between open-ended and direct question estimates is constant from year to year; if this condition holds, various adjustment procedures could be considered for simulating the trends in prevalence for these drugs prior to 2006. Additional data from future modelling activities could be applied to these extrapolations to determine the levels of adjustment that should be made to open-ended question data from users in different demographic subgroups.

Strengths of this study include the use of a large, national probability sample (~67 000 completed interviews) with a respectable response rate, and the use of well-developed procedures for sampling, data collection, coding, data processing and weighting. In addition, the survey instrument design featured a stable 'core' drug use section (where the open-ended drug use questions occurred that were used in this study), followed by supplementary questions (including direct questions about the drugs of interest).

A key study assumption was that this core/non-core design would ensure that respondents' exposure to direct questions would not influence their answers to open-ended questions. Although respondents in principle could go back and change an answer to a previous open-ended item, doing so would be time-consuming; they would need to back up one question at a time to change their answers. Lifetime trends for hallucinogens, stimulants, and sedatives between 2005 (without the direct questions) and 2006 also were stable (SAMHSA, 2007b), suggesting minimal effects on estimates due to any respondents in 2006 who revised earlier open-ended items based on any stimuli provided by the direct questions.

Further, NSDUH has a long history of methodological research to identify and quantify survey errors, improve the validity of drug use data, guide redesign efforts, and improve the efficiency of the survey procedures (Gfroerer *et al.*, 2002; Harrison *et al.*, 2007; Kennet and Gfroerer, 2005; SAMHSA, 2001, 2006; Turner *et al.*, 1992). Together, these procedures and the history of methodological investigation that went into their development support the validity of this study's findings.

As in most surveys of sensitive behaviours, a design limitation is that drug use estimates are based solely on respondent self-reports. However, respondents could answer drug use questions privately, and those with limited reading ability could listen to recordings of the questions. Despite the large overall sample size, an additional limitation concerned the small numbers of reports of some drug use in open-ended questions or within certain demographic subgroups. As noted previously, combining data from multiple years would further increase the statistical power to detect differences or allow the inclusion of additional covariates. A third limitation was that data from the open-ended drug use questions were limited to the lifetime period. Consequently, one cannot make reliable inferences about more recent use of these drugs based solely on the open-ended data.

Information on past year and past month use will be available from direct questions in the 2006 NSDUH and future years that could be used in combination with open-ended question data to overcome this third limitation. Specifically, direct question data from 2006 and subsequent years can be used to examine the relative proportions of lifetime users who are past year or past month users, overall and by selected demographic characteristics. If these proportions are stable over time, this information could be used in combination with other extrapolation procedures mentioned earlier for open-ended question data prior to 2006 to make inferences

about the proportions of lifetime users in these earlier survey years who would be more recent users.

Conclusions

This study offers quantitative information to support the conventional wisdom that data from open-ended questions will considerably underestimate the prevalence of use of specific drugs compared with data from direct questioning. For the drugs that were investigated, estimates of lifetime drug use based on open-ended questions often were seven to 10 times lower than the corresponding estimates based on direct questions, and in some instances, the estimates based on open-ended questions were 20 or more times lower than those based on direct questions. For some drugs, these differences can represent millions of persons who would not be estimated to be users based on open-ended questions. Among adults, educational level was a consistent predictor of whether lifetime users (based on direct questions) would report use of the same drug in the open-ended questions, with non-reporting in the open-ended questions being more likely among users in lower educational groups compared with users who had completed more education. For adult users of some hallucinogens, the failure to report use in the open-ended questions also was associated with indicators of lower SES.

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Declaration of interest statement

The authors have no competing interests.

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Appendix

Fieller's confidence interval for the ratio of two proportions

Suppose that p_1 and p_2 represent estimates of two proportions of interest, and we define the ratio between these two estimated proportions as: $R = p_1/p_2$. Then Fieller's (1940) exact asymmetric $100(1 - \alpha)\%$ confidence interval (CI) around R is as follows:

$$\mathrm{UCL} = \frac{R - g\frac{v_{12}}{v_{22}} + \frac{t_{\alpha/2,df}}{p_2} \times \sqrt{v_{11} - 2Rv_{12} + R^2 v_{22} - g\left(v_{11} - \frac{v_{12}^2}{v_{22}}\right)}}{1-g},$$

$$\mathrm{LCL} = \frac{R - g\frac{v_{12}}{v_{22}} - \frac{t_{\alpha/2,df}}{p_2} \times \sqrt{v_{11} - 2Rv_{12} + R^2 v_{22} - g\left(v_{11} - \frac{v_{12}^2}{v_{22}}\right)}}{1-g},$$

where UCL and LCL represent the upper and lower limits of the CI, respectively, $v_{11} = \mathrm{var}(p_1)$, $v_{22} = \mathrm{var}(p_2)$, $v_{12} = \mathrm{cov}(p_1, p_2)$, $g = t^2_{\alpha/2,df} v_{22}/p_2^2$, and $t_{\alpha/2,df}$ represent the $100(1 - \alpha/2)$ percentile of the t distribution at df denominator degrees of freedom and significance level α.

Fieller's CI is exact in cases where the two estimators in the ratio have a bivariate normal distribution. In this case, the estimators in the ratio are proportions, which have binomial distributions. However, if the sample size is reasonably large, then the proportions also are approximately normally distributed. Hence, Fieller's CI of a ratio of those proportions will be reasonably approximate.