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Article

"Look at Me, I Plan to Quit Smoking": Bayesian Hierarchical Analysis of Adolescent Smokers' Intention to Quit Smoking

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Abstract: The tobacco epidemic is one of the leading public health threats the world has ever faced and public health policy that seeks to limit the problem may not only have to target the price of tobacco but also the initiation stage in a smoker's life – the adolescent stage. This research contributes to the health economics literature by using a Bayesian hierarchical logistic model, estimated using Hamiltonian Monte Carlo (HMC) methods to empirically identify what drives the intentions to quit smoking among adolescent smokers in Zambia. Results suggest that among the junior secondary school-going adolescent smokers in Zambia, about 63% have plans to quit smoking. We find socio-demographic characteristics and several tobacco-smoking-related factors as the main drivers of adolescent smokers' plans to quit smoking. Most importantly, we provide insights that could be useful to help adolescent smokers realize their quitting plans.

Keywords: tobacco smoking; intention to quit smoking; Hamiltonian Monte Carlo; Bayesian analysis; Zambia

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JEL Codes: H10, I12, C5

1. Introduction

"While smoking-related mortality occurs mostly in adulthood, smoking is usually initiated during adolescence, and the additive nature of the habit makes quitting extremely difficult." (Shafey et al. [1]; Brook et al. [2]).

Do adolescent smokers have any plans to quit smoking? What factors influence their intentions to quit smoking? This paper seeks to address these questions. The objective is to elicit opinions about adolescent smokers' plans to quit smoking. Specifically, we determine among adolescent smokers, the proportion that intends to quit smoking, as well as examine what drives their intentions to quit smoking in Zambia. While scientific evidence indicates tobacco use is one of the leading causes of preventable death in the world, people still smoke and even so, smoking is usually initiated during adolescence [1]. By 2020, smoking-attributable deaths are expected to reach 7 million a year and at least 8 million each year by 2030 [1]. But most people initiate their smoking behavior as adolescents or young adults. Unless research reveals more information about what drives adolescent smokers' plans to quit smoking, the World Health Organization's (WHO) 2025 targets of 30% relative reduction in prevalence of tobacco use among persons aged at least 15 years may not be achieved. In practice, knowledge about these factors may provide insights for tobacco prevention interventions and effective policy targeting to help current youth smokers successfully realize their quitting plans.

While the tobacco use problem is more prevalent in developed countries, tobacco use is also rising in many developing countries (Chaloupka [3]; Salloum et al. [4]). For example, smoking rates are relatively low in sub-Saharan Africa (SSA) but projection rates indicate prevalence rates of around 39% by the year 2030 (Blecher and Ross [5]; Mendez, Alshangeety, and Warner [6]). For Zambia, a Southern African country, tobacco use is on the rise in part due to lower cigarette pricing and tax rates than other countries in SSA (Stoklosa et al. [7]). According to the WHO [8], the most effective way to decrease cigarette consumption and its prevalence is to increase cigarette taxes. Also, Stoklosa et al. [7] suggest that increasing cigarette tax with corresponding price increases could reduce cigarette use in Zambia. However, Stoklosa et al. [7] assert that efforts to reduce cigarette use in Zambia are hampered by the availability of cheaper tobacco substitute brands. For example, about 39% of Zambian smokers smoke such brands as roll-your-own rather than factory-made cigarettes, and among them, about 88% say they do so because it is cheaper [7]. This means that like any other smoker, adolescents may not find it hard to access tobacco in Zambia and other developing countries in SSA. Based on the 2007 Global Youth Tobacco Survey (GYTS), 10.5% of Zambian students aged between 13 and 15 years were smokers (Zulu et al. [9]).

In addition, while measures to increase taxes on cigarettes maybe effective at reducing tobacco use, Zambia's tax rate on cigarettes does not match WHO recommendations. The WHO endorses a tax share of 75% [8] while by 2016, Zambia's tax share was on average about 37% of the retail price of cigarettes (WHO [10]). Thus, even if Zambia implemented WHO recommendations, tobacco consumers would still have the opportunity to access cheaper locally produced tobacco [7], thereby undermining tobacco control policies. Given these social concerns, tobacco control policies may not only have to target the price of tobacco but also the behavioral origin of smoking in a smoker's life – the adolescent stage – the stage in life at which smoking is initiated – where the addictive nature of the habit makes quitting particularly hard [1].

Cumulatively, there have been other attempts to reduce tobacco use in Zambia (e.g., the National Public Health Act of 1992, 2008 smoking ban at public places, 2009 smoking ban enforcement, increased cigarette taxes, and others [4]). Nonetheless, tobacco-related deaths increased from 3000 per year in 1990 to 8000 per year in 2015 (Institute for Health Metrics and Evaluation [11]). Projections indicate that children and young people alive today from developing countries are to bear the most burden of tobacco-related morbidity and mortality in the near future [8]. For example, the WHO forecasts an increased number of smokers in Zambia from 1.2 million in 2015 to 1.5 million in 2025, which suggests that tobacco use in Zambia is a public health concern, largely expected to spill into the future. This research is motivated by these concerns as well as insufficient empirical literature that explains adolescent smokers' intentions to quit smoking.

The main contributions of this research to the tobacco control and health economics literature are both topical and methodological. First, despite tobacco smoking being the most preventable cause of death, there is a dearth of empirical research that explains youths' intentions to quit smoking even if smoking is mostly initiated during adolescence. Most research on adolescents' smoking behavior has focused on initiation other important issues but not quitting intentions which is an important stage toward successful cessation (e.g., Emery, White, and Pierce [12]; Cawley, Markowitz, and Tauras [13]; [2]; [9]; Odukoya et al. [14]; Friedman [15]; Smith et al. [16]; Martín-Sánchez et al. [17]; Kowitt et al. [18]). We are the first to empirically and rigorously identify what drives the adolescents' preferences to quit smoking. This is important because as governments try to achieve the WHO 2025 target of 30% relative reduction in prevalence of tobacco use among adolescents, understanding what drives adolescents' intentions to quit smoking is necessary because it could help effective targeting of more robust and proactive tobacco control policies.

The second contribution is methodological because the paper employs an empirical application of a Bayesian hierarchical logistic model estimated using Hamiltonian Monte Carlo – a modern Markov chain Monte Carlo (MCMC) procedure that uses the no-U-turn sampler (NUTS) – a more efficient algorithm at estimating nonlinear Bayesian models (Gelman et al. [19]; Hoffman and Gelman [20]). A Bayesian hierarchical logistic regression is a class of regression models where the outcome is dichotomous and inference is under a Bayesian framework while taking advantage of information

across groups of observations to reduce sensitivity of lower-level parameters to noise ([19]; McElreath [21]; Bølstad [22]). We prefer modeling our problem in a Bayesian framework because Bayesian inference is exact and valid for any sample size (Gill [23]; Skevas et al. [24]; Ng'ombe and Boyer [25]).

2. Data

Data description

Data used in this study are from the most recent Global Youth Tobacco Survey (Centers for Disease Control (CDC) [26]) for Zambia, made available in 2018. The WHO-designed GYTS is a global standard survey that monitors youth tobacco use and tracks important tobacco control indicators. The GYTS is a cross-sectional survey of students that are in junior secondary schools. It is designed as a standardized tool to collect data on tobacco use among adolescents in countries around the globe. Thus, the GYTS is mainly a school-based survey of students usually aged between 13 and 15 years (WHO [27]).

The GYTS comprises 56 core questions and the questionnaire covers such topics as young people's knowledge and attitudes about smoking, prevalence of tobacco use, and access to cigarettes among others. Numerous studies have used the GYTS for research because it offers uniform and nationally representative data (e.g., Zulu, Siziya, and Nzala [28]; Warren et al. [29]; GYTS Group [30]; Arrazola et al. [31]). For Zambia the GYTS had 3,377 observations capturing students in grades 7, 8, and 9. Because this study focuses on tobacco smokers, the respondents were those that indicated that they were smokers at the time of the survey. After omitting non-response observations, our final sample comprised of 640 students.

A full description of the variables used in the analysis is presented in Table 1. Column 1 presents variable names while column 2 presents variable descriptions. The response variable is *intention to quit smoking*, which equals 1 if the respondent wants/intends to quit smoking, and 0 otherwise. The explanatory variables are presented below the response variable. We grouped explanatory variables into socio-demographic characteristics and tobacco smoking-related factors. Descriptive statistics of these variables are in Table 2. A check on Table 2 indicates that students in the survey were from grades 7, 8, and 9. Students in grade 7 contributed 39.8% of the total sample while those from grade 8 contributed 32.5%.

Table 1. Definition of variables used in the analysis.

Variable Name	Variable description
Dependent variable	
Intention/plan to quit smoking	Respondent intends or plans to quit smoking, equals 1 if yes, otherwise
Explanatory variables	
Socio-demographic characteristics	
Gender	Gender of respondent, equals 1 if male, 0 otherwise
Age group one	Respondent is aged 11 years or less
Age group two	Respondent is aged between 12 and 17 years old
Age group three	Respondent is aged at least 17 years old
Grade 7	Respondent is in Grade 7
Grade 8	Respondent is in Grade 8
Grade 9	Respondent is in Grade 9
Tobacco smoking-related factors	
Cigarettes per day	Number of cigarettes smoked per day
Smokeless tobacco in past 30 days	Respondent smoked smokeless tobacco in past 30 days

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Smoking for past 5 years	Respondent has been smoking for past 5 years
Difficult to quit smoking	Respondent believes it is difficult to quit smoking
Smoking is harmful to health	Respondent believes smoking is harmful to health
Gained weight following smoking	Respondent believes he/she has gained weight after smoking
Lost weight following smoking	Respondent believes he/she has lost weight after smoking
Smokers should ask permission to smoke	Respondent believes smokers should ask permission to smoke
Smoking is safe for 1 or 2 years	Respondent believes smoking is safe for one or two years
Number of times smoked in-house	Number of times respondent smoked inside a house
Number of times smoked inside enclosed public places	Number of times respondent smoked inside enclosed public places
Times smoked at outdoor public places	Number of times respondent has smoked at outdoor public places
Favors ban of smoking at public places	Respondent favors a ban of smoking at public places
Advised to stop smoking	Respondent received advice/help to stop smoking in the past
Owns cigarette brand logo	Respondent owns cigarette product brand logo
Attends cigarette ad events	Respondent attends cigarette advertisement events
Offered free cigarettes	Respondent is offered free cigarette
Taught dangers of smoking before	Respondent has before been taught about dangers of smoking
Number of cigarettes in life	The maximum number cigarettes the respondent has smoked in life
Cigarette sold near home	Respondent knows place(s) that sell single cigarettes near home
Youth groups discourage smoking	Youth groups are considered to be discouraging smoking
Health workers explained smoking dangers	Health worker explained dangers of smoking
Religious groups discourage smoking	Religious groups are considered to be discouraging smoking
Haven't tried to stop smoking	Respondent has not tried to stop smoking
Tried to stop to improve health	Respondent tried to stop to improve own health
Tried to stop to save money	Respondent tried to stop to save money
Tried to stop because family dislikes it	Respondent tried to stop smoking because the family dislikes it
Closest friends smoke tobacco	Respondent's closest friends smoke
Both parents smoke	Respondent's father and mother smoke tobacco
Only father smokes	Respondent's father smokes tobacco
Only mother smokes	Respondent's mother smokes tobacco
No usual brand	Respondent uses no usual brand
Peter Stuyvesant	Respondent uses no usual brand uses Peter Stuyvesant brand
Roth man	Respondent uses Roth man’s brand
Consulate	Respondent uses consulate brand
Safari	Respondent uses safari brands
From own burns	Respondent smokes tobacco from burns

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Table 2. Descriptive statistics of variables used in the study.

Variable Name	Mean	Std. Dev.
Dependent variable		
Intention to quit smoking	0.633	0.482
Explanatory variables		
Socio-demographic characteristics		
Gender	0.492	0.500
Age group one	0.048	0.215
Age group two	0.577	0.494
Age group three	0.375	0.485
Grade 7	0.398	0.490
Grade 8	0.325	0.469
Grade 9	0.277	0.448
Tobacco smoking-related factors		
Cigarettes per day	1.792	1.571
Smokeless tobacco in past 30 days	0.245	0.431
Smoking for past 5 years	0.230	0.421
Difficult to quit smoking	0.528	0.500
Smoking is harmful to health	0.441	0.497
Gained weight following smoking	0.209	0.407
Lost weight following smoking	0.444	0.497
Smokers should ask permission to smoke	0.358	0.480
Smoking is safe for 1 or 2 years	0.291	0.454
Number of times smoked in-house	2.261	1.595
Number of times smoked inside enclosed public places	2.319	1.486
Times smoked at outdoor public places	2.248	1.522
Favors ban of smoking at public places	0.359	0.480
Advised to stop smoking	0.809	0.393
Owns cigarette brand logo	0.313	0.464
Attends cigarette ad events	0.530	0.500
Offered free cigarettes	0.267	0.443
Taught dangers of smoking before	0.436	0.496
Number of cigarettes in life	2.289	2.004
Cigarette sold near home	0.405	0.491
Youth groups discourage smoking	0.356	0.479
Health workers explained smoking dangers	0.452	0.498
Religious groups discourage smoking	0.413	0.493
Haven't tried to stop smoking	0.111	0.314
Tried to stop to improve health	0.227	0.419
Tried to stop to save money	0.059	0.237
Tried to stop because family dislikes it	0.209	0.407

Table 2. Continued.

Tobacco smoking-related factors		
Closest friends smoke tobacco	0.603	0.490
Both parents smoke	0.069	0.253
Only father smokes	0.213	0.409
Only mother smokes	0.047	0.212
Neither of the parents smokes	0.672	0.470
No usual brand	0.230	0.421
Peter Stuyvesant	0.077	0.266
Roth man	0.045	0.208
Consulate	0.059	0.237
Safari	0.006	0.079
From own burns	0.034	0.182
Number of observations	640	

The remainder (27.77%) were in grade 9. In this study, we assume our model's intercepts vary by the variable *grade* because students from these three grades may not have similar characteristics and thus their responses could be affected by grade-variation. Table 2 further shows that 63.33% reported they intended to quit smoking while the rest (36.7%) did not. In terms of age, 4.8% of the students were aged 11 or below. About 58% of the respondents were aged at least 12 years up to 16 years old, and the rest were at least 17 years old.

3. Materials and Methods

3.1. Conceptual Model

Following Gelman and Hill [32] and Greenberg [33], in a logistic model, the underlying dependent variable y_{ij} follows the Bernoulli distribution, $y \sim Bin(1, \pi)$ assuming **x** as a vector of exogenous explanatory variables. The model is

$$y_{ij} = \pi_{ij} + \varepsilon_{ij}, \tag{1}$$

where $i = 1, \ldots, N_j$ is the individual-level indicator, $j = 1, \ldots, J$ group of interest-level indicator, π_{ij} is the probability of success for ith individual from jth group, and ε_{ij} are individual level random errors. The probability of success is conditional on the influence of factors in **x**. Based on this information, the logit function is

$$\text{logit}(\pi_{ij}) = \log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \alpha + x'_{ij}\beta \tag{2}$$

For equation (2), ε_{ij}'s (as shown in equation (1)) are assumed as independent with mean zero and $Var(\varepsilon_{ij}) = \pi_{ij}(1 - \pi_{ij})$. Solving for π_{ij} in equation (2) yields

$$\pi_{ij}(\boldsymbol{x}; \beta) = \frac{e^{\alpha + x'_{ij}\beta}}{1 + e^{\alpha + x'_{ij}\beta}} = \frac{1}{1 + e^{-(\alpha + x'_{ij}\beta)}} \tag{3}$$

where the terms in equation (3) are as defined previously. Partly because of its mathematical convenience, the logistic model is widely used in econometric applications (Greene [34]). Following Shaliz [35], since logistic regression predicts probabilities instead of classes, it can be estimated using maximum likelihood. For a given set of data point $\boldsymbol{x}$ and observed class y_{ij}, the probability of the classification variable is either π_{ij} given $y = 1$, or $1 - \pi_{ij}$ if $y = 0$. Thus, the likelihood function of the logit model is

$$f(y_{ij}|\alpha,\beta,\sigma_\varepsilon^2) = \prod_{i=1}^{n} \pi_{ij}(x)^y (1-\pi_{ij}(x))^{(1-y)}, \quad y = 0, 1 \tag{4}$$

The frequentist approach would require maximizing the log likelihood function in equation (4) over the sample to obtain estimates for α and β. This paper adopts a Bayesian approach incorporates the hierarchical structure to better understand what drives adolescent's preference to quit smoking. The Bayesian approach enables one to obtain model parameters' posterior distributions. Following Gelman et al. [19], posterior distributions allow one to make robust informative statements about their findings by using Bayesian credible intervals – the Bayesian equivalent of confidence intervals used in classical econometrics. Proponents of Bayesian inference posit that the frequentist approach draws its conclusions directly from the data. A frequentist approach interprets the confidence interval such as a 90% confidence interval as the range of values that would include 90% of parameter estimates if the data generating mechanism is repeated independently for a huge number of times [25, 36]. But the Bayesian framework substitutes repeating experiments for a huge number of times by advocating for a combination of prior information and data. It thus substitutes confidence intervals with Bayesian credible intervals which are interpreted as the probability that a given estimate lies in the range of the values given the data, regardless of the data [36]. This presents a more intuitive interpretation of results regardless of how scarce the data are [24]. Motivated by these observations, this paper employs a Bayesian hierarchical logistic regression model.

Our procedure is as follows. We consider the vector of parameters of interest as $\vartheta = [\alpha, \beta]'$, where α and β were defined previously. Using the likelihood function in equation (4) and the prior distributions $f(\vartheta)$ for all parameters, we use Bayes' rule to obtain the posterior density of all parameters using equation (5)

$$f(\vartheta|y_{ij}) \propto f(y_{ij}|\vartheta) f(\vartheta) \tag{5}$$

Equation (5) is based on regular Bayes' rule, but in a hierarchical framework as in our case, the prior density also depends on its lower level hyper-parameters, δ. The likelihood function also changes in a similar manner resulting in equation (5) to become

$$f(\delta, \vartheta|y_{ij}) \propto f(y_{ij}|\vartheta, \delta) f(\vartheta|\delta) f(\delta) \tag{6}$$

Obtaining the posterior distributions in equation (6) by numerical integration methods especially with multiple parameters can be challenging but the advent of Markov chain Monte Carlo (MCMC) methods makes computation of equation (6) easier. Further details about estimating Bayesian hierarchical models can be found in [19 and 21].

3.2. Empirical model

Equation (2) is rewritten in a way to show the full empirical specifications. Our interest is to model the intention to quit smoking among adolescents to account for the between-grade heterogeneity in student responses. As discussed before, respondents in our data were from grades 7, 8, and 9, we specify our Bayesian hierarchical logistic regression model as one with varying intercepts according to grade. The full model is specified in equation (7) and equation (8)

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \alpha_{0j} + \sum \beta_k x_{ik} \tag{7}$$

$$\alpha_{0j} = \alpha_0 + \mu_j \tag{8}$$

$$\beta_k \sim N(0, 10), \quad \alpha_0 \sim N(0, 10), \quad \sigma_\mu \sim Cauchy(0, 2.5)$$

where α_{0j} is the varying intercept, β_k indexes the kth coefficient of the kth independent variable, x_{ik} is the kth independent variable of the ith student in the sample (x_{ik}'s are explanatory variables shown in Table 2). The varying intercept model (equation (8)) is the lower-level model showing that intercepts would vary according to α_0 and the between-intercept error μ_j whose variance is σ_μ^2. Following Gelman and Hill [32], Gelman et al. [37], and [19], we impose weakly-normal priors on α_0 and β_k because these can be either positive or negative even if our null hypotheses for these are that they are zero. We further impose Cauchy priors for σ_μ^2 (between-intercept variance represented by

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its standard deviation σ_μ shown in equation (8)). The priors are chosen to provide little information which conforms with Gelman [38] that posterior standard deviations should be smaller than 10% of the corresponding prior standard deviations.

We then use HMC methods to sample from the posterior. As mentioned before, HMC uses NUTS which is proposed to reduce the HMC dependency on its parameters and is more efficient than both the Gibbs sampler and Metropolis Hastings [20, 39]. All estimations were conducted in R, RStudio, and Stan software [40, 41, and 42]. Our HMC techniques involved 2 chains with a burn-in phase of 2,500 to enable the Markov chains forget their in initial regions [23, 25] with the total iterations of 4,000 per chain. We present convergence diagnostics to show that our MCMC chains converged to their target posterior distributions. Convergence diagnostics are shown in Figure 1. Since we have multiple independent variables, trace plots as convergence diagnostics for only two variables: *gender* and *age group two* are shown in Figure 1. The trace plots for both variables indicate that MCMC chains exhibit good mixing which suggests successful convergence. We also applied the Gelman and Rubin [43] test to confirm convergence of the sequences. The Gelman-Rubin test carried out checks whether parameter estimates are stationary, that is whether the Markov chains converged to their posterior distributions. The Gelman-Rubin test statistics are smaller than 1.004 for all parameters of the estimated models, which provides strong evidence of convergence – a result consistent with trace plots in Figure 1.

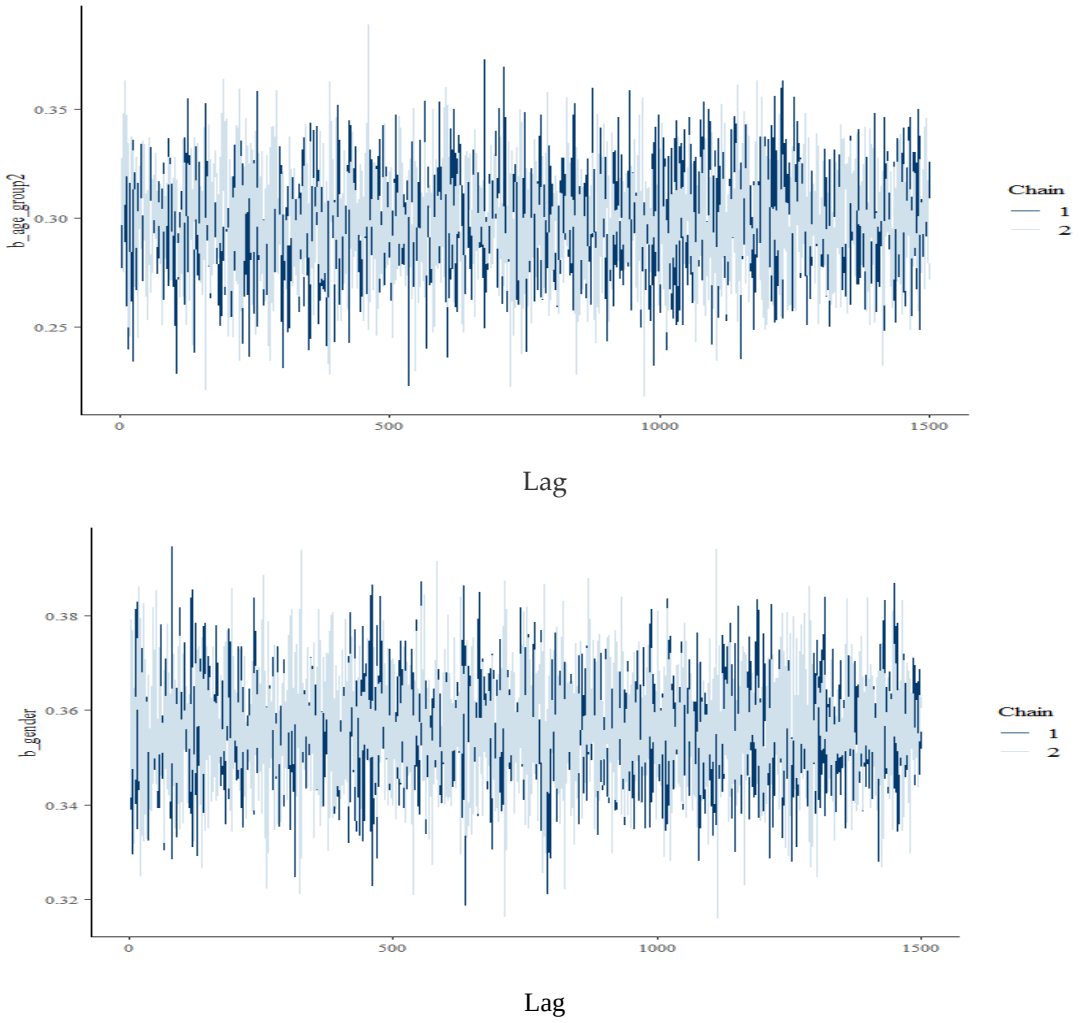

Figure 1. Trace plots for age group 2 and gender of the respondents.

4. Results and Discussion

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Estimation results are presented in Table 3. Column 1 presents variable names while columns 2 and 3 respectively present mean odds ratios and their standard deviations. The Bayesian 95% credible interval is in column 4 while percentage effects are presented in column 5. Percentage effects display the percentage change in the odds of a respondent's intention to quit smoking.

Table 3. Odds Ratios, Standard Deviations, Bayesian 95% Credible Intervals, and Percentage Effects.

Variable Name	Odds Ratios	Std. Dev.	95% Credible Interval		Percentage Effects (%)
Socio-demographic characteristics					
Intercept	0.078	1.423	0.008	0.069	-92.237
Gender	1.428	0.017	1.396	1.460	42.761
Age group two	1.347	0.032	1.286	1.410	34.737
Age group three	1.333	0.032	1.269	1.395	33.251
Tobacco smoking-related factors					
Cigarettes per day	1.050	0.004	1.041	1.059	5.005
Smokeless tobacco in past 30 days	2.035	0.029	1.980	2.092	103.463
Smoking for past 5 years	1.387	0.020	1.348	1.426	38.675
Difficult to quit smoking	2.262	0.026	2.213	2.311	126.158
Smoking is harmful to health	1.211	0.015	1.182	1.241	21.117
Gained weight following smoking	1.890	0.030	1.833	1.947	89.037
Lost weight following smoking	2.371	0.032	2.308	2.434	137.062
Smokers should ask permission to smoke	0.779	0.010	0.758	0.798	-22.141
Smoking is safe for 1 or 2 years	1.294	0.017	1.259	1.328	29.371
Times smoked in-house	1.125	0.005	1.115	1.135	12.482
Times smoked inside enclosed public places	1.163	0.006	1.152	1.173	16.256
Times smoked at outdoor public places	0.994	0.004	0.985	1.002	-0.647
Favors ban of smoking at public places	2.633	0.037	2.563	2.705	163.269
Advised to stop smoking	2.884	0.042	2.802	2.966	188.394
Owns cigarette brand logo	1.471	0.019	1.434	1.507	47.113
Attends cigarette ad events	1.889	0.021	1.848	1.932	88.933
Offered free cigarettes	1.031	0.015	1.004	1.060	3.135
Taught dangers of smoking before	1.444	0.017	1.410	1.479	44.371
Number of cigarettes in life	0.901	0.003	0.895	0.906	-9.932
Cigarettes sold near home	0.679	0.008	0.663	0.696	-32.062
Youth groups discourage smoking	1.209	0.016	1.177	1.240	20.905
Health workers explained smoking dangers	1.591	0.019	1.553	1.629	59.118
Religious groups discourage smoking	0.906	0.011	0.884	0.928	-9.373
Haven't tried to stop smoking	0.733	0.013	0.708	0.759	-26.713
Tried to stop to improve health	2.661	0.042	2.579	2.745	166.061
Tried to stop to save money	1.812	0.045	1.726	1.901	81.197
Tried to stop because family dislikes it	2.013	0.031	1.952	2.075	101.284

Closest friends smoke tobacco	0.839	0.010	0.820	0.858	-16.116
Both parents smoke	0.984	0.021	0.943	1.028	-1.551
Only father smokes	1.324	0.019	1.286	1.363	32.426
Only mother smokes	0.348	0.010	0.329	0.368	-65.181
Peter Stuyvesant	0.429	0.010	0.409	0.450	-57.079
Roth man	1.407	0.041	1.327	1.489	40.737
Consulate	1.001	0.025	0.952	1.051	0.0738
Safari	1.381	0.096	1.201	1.569	38.053
From own burns	3.486	0.125	3.248	3.734	248.557
Varying intercept effects					
Between-grade intercept variance	1.931	2.115	1.149	16.002	93.100

The upper and lower bounds of the Bayesian 95% credible intervals shown here are the 2.5% and 97.5 quantiles of the corresponding posterior odds ratios derived as exponentiated posterior means. Though we have reported odds ratios in Table 3, the actual posterior means are shown in Table A1 in the appendix to conserve space. In terms of statistical significance, we consider the odds ratios as statistically significant if their Bayesian credible intervals do not include the value of one, which is equivalent to parameter estimates (i.e., posterior means) being statistically significant if the credible intervals do not span zero. The varying intercepts in the model accounted for inter-grade variation of the multiple responses from students in each grade. This accounted for heterogeneity from the fact that students from some grades would more than average intend to quit smoking while others would less than average intend to quit smoking. Results of group effects are shown in last rows of Table 3 while the overall standard deviation results are indicated in Table A1.

Regarding socio-demographic characteristics, male students would more likely intend to quit smoking than female students. On average, male students' odds of planning to quit smoking are about 42% more than female students, keeping other factors constant. This finding is consistent with [16] who find that female smokers exhibit more difficulty at sustaining long-term abstinence from smoking than males which could be due to multiple-level bio-psycho-social factors. Smith et al. [16] contend that such factors could lead to psychiatric distress which more likely stimulates some female smokers to smoke again even when they attempt to stop smoking. We also find that students that are aged between 12 and 16 are, on average more likely to plan to quit smoking than those aged 11 or below. Similar results were found for students aged at least 17 years. The odds of the intention to quit smoking are about 33% higher for students aged at least 17 years than those aged 11 or less, and this value ranges between 26.9% and 39.5% with probability of 95%, when other factors are held constant.

For the tobacco smoking-related factors, we find that smoking an additional cigarette per day increases the odds of the intention to quit smoking by 5%, the value that ranges from 4.2% to 5.9% with a probability of 0.95, *ceteris paribus*. This could be in response to the negative mood smokers feel after smoking the last cigarette. Folan et al. [44] contend that smokers feel a negative mood change after smoking because they no longer get what the brain feels to work well. Folan et al. [44] further suggest smokers usually get relief from such unpleasant feelings once they smoke again – which makes them smoke again despite having planned to quit smoking. We find that students that smoked smokeless tobacco in last 30 days have higher odds of planning to quit smoking than otherwise, *ceteris paribus*. The more likely reason for this could be smokeless tobacco-associated lesions. Smokeless tobacco is usually associated with cavity lesions in smokers [45, 46] which would perhaps result in students that smoke it to dislike these effects. Furthermore, students that have been smoking in the previous 5 years are found to be more likely to plan to quit smoking than those that have not, which suggests they could have been ready to quit in the past 5 years but possibly because of such factors as nicotine addiction, they still smoke. As argued by Forlan et al. [44], smokers are susceptible to moderate or severe nicotine addiction and may have difficulty stopping tobacco use without serious assistance which could be the case for students that have been smoking the past 5 years but strongly plan to quit.

In terms of students' perception about the difficulty to quit smoking, results show that the odds of planning to quit smoking among respondents that believe it is difficult to quit smoking are higher than those that do otherwise. Perhaps these are such students that could have attempted to quit smoking but failed. As in Zhou et al. [47], quitting smoking is dynamic and involves a sequence of unsuccessful attempts before long-term abstinence. Our finding implies that there are students that believe quitting is difficult, something that requires serious cessation aids to them such as serious media awareness about the dangers of smoking and other evidence-based methods. For example, we find that belief among students that smoking is harmful to health increases the odds of their plans to quit smoking by about 21%, a value that lies between 18.2% and 24.1% with a probability of 0.95, everything else held constant. This finding is novel as tobacco smoking is known to cause death and cancer-related mortality even among young people [8, 48]. In terms of the effects of smoking on smoker's weight, results show that belief among students that smoking results in weight-gain or weight-loss since its initiation increases the odds of plans to quit smoking tobacco among school-going adolescents. Both results are plausible because nicotine is linked to increasing energy expenditure and decreased appetite which is conducive to weight loss in smokers [49]. Chiolero et al. [49] also posit that sometimes smoking increases insulin resistance resulting in central fat accumulation and ultimately weight gain in heavy smokers.

Students that believe school-going adolescent smokers should seek permission to smoke tobacco are less likely to plan to quit smoking than otherwise. Specifically, belief among students that school-going adolescent smokers should seek permission from adults to smoke decreases the odds of plans to quit smoking by 22%, and this value ranges between 18.2% and 24.1%, when other factors are held constant. Moreover, those that believe smoking is safe for first one or two years have higher odds of planning to quit smoking than otherwise. This result just reveals how students underestimate the dangers of smoking because even a day's cigarette can be harmful to their health (National Institutes of Health [NIH] [50]). We also find that the number of times students have smoked in-house or inside public buildings affects the probability of their intention to quit smoking. The more they smoke in-house or at public places, the higher the odds of intending to quit smoking. This could be due to smoke-free warnings at public places or enclosed buildings. Smoke-free laws and policies may reduce smoking prevalence among workers and smoking initiation among adolescent smokers (Siegel et al. [51]). Those that favor ban of smoking at public are more likely to plan to quit smoking. Keeping other factors constant, we are 95% confident that favoring a ban of smoking at public places, on average increases the odds of one's plans to quit smoking by about 163% and this value ranges between 156.3% and 170.5%. Because tobacco-free laws motivate and help tobacco users to quit smoking and also thwart initiation of tobacco use among youths (U.S. Department of Health and Human Services [USDHHS] [52]), students who support a ban of smoking at public places may indeed be more likely to have plans to quit smoking.

Results further show that advice to stop smoking strongly increases the odds of adolescents' plans to quit smoking. Receiving advice to stop smoking on average increases the odds of students' plans to quit smoking by 188.4%, a result that varies between 180.2% and 196.6% with a chance of 95%, keeping other factors constant. While advice could be helpful, the smoker also needs to be motivated to do so because quitting may be affected by other exogenous factors around the smoker's habitat. For example, results further show that students that own cigarette brand or logo on cloth, attend cigarette advertisement events, or have in the past been offered free cigarettes before to be more likely to plan to quit smoking than otherwise. Even students that in the past have received lessons about dangers of smoking are more likely to plan to quit smoking than otherwise. Our results reveal that teaching students about the dangers of smoking increases the odds of students' intention to quit smoking by 44.4%, a result that varies between 41% and 47.9% with probability of 0.95, everything else held constant. These results highlight the role played by the social environment and education at influencing adolescents' intentions to quit smoking.

The number of cigarettes a student has smoked in life also has important effects on their intention to quit smoking. We find that the number of cigarettes a student has smoked in life significantly affects his/her plans to quit smoking. Students that have smoked more cigarettes in life

are on average less likely to quit smoking which could be due to nicotine addiction. This finding is consistent with Burns et al. [53] who find that smokers are more likely to attempt to quit smoking if they have smoked fewer cigarettes in their lives. When cigarettes are sold near students' residences or homes, the odds of students' intention to quit smoking, on average decrease by about 32%, a value that ranges between 30.4% and 33.7% with 95% chance. While cigarettes sold in close-proximity would be expected to boost their access, the price at which they are sold could be main deterrence especially for school-going adolescents. As in Levy, Romano, and Mumford [54], a general environment of higher cigarette prices encourages quit attempts because it may limit access.

Those that consider that youth groups are discouraging smoking are more likely to have the intention to quit smoking than otherwise. This suggests that youth groups such as School Unions or Associations may be strongly discouraging smoking among students leading to students have plans to quit smoking. But results suggest students that believe with conviction that religious groups discourage smoking are less likely to plan to quit smoking. This could be because just belief that religious groups discourage smoking may not be necessary for planning to quit smoking but rather getting involved in activities of such religious groups or institutions. For example, Whooley et al. [55] find adolescents that attend religious services to have lower cigarette smoking rates than otherwise. Furthermore, we find that when health workers explain the dangers of smoking to school-going smokers, it increases the latter's odds of planning to quit smoking by about 59%, a result that ranges between 55.3% and 62.9%, *ceteris paribus*. This highlights the important role health practitioners could play at helping to reducing smoke rates among students in schools.

Most tobacco users desire to quit smoking. Some succeed to quit while others do not. The desire to quit smoking varies from person to person. Here we find that students attempt to quit smoking for several reasons that include: to improve health, save money or because their families dislike smoking tobacco. Results suggest quitting attempts to improve health, save money or because their families dislike smoking, on average increase the odds of the students' intention to quit smoking by about 166%, 81%, and 101%, respectively, holding other factors constant. These results suggest increasing sensitization among youths about health hazards from smoking, or spending their money on alternative items such as school needs or encouraging families to discourage their children from smoking could perhaps contribute to control of tobacco use among adolescents.

In terms of peer-effects, we find that having closest friends that smoke decreases the odds of intention to quit smoking by 16.1%, a result that ranges from 14.8% and 18%, with probability of 0.95. Compared to having both parents that do not smoke, our results suggest that when it is only a father who is a smoker, on average, it increases the odds of a student's plans to quit smoking by about 32%, a result that varies between 28.6% and 36.3% with 95% chance. In contrast, when it is only a mother who smokes, the odds of planning to quit smoking among students decrease by 65.2% more than when both parents do not smoke, a result that ranges from 63.2% and 67.1% with a 95% chance, *ceteris paribus*. These findings are novel and illustrate how significant the effects from peers and parents could foster or undermine students' plans to quit smoking.

We also considered common brands of cigarettes that students smoke. These include Peter Stuyvesant, Roth-man, Consulate, Safari, roll-your-own, and one without any known brands. Compared to brandless cigarettes, smoking Peter Stuyvesant cigarettes reduces the odds of the intention to quit smoking by about 57% and this value ranges between 55% and 59.1%, with a probability of 0.95, other factors held constant. This could be due to higher prices of Peter Stuyvesant cigarettes than brandless cigarettes because the former is factory-made and therefore more likely to be costly and unaffordable. In contrast, students that smoke Roth-man or Safari brands are more likely to plan to quit smoking than those that smoke brandless cigarettes. Additionally, smoking roll-your-own significantly increases odds of students' plans to quit smoking relative to smoking brandless cigarettes. The reason for differences in the plans to quit smoking across different brands could be pricing of these products as well as the students' perceptions about their health hazards. For example, Stoklosa et al. [7] contend that local farmers in Zambia also produce and supply tobacco as part of the roll-your-own brand, a lower priced burnable tobacco product which is used to substitute highly priced factory-made tobacco. But the ingredients of such products may not be scientifically

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known among smokers because such tobacco is locally produced [7] and maybe consumed just after harvesting from farm fields, which could pose health risks.

5. Conclusion

While the tobacco use problem is more prevalent in developed countries, smoking rates are rising in most developing countries and projection rates indicate high pervasiveness rates of around 39% by the year 2030 [5, 6]. Health policy that seeks to limit the problem may not only have to target the price of tobacco but also the common stage at which smoking is initiated – the adolescent stage. This research contributes to the health economics literature by using Bayesian hierarchical logistic model to empirically identify what drives the intentions to quit smoking among adolescent smokers.

Based on our findings, the following conclusions are drawn. First, the average number of school-going adolescent-smokers that plan to quit smoking in Zambia is about 63%. This clearly reveals that a large number of adolescent smokers in Zambia plan to quit smoking and to help them achieve their plans, smoking cessation aids need to be available for them. Such aids could include smoking cessation programs at schools, small enticements to people that successfully quit smoking, short sessions on dangers of smoking [56], and possible school visits by health professions to make students more aware about detrimental effects of tobacco use on their health. Second, socio-demographics characteristics shape students' plans to quit smoking. For example, the finding that students aged 11 or less would less likely plan to quit smoking than those older than 11 suggests such young students require special care and assistance to quit smoking for a future active and healthy population. That female smokers are less likely plan to quit smoking than their counterparts is an important result. Consistent with [6 and 16], this finding implies the need for special attention on young female smokers through strengthening public health interventions, focusing on them to help them withstand the stress or the so-called bio-physical and social factors that may undermine their plans to quit smoking.

Third, several tobacco-smoking related factors were found to strongly affect adolescents' plans to quit smoking. Positive significant effects of the belief among students that smoking is harmful to health, or that smoking leads to weight gain/loss on students' plans to quit smoking suggest serious public awareness of the dangers of smoking in schools could motivate many students to plan to quit smoking. On average, teaching students about the dangers of smoking or school visits by health workers to advise students to abstain from smoking would help encourage students to plan to quit. The media are also possible avenues to do so. Obviously the next step would be ensuring that they attempt to quit smoking and how long they would maintain abstinence is an important challenge for future research.

While the strategies to help students plan to quit smoking proposed in this article could be effective at improving adolescents to quit smoking, peer effects and parental smoking behavior may undermine them. Most importantly students whose closest friends smoke, or only the mother smokes were found to less likely plan to quit smoking. This result is consistent with [14, 57, and 58]. Thus, efforts aimed at encouraging youths to quit smoking should also be directed at parents because they shape their children's behavior. Additionally, efforts directed at peer influence like discouraging students from involving or interacting themselves with smokers should also be encouraged. This would not only prevent children from quitting tobacco use but would also prevent them from being exposed to passive smoking which is also dangerous to health.

Based on our findings, an important implication for tobacco control policy is how students should be encouraged to quit smoking successfully. As discussed before, a possibility is introduction of smoking cessation programs at schools by governments or responsible agencies. Students should be incentivized to participate in such programs to help or aid their plans to quit smoking. They would have to be taught and raised under stricter public policies of smoking regulation [17] to aid their plans to quit smoking and most importantly attempt to quit. Obviously any student that plans to quit smoking will be more enthusiastic to follow quitting routines presented to them during cessation programs. This article does not scorn the need for higher taxes that other studies acclaim (e.g., [7] and many others), but rather provides the non-price methods that complement them. For example,

increased taxes on all cigarette brands as well as increased sensitization against smoking the locally farmed and produced tobacco products whose nicotine contents are unknown to the consumers should also be part of targets of effective tobacco control policies in developing countries.

Future research should use richer data sets such as longitudinal data that would ideally add more evidence on adolescents' smoking behavior, quit attempts and their abstinence success rates. Our data focused only on grades 7, 8, and 9, but data that would include all school levels would be richer. However, our data are from a global survey, designed as a standard tool by the CDCs, which makes it a robust dataset. In addition, the Bayesian hierarchical methods used in this study help to account for sources of uncertainty from both data and parameters which is a novel contribution. While the analysis was conducted for Zambia, our results provide general implications for readers and policy-makers across the world at a time when the tobacco epidemic is one of the biggest public health threats the world has ever faced (WHO [59]).

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Appendix

Table A1. Posterior Means, Standard Deviations, and Bayesian 95% Credible Intervals.

Variable Name	Posterior Mean	Standard Deviation	95% Credible Interval	
Socio-demographic characteristics				
Intercept	-3.720	0.670	-4.775	-2.672
Gender	0.356	0.012	0.333	0.379
Age group two	0.298	0.024	0.251	0.344
Age group three	0.287	0.024	0.239	0.333
Tobacco smoking-related factors				
Cigarettes per day	0.049	0.004	0.040	0.057
Smokeless tobacco in past 30 days	0.710	0.014	0.683	0.738
Smoking for past 5 years	0.327	0.015	0.298	0.355
Difficult to quit smoking	0.816	0.011	0.794	0.838
Smoking is harmful to health	0.192	0.012	0.167	0.216
Gained weight following smoking	0.637	0.016	0.606	0.666
Lost weight following smoking	0.863	0.014	0.836	0.890
Smokers should ask permission to smoke	-0.250	0.013	-0.277	-0.226
Smoking is safe for 1 or 2 years	0.257	0.013	0.231	0.284
Times smoked in-house	0.118	0.005	0.109	0.127
Times smoked inside enclosed public places	0.151	0.005	0.141	0.160
Times smoked at outdoor public places	-0.007	0.005	-0.015	0.002
Favors ban of smoking at public places	0.968	0.014	0.941	0.995

Advised to stop smoking	1.059	0.015	1.030	1.087
Owns cigarette brand logo	0.386	0.013	0.361	0.410
Attends cigarette ad events	0.636	0.011	0.614	0.659
Offered free cigarettes	0.031	0.014	0.004	0.058
Taught dangers of smoking before	0.367	0.012	0.343	0.391
Number of cigarettes in life	-0.105	0.003	-0.111	-0.099
Cigarettes sold near home	-0.387	0.012	-0.411	-0.363
Youth groups discourage smoking	0.190	0.013	0.163	0.215
Health workers explained smoking dangers	0.464	0.012	0.440	0.488
Religious groups discourage smoking	-0.098	0.013	-0.123	-0.075
Haven't tried to stop smoking	-0.311	0.018	-0.345	-0.276
Tried to stop to improve health	0.978	0.016	0.947	1.010
Tried to stop to save money	0.594	0.025	0.546	0.642
Tried to stop because family dislikes it	0.699	0.016	0.669	0.730
Closest friends smoke tobacco	-0.176	0.012	-0.199	-0.153
Both parents smoke	-0.016	0.022	-0.058	0.027
Only father smokes	0.281	0.015	0.251	0.310
Only mother smokes	-1.055	0.028	-1.112	-1.001
Peter Stuyvesant	-0.846	0.024	-0.894	-0.799
Roth man	0.341	0.029	0.283	0.398
Consulate	0.000	0.025	-0.049	0.050
Safari	0.320	0.070	0.183	0.450
From own burns	1.248	0.036	1.178	1.318
Group-level effects	0.658	0.749	0.139	2.774

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