Application of randomized response techniques for investigating cannabis use by Spanish university students

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Abstract

Cannabis is the most widely used illicit drug in developed countries, and has a significant impact on mental and physical health in the general population. Although the evaluation of levels of substance use is difficult, a method such as the randomized response technique (RRT), which includes both a personal component and an assurance of confidentiality, provides a combination which can achieve a considerable degree of accuracy. Various RRT surveys have been conducted to measure the prevalence of drug use, but to date no studies have been made of the effectiveness of this approach in surveys with respect to quantitative variables related to drug use.

This paper describes a probabilistic, stratified sample of 1146 university students asking sensitive quantitative questions about cannabis use in Spanish universities, conducted using the RRT.

On comparing the results of the direct question (DQ) survey and those of the randomized response (RR) survey, we find that the number of cannabis cigarettes consumed during the past year (DQ = 3, RR = 17 approximately), and the number of days when consumption took place (DQ = 1, RR = 7) are much higher with RRT.

The advantages of RRT, reported previously and corroborated in our study, make it a useful method for investigating cannabis use. Copyright © 2016 John Wiley & Sons, Ltd.

Introduction

Cannabis (or marijuana) is the illicit drug that is most commonly used by young adults in Spain. On average, it is consumed by nearly 17% of the European Union

(EU) population aged 15–34 years (EMCDDA, 2015; PNSD, 2013). The prevalence of past 30-day use from 1999 to 2013 for all groups and both sexes was 22.5%. Although young males have historically had a higher

prevalence of marijuana use, current results indicate that male–female differences in marijuana use are decreasing (Johnson *et al.*, 2015). Cannabis is often used for its mental and physical effects, such as heightened mood and relaxation, and it has been cited in the medical literature as a potential secondary treatment agent for severe pain, muscle spasticity, anorexia, nausea, sleep disturbances and numerous other conditions (Lamarine, 2012). However, the Spanish National Plan on Drugs (PNSD, 2013) has called for a change in the approach taken to understanding this phenomenon, especially as regards how young people, influenced by subcultural networks, become regular cannabis users. Patterns of consumption should be analysed so that appropriate intervention and prevention programmes can be designed.

Health care and social problems related to the use of cannabis have led researchers to investigate screening procedures aimed at detecting persons at risk. Two such procedures, which are now commonly used, are the Cannabis Abuse Screening Test (CAST; Cuenca-Royo *et al.*, 2012), in which response options are based on a five-point Likert scale (never, rarely, occasionally, quite often and very often) and the cannabis Severity of Dependence Scale (SDS; Cuenca-Royo *et al.*, 2012), with response options based on a four-point Likert scale (never, rarely, often and always). These screening instruments are capable of detecting (probable) cannabis dependence or problematic use and have been used in Spain in surveys for the National Plan on Drugs in schools and among the general population (Cuenca-Royo *et al.*, 2012). The application of short screening scales to assess dependence and other problems related to the use of cannabis presents a time and cost-saving means of estimating the overall prevalence of cannabis use and of related negative consequences (Bastiani *et al.*, 2013; Gyepesi *et al.*, 2014; Hides *et al.*, 2007; Legleye *et al.*, 2013). These instruments can also help identify persons at risk, as an initial approach before using more extensive diagnostic instruments. Nevertheless, there is a need to formally evaluate the validity of the data gathered (Piontek *et al.*, 2008). Studies by Harrison (1997) and Ramo *et al.* (2012) have evaluated the reliability and validity of anonymous studies of cannabis use, but these reports do not examine the other side of validity, namely the fact that respondents may lie, when faced with a question that they find embarrassing, or refuse to answer, or choose a response that prevents them from having to continue and, clearly, this situation may arise in questionnaires related to the use of illegal drugs. Other potential threats to survey accuracy are non-response and reporting error (Tourangeau and Yan, 2007).

The aim of the randomized response technique (RRT) is to decrease social desirability bias, thus guaranteeing

confidentiality, improving respondent cooperation and procuring reliable estimates. This technique obtains stronger estimates of sensitive characteristics, compared to the direct question (DQ) survey, by reducing respondents' motivation to falsely report their attitudes.

The RRT was introduced by Warner in 1965. The procedure is as follows, to estimate for a community the proportion of people bearing a stigmatizing characteristic (denoted by the symbol A), like addiction to marijuana consumption, a sampled person is offered a box of a considerable number of identical cards with a proportion p ($0 < p < 1$, $p \neq 0.5$) of them marked A and the rest marked A^c . The person on request is required to draw a “random” card and respond by answering “Yes” for a “match” between the card type and the person's own real characteristic or a “No” for a “non-match” before returning the card to the box.

The randomization is performed by the interviewee, and the interviewer is not permitted to observe the outcome of the randomization. The interviewee responds to the question selected by the randomization device, and the interviewer knows only the response provided. The respondent's privacy or anonymity is fully protected because no one but the respondent knows which question was answered. But it is possible statistically to derive a plausible estimate, on analysing the bunch of randomized responses thus collectively gathered, for the required proportion bearing A . It is hoped that the privacy of the person responding is securely protected.

It is assumed that respondents are more willing to provide honest answers with this technique because their answers do not reveal any information about themselves.

Some studies have addressed situations in which the response to a sensitive question results in a quantitative variable. Thus, Greenberg *et al.* (1971) extended RR to this case, rather than a simple Yes or No. Other important work in this respect includes Bar-Lev *et al.* (2004); Bouza (2009); Diana and Perri (2010, 2012); Eichhorn and Hayre (1983); Saha (2007); Gjestvang and Singh (2006, 2007) and Odumade and Singh (2010). These authors concur that the RRT is an effective means of obtaining estimates with a relatively high degree of reliability. However, most studies concern only simple random sampling, while most of the surveys conducted in practice are complex, involving stratification, clustering and unequal probability in the sample selection.

The RRT was developed in an attempt to improve the quality of self-reported survey research, but it is not very often applied in the educational or psychological context (Dietz *et al.*, 2013; Goodstadt and Gruson, 1975; Pitsch *et al.*, 2007; Striegel *et al.*, 2009; Weissman *et al.*, 1986).

Specifically, Goodstadt and Gruson (1975) compared 854 students' responses concerning drug use, derived from either traditional direct questioning or an indirect, more anonymous method of inquiry, the RR procedure. The results obtained in this study showed that the RR procedure produced significantly fewer response refusals and significantly higher drug use estimates, thus supporting the hypothesized greater sensitivity and validity of the RR procedure. Weissman *et al.* (1986) examined whether telephone interviewing could be a viable alternative to field interviewing as a method for eliciting drug use information. Pitsch *et al.* (2007) used the RRT to examine whether the use of performance-assisting doping was prevalent in certain professional sports. Striegel *et al.* (2009) estimated the prevalence of doping and illicit drug abuse among athletes. In this study, the subjects were either asked to complete an anonymous standardized questionnaire or were interviewed using the RRT. According to this analysis, doping tests produce 0.81% positive test results, but the RRT shows that the real prevalence is 6.8%. In another study, Dietz *et al.* (2013) calculated the prevalence of students who take drugs in order to improve their cognitive performance, and reported that 20% used cognitive-

enhancing drugs. The authors concluded that the RRT revealed a high 12-month prevalence of cognitive-enhancing drug use by university students and suggested that other direct survey techniques may underestimate the use of these drugs. Kerkvliet (1994) combines RRTs with logit models. The academic performance of college students, their personal habits and socio-economic characteristics are used to estimate a logit model for predicting whether or not they have consumed cocaine.

Surveys based on the RRT are widely used when the questions are sensitive, and especially when the variable of interest is a qualitative one. Techniques also exist for quantitative variables, but these are not used as commonly. In our study, conducted in Spain (where RRTs are not generally used for studies of drug consumption), we took into account quantitative variables in order to make the scope of the study as complete as possible.

Methods

To investigate cannabis use in the Spanish universities, we conducted a survey of university students.

Figure 1. “Baraja Española” app.

Figure 2. card from deck.

Participants and sampling method

The target population for this survey included students at the University of Granada and the University of Murcia. Subjects were selected using probabilistic sampling stratified by university. Respondents were randomly selected to use the RRT (sub-sample 1) and to be asked directly about illicit drug use (sub-sample 2). We determinate the sample size to estimate the population mean in stratified sampling with a coefficient of variation of 0.25. We used a pilot sample to estimate the unit relvariances.

One thousand one hundred and forty-six student participants voluntarily responded to a questionnaire. All questionnaires were administered during the class time break. All students were invited to participate in a study and provided informed signed consent.

Procedure and measure

The questionnaire is the same in two sub-samples. This questionnaire began with some academic questions followed by a set of basic demographic questions and then a block containing the sensitive questions, referring to drug use (taken from the questionnaire proposed by Miller and Rollnick, 2015).

The following sensitive questions were asked:

- P1: How many cannabis cigarettes did you consume last year?
- P2: Over the past 90 days, how many days did you consume cannabis?

In sub-sample 1 (using RRT), for the block of sensitive questions, the interviewer explained how the survey was

being conducted, and gave an example of its use. The responses were randomized using a generalization of the model proposed by Bar-Lev *et al.* (2004) for simple random sampling and later extended by Arcos *et al.* (2015) for use with complex samples.

The randomizing device used was the app “Baraja Española” (“Baraja Española” is a deck composed of 40 cards, divided into four families or suits, each numbered one to seven and three figures) (Play Store, 2015), which had previously been installed on the student’s phone (see Figures 1 and 2). The application is very simple to use: for each sensitive question the user touches the screen and a card is shown. If it is a face card, the sensitive question (P1, P2) should be answered; otherwise, the real number should be given, multiplied by the number shown on the card.

Figure 3 shows the procedure of response for the two sub-samples.

The interviewer explained that this technique preserved the students’ anonymity with the aim not to provoke mistrust of them. The data collection and fieldwork was conducted by the research group FQM365 of the Andalusian Research Plan. The interviews were carried out during 2015, in Spain. Data were obtained from 654 students using the RRT and from 492 using DQ.

Response rates

Table 1 shows the non-response rates for the questions for the full sample and for the sample separated by gender considering DQ response and RR.

The non-response rate for the question was lower in the RR than in the DQ condition. These differences are

Figure 3. Procedure of response for the two sub-samples.

Table 1. Non-response rates

	DQ	RR
P1: units	010975610	005810398
P2: days	012601626	001834862
<i>Men</i>		
P1: units	030331754	008088235
P2: days	032227488	003676471
<i>Women</i>		
P1: units	024199288	004188482
P2: days	025622775	000523560

statistically significant (p -value < 0.001). However, the non-response rate between men and women is similar and therefore not significant statistically (p -value > 0.05).

Statistical analysis

Inference is used in survey sampling to estimate the parameters of interest. The Horvitz–Thompson estimator (Singh, 2003) was used to estimate the mean values for the direct questions.

We use the unified method of estimating population surveys characteristic in RR proposed by Arnab (1994). For each unit in the sample the RR induces a random response (denoted scrambled response) and we can obtain a certain transformation of these scrambled responses that is an unbiased estimation of the population mean [see Arnab (1994) or Arcos *et al.* (2015) for a detailed description].

Software

Standard software packages for complex surveys cannot be used directly when the sample is obtained using RRTs. Although analyses with standard statistical software, with certain modifications in the randomized variables, can yield correct point estimates of population parameters

they could still yield incorrect results for the standard errors estimated.

R-packages have been developed for estimation with RR surveys, such as the RRreg package (Heck and Moshagen, 2014) and the rr package (Blair *et al.*, 2015) but the methods implemented in these packages assume simple random sampling. Therefore, we used the package RRTCS (Rueda *et al.*, 2015), which is the only one that incorporates estimation procedures for handling RR data obtained from complex surveys.

In this package, the function BarLev() (see Appendix) implements the BarLev model.

Results

The socio-demographic distribution of the samples is shown in Table 2.

The study was conducted for all students and also separating respondents by gender.

In DQ, the survey had a population of 492 individuals, of whom 42.89% were men and 57.11% were women. In RR, the study population was composed of 654 students, with 41.59% men and 58.41% women.

The point estimates of the sensitive variables and the corresponding 95% confidence intervals for each technique (DQ and RR) are summarized in Table 3.

- P1: How many cannabis cigarettes did you consume last year?
- P2: Over the past 90 days, how many days did you consume cannabis?
- P1: By DQ, the mean number of cannabis cigarettes consumed in the previous year was approximately three, but according to RR, seventeen units were consumed.
- P2: By DQ, the students had consumed cannabis on approximately one of the previous 90 days, and on seven according to RR.

The estimate of the number of cannabis cigarettes consumed and the estimate of the number of days when consumption took place for the RR group were significantly

Table 2. Socio-demographic distribution of sample

	DQ		RR	
	Frequency	Percentage	Frequency	Percentage
Total	492	100	654	100
Male	211	42.8861	272	41.5902
Female	281	57.1138	382	58.4098

higher than the estimates for the DQ group (p -values < 0.001).

For all questions, the standard deviation was higher for the RR than for the DQ survey. This result is as we expect because surveys conducted with RRT require large sample sizes.

If we consider the results by gender, we get more units of cannabis consumed and more number of days of consuming in men than women. This difference is statistically significant by DQ (p -value $= 3.8 \times 10^{-5}$ and 0.002 respectively) but this difference is not statistically significant for RR (p -value 0.105 and 0.108 respectively) because the RR estimates have higher variances.

Discussion

In this paper, we present a survey related to the use of cannabis, in which a RRT is used to determine population means that are valid for any sampling design. On comparing the results of the DQ survey and those of the RR survey we find that the number of cannabis cigarettes consumed during the past year (DQ = 3, RR = 17 approximately), and the number of days when consumption took place (DQ = 1, RR = 7 approximately) are much higher with RRT in these universities.

These results are in line with those reported by Dietz *et al.* (2013); Goodstadt and Gruson (1975); Pitsch *et al.* (2007) and Striegel *et al.* (2009). All of these authors conclude that the RRT is an effective means of obtaining estimates with a relatively high degree of reliability. In the case

of doping among professional athletes, this approach could be a promising means of evaluating the effectiveness of anti-doping programmes. The RRT has also highlighted the existence of high values for the 12-month prevalence of cognitive-enhancing drug use among university students, which suggests that other direct survey techniques underestimate this kind of drug use.

The results obtained suggest that estimates derived from standard questionnaire forms underestimate the incidence of drug use by university students. We believe that the advantages of RR revealed in this study and elsewhere make it a useful method to investigate sensitive behaviour related to alcohol and drug use. It must be stressed, however, that RR has wide confidence intervals. The randomization procedure introduces additional random error into the data and increases the standard errors of the parameters estimated: thus, larger sample sizes are needed in order to increase the statistical power. Another important issue in RRT is the choice of an appropriate randomizing device, which should be implemented in such a way as to make the confidentiality protection offered very clear to the respondent. The randomizing devices most commonly employed to date have been serial numbers on a banknote, the flip of a coin, a spinner, playing cards, numbers selected from the phone book or the respondent's month of birth. However, the new technologies currently available offer alternatives that are more attractive to users, such as mobile phones. Thanks to smartphones, we have access to many interesting applications that can help in the randomization of

Table 3. Estimation of the patterns of cannabis consumption

Study technique	DQ ($n = 492$)				RR ($n = 654$)			
	Estimation	Standard deviation	Confidence interval (95%)		Estimation	Standard deviation	Confidence interval (95%)	
			Lower bound	Upper bound			Lower bound	Upper bound
P1: units	3.1142	0.5592	2.0181	4.2103	17.0011	3.6790	9.7903	24.2119
P2: days	0.6837	0.1498	0.3902	0.9773	7.0179	0.9367	5.1819	8.8538
<i>Men</i>								
P1: units	6.3452	1.2522	3.8910	8.7995	24.4972	7.3536	10.0843	38.9100
P2: days	1.2805	0.3220	0.6494	1.9115	8.7713	1.6352	5.5664	11.9763
<i>Women</i>								
P1: units	0.2479	0.1090	0.0341	0.4616	11.6636	3.4850	4.8331	18.4941
P2: days	0.1304	0.06605	0.0010	0.2599	5.7693	1.0999	3.6136	7.9250

telephone and personal surveys (Rueda *et al.*, 2016), especially among young people.

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Declaration of interest statement

The authors have no competing interests.

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Appendix

Description of use of BarLev function in R

```
BarLev(z,p,mu,sigma,pi,type=c
("total","mean"),cl,N=NULL,pij=NULL)
z vector of the observed variable; its length is equal to n
(the sample size)
p probability of direct response
mu mean of the scramble variable S
sigma standard deviation of the scramble variable S
pi vector of the first-order inclusion probabilities
type the estimator type: total or mean
cl confidence level
N size of the population. By default it is NULL
pij matrix of the second-order inclusion probabilities. By
default it is NULL
```

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