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ORIGINAL ARTICLE

Examining Potential Mechanisms of an Online Universal Prevention for Adolescent Alcohol Use: a Causal Mediation Analysis

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Abstract
Several universal school-based prevention programs, notably the Australian *Climate Schools* program, have proven efficacious at reducing and maintaining a lower level of harmful alcohol consumption relative to a control condition. Yet, there are limited studies investigating the potential mechanisms that account for the reduction in harmful alcohol consumption. The current study utilised modern causal mediation analysis to investigate whether several harm minimisation and social influence mediators could jointly account for the intervention effect observed in a large school-based sample. Four mediators representing knowledge, attitudes, normative perceptions, and self-efficacy to resist peer pressure were entered into a multiple casual mediation model using the potential outcomes framework. The results did not provide evidence for a joint multiple mediation model consisting of the hypothesised harm minimisation and social influence mediators. Additional research is required to further investigate the potential mechanisms underlying universal school-based prevention programs including social connectedness and cultural/environmental factors.

Keywords Prevention · Alcohol use · Mediation · Harm minimisation · Social influence

Introduction

Harmful consumption of alcohol is among the top modifiable contributors to the global burden of disease and is associated with significant and enduring impacts on individuals, families, and communities (Bryazka et al., 2022; World Health Organization, 2018). Despite growing evidence of an increasing age of drinking onset across multiple western countries, levels of risky drinking among adolescents in Australia remain relatively stable (AIHW, 2020; Chan et al., 2016). Risky or harmful alcohol use is not only associated with development of alcohol use disorder, but it can also lead to numerous health issues including mental disorders, suicide, stroke, heart disease, and cancer (Rehm et al., 2010, 2017; Schuckit, 2009). For this reason, prevention of

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harmful alcohol use in adolescence is an ongoing public health priority.

Prevention programs aim to delay the uptake of alcohol use and minimise the associated harms and risks. These programs are commonly delivered in secondary school, when alcohol initiation tends to occur (AIHW, 2020). Universal (i.e., delivered to the whole student population) school-based prevention programs provide optimal and scalable methods for potentially delaying onset and reducing harms associated with alcohol use. An overview of reviews of Australian alcohol use prevention programs found that universal school-based programs were effective at delaying alcohol use onset, as well as reducing frequency and quantity of alcohol consumption (Mewton et al., 2018). Internationally, a meta-analysis of 288 programs reported that universal, school-based substance use prevention programmes in early adolescence were effective at preventing alcohol use ($d = -0.10$). However, universal prevention programmes were not effective at preventing alcohol use when delivered in mid-adolescence (Onrust et al., 2016).

The Australian *Climate Schools* (recently rebranded as *OurFutures*) program is a world-first suite of effective, universal eHealth prevention programs that utilise interactive cartoon storyboards and class activities to empower secondary students to improve their health and wellbeing. The modules provide developmentally appropriate information about mental health, alcohol and other drugs, resistance skills training, and normative education. Co-designed with over 210 young people and over 390 teachers, parents, and health and education experts, each module includes 4–6 lessons that are delivered in health education classes and are aligned with state and national curricula. The preventative effects of the universal *Climate* programs are well established. Seven large randomised controlled trials (RCTs) across Australia (240 schools, > 21,000 students) demonstrate that, compared to standard education, the *Climate* program significantly reduced the odds of alcohol use, risky binge drinking and alcohol-related harms in adolescents (Champion et al., 2016; Newton et al., 2009, 2010, 2021; Slade et al., 2021; Teesson et al., 2017; Vogl et al., 2012). Reductions in harmful alcohol use have been observed up to age 20 (i.e., 7 years following intervention delivery), representing some of the longest follow-up data to date in the prevention field (Newton et al., 2022). Moreover, an independent review reported *Climate* programs were one of only two school-based substance use prevention programs in Australia with a strong evidence base (Rowland et al., 2019).

The universal *Climate Schools* programs are underpinned by both social influence theory and harm-minimisation skills building (Newton et al., 2011, 2018). The *Climate Schools* programs address social influence through two approaches. First, it addresses susceptibility to peer pressure through assertiveness skills training. Second, it challenges perceptions of normative substance use by educating students on true estimates of alcohol use in their age group. The program also teaches multiple harm minimisation strategies. These include education and knowledge building on alcohol-related harms, and harm-minimisation strategies such as understanding the alcohol content in different beverages and recognising signs of an emergency and how to respond to keep friends safe if they have been drinking alcohol. The hypothesised mechanisms for change in the *Climate Schools* programs include increasing knowledge of alcohol-related harms, reducing harmful attitudes towards alcohol and other drug use, correcting inflated perceptions of peer alcohol and other drug use, and enhancing self-efficacy to resist peer pressure. However, it remains unclear whether these are potential active mechanisms that lead to reduced alcohol and other drug consumption and harms among those who receive the intervention. The present study aimed to address this gap by investigating potential mediators of the success of the *Climate Schools: Alcohol and Cannabis course*.

In one of the earliest studies to investigate potential mediators of school-based substance use prevention, Botvin and colleagues (1995) investigated three possible mediators of program effectiveness to reduce alcohol consumption: anti-alcohol attitudes, refusal assertiveness, and risk taking. Using regression analyses on mediators and outcomes at post-intervention ($N=456$), the authors found that all three variables significantly mediated the effects of the program on alcohol consumption frequency, quantity, and drunkenness. That is, the program improved attitudes and assertiveness and lowered risk taking, and this in turn was associated with reductions in alcohol consumption. These findings have been extended in further research on the Life Skills Training program, which suggest peer normative expectations, behavioural intentions and social competence may also mediate the effects of the intervention on substance use (Botvin & Griffin, 2015).

Research from a different group used structural equation modelling to investigate the effects of a school-based drug prevention program, project ALERT ($N=4,689$), on alcohol and cigarette use (Orlando et al., 2005). The authors hypothesised that resistance self-efficacy, beliefs about the consequences of substance use (e.g., drinking alcohol gets you into trouble; drinking alcohol relaxes you) and peer influence would mediate the effects of ALERT on alcohol use. Contrary to other findings, Orlando et al. (2005) found that only positive beliefs about consequences of substance use mediated the effects of the intervention on alcohol misuse at the same time point. Another study investigated potential mediators of project ALERT Plus in at-risk girls (Longshore et al, 2007). They found that friend's respect for not drinking, and positive and negative beliefs about alcohol consumption consequences at 30-month follow-up mediated the effect of the program on weekly alcohol use and high-risk drinking (Longshore et al., 2007).

Studies on prevention of other substances (e.g., tobacco, cannabis) have also reported significant mediation effects. For instance, one study used multilevel multiple mediation to investigate mediators of the European 'Unplugged' program ($N=7,079$), a school-based substance-use prevention program. Findings from this study suggest the program increased refusal skills, decreased positive attitudes, and reduced perceptions of peer tobacco and cannabis use, all of which were associated with an attenuation of use of these substances at the same post-intervention measurement (Giannotta et al., 2014). In contrast, a study of the Mobilizing Youth for Tobacco Related Initiatives program in India ($N=14,085$) used both single and multiple mediator analysis (Harrell Stigler et al., 2011). They found that knowledge of health consequences, reasons to use (and not to use), self-efficacy and normative beliefs about tobacco use all mediated the effect of the intervention on tobacco use in single mediator models. However, when these variables were included in a multiple mediation model, only reasons to use and normative beliefs remained significant (Harrell Stigler et al., 2011).

Although promising, existing studies of substance use prevention program mediation effects have somewhat inconsistent findings and have room for methodological improvement. Studies have often used mediator variables collected at the same time point as the outcome variable (e.g., Botvin et al., 1995; Giannotta et al., 2014; Orlando et al., 2005), violating important assumptions of causal effects in mediation. Moreover, past studies have tended to use methodological approaches to mediation that lack robust causal inference. Many studies have also relied on short-term follow-ups (e.g., 3 months, Giannotta et al., 2014), or have had a large amount of time between intervention and follow-up (e.g., 2 years, Botvin et al., 1995). Taking measurements of mediators and outcomes at the same time-point and having large gaps between measurements limits the ability to infer true temporal sequence of mediators and outcomes.

The Current Study

This is the first study to investigate mediators of *Climate Schools*, the Australian substance use prevention program with a strong evidence base. The primary aim of the study was to use novel and robust methods to investigate the mediating effects of social influence and harm-minimisation variables on the impact of the universal *Climate Schools: Alcohol and Cannabis course* on alcohol use and binge drinking at 24 months. To this end, we used causal multiple mediation analyses, couched within a *potential outcomes framework* (Pearl, 2001), to investigate the effects of *Climate Schools* on alcohol use and binge drinking at 24 months, mediated by the social influence and harm minimisation variables at 12-month post-intervention.

Based on the theoretical grounding of the *Climate Schools* program, and prior substance use prevention mediation studies, we hypothesised that:

- Increases in *knowledge of alcohol-related harms and harm minimisation strategies* at 12 months will mediate the effects of the *Climate Schools* program on reducing the odds of alcohol use and binge drinking at 24 months.
- Decreases in *harmful attitudes toward alcohol* at 12 months will mediate the effects of the *Climate Schools* program on reducing the odds alcohol use and binge drinking at 24 months.
- Greater *perception that fewer peers drink alcohol* at 12 months will mediate the effects of the *Climate Schools* program on reducing the odds of alcohol use and binge drinking at 24 months.
- Increases in *self-regulatory efficacy to resist peer pressure* at 12 months will mediate the effects of the *Climate Schools* program on reducing odds of alcohol use and binge drinking at 24 months.

Methods

Design

Data for the current study were derived from a cluster RCT. A total of 26 (17 private, 9 public) schools participated in the study beginning in September 2011. Block randomisation was used to assign each school to one of four study conditions: (1) control, (2) climate, (3) preventure, and (4) climate and preventure. Given the current study was interested in identifying mechanisms for the universal climate intervention, only the control and climate arms of the wider study were selected and analysed. The Consolidated Standard of Reporting Trials (CONSORT) diagram summarizing participant flow and retention rates for the two arms is provided in Fig. 1. The study protocol including informed consent and sample size calculations was approved by the University of New South Wales Human Research Ethics Committee, the Sydney Catholic Education Office, and the New South Wales Department of Education and Training. The trial is registered with the Australian and New Zealand Clinical Trials Registry (Number removed for blinded review).

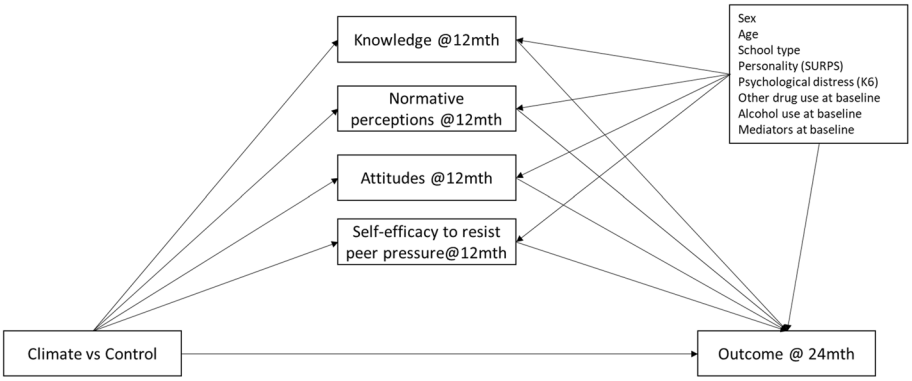

Fig. 1 Hypothesized multiple mediation model of intervention on alcohol-related outcomes

Participants

Only consenting students who also received parental consent and allocated to either the control or climate conditions were included in the current study ($N = 1{,}103$). However, due to missing data on either the outcomes or the included covariates, there were 979 students analysed in total. All students were invited to participate in self-report follow-up assessments immediately post-intervention (approximately 6- to 9-month post-baseline) and 12- and 24-month post-baseline. Study retention was high with 83% at 12-month assessment and 79% at 24-month assessment, with no differences in retention rates across groups.

Interventions

Schools randomised to the climate condition were administered the universal *Climate Schools: Alcohol and Cannabis course* during health education classes. The course comprises 12 lessons of approximately 40 min in duration. The first six lessons were administered in term 1 and the remaining six lesson delivered 6 months later. Each lesson includes a 20-min online cartoon component that is completed individually by all students followed by a 20-min group discussion or class activity facilitated by the teacher. The companion discussion or activity reinforces information delivered during the cartoon presentation and allows communication and interaction between students. All teachers were provided a manual that contained activities, online access to implementation guidelines, links to the education syllabus, and teacher/student summaries for each lesson. All students were provided with individual confidential login details to access the study website, including access to the lesson content and the online assessment/questionnaires. Further detail on the content of each of the lessons is provided elsewhere (Newton et al., 2011).

Schools randomised to the control condition received their usual health education classes administered by each school. Drug and alcohol education is a mandatory part of the year 8 curriculum in Australian schools. Teachers were asked to provide details about the number and format of these lessons. Details on implementation fidelity of the intervention and control group is provided elsewhere (Teesson et al., 2017).

Measures

At baseline, post-intervention, 12-month, and 24-month follow-up, a self-report questionnaire was administered to all students that assessed the primary outcomes as well as demographic data and potential mediating variables.

Outcomes

Alcohol use was assessed by asking students to indicate the frequency with which they had consumed a standard drink (10 mg of pure alcohol) of any kind in the past 6 months ranging from "never" to "daily or almost daily". This variable was dichotomised to indicate the presence of absence of any alcohol use in the past 6 months with "never" vs more than never set as the cut-point. Similarly, *binge drinkin*g was assessed by asking the students how often they consumed five or more standard alcohol drinks on one occasion in the past 6 months ranging from "never" to "daily or almost daily". Again, this variable was dichotomised using "never" and more than never as the cut-point to indicate the presence of absence of any binge drinking in the past 6 months. Both outcomes were dichotomised based on initial inspection of the data indicating alcohol use and binge drinking as a rare event in this population, and therefore, the cells were collapsed to avoid problems with sparse cell counts.

Harm Minimisation Mediators

Knowledge of alcohol related harms and harm minimisation strategies was measured at baseline and all follow-ups using a bespoke set of knowledge questions tailored to the alcohol-related content delivered by the climate intervention. A series of 16 questions were used to assess knowledge in relation to physical and mental health problems, legal consequences, and information requires to minimise harms. Each item was scored as correct or incorrect and the total score summed to range from 0 to 16, with higher scores indicating higher knowledge.

Attitudes toward alcohol were assessed using a 7-item scale developed by the School Health and Alcohol Harm Reduction project (McBride et al., 2004). Each item asks the students to indicate whether they strongly agree, agree, uncertain, disagree, or strongly disagree with statements such as "I know a lot about alcohol", "People my age have a good time at parties when they get drink", etc. Scores on each of the statements are summed to represent a score between 0 and 28 with higher scores indicating harmful attitudes.

Social Influence Mediators

Normative perceptions of alcohol use were assessed by two questions using a 5-point Likert scale designed to determine the proportion of friends and acquaintances that drink any alcohol and the proportion of friends and acquaintances that drink alcohol to get drunk. Responses on the two questions ranged from 0 to 4 representing "All of almost all", "More than half", "About half", "Less than half", and "None". Scores on both questions were

summed and ranged from 0 to 8 with higher scores indicating the perception of a lower proportion of friends/acquaintances who use/used alcohol.

Participant beliefs in their *self-regulatory efficacy to resist peer pressure* to engage in high-risk activities were measured using eight items design to measure the perceived efficacy to refuse use of alcohol and other drugs, as well as to refuse to engage in other types of transgressive behaviours. The measure was adapted from an original 10-item scale developed by Bandura et al., (2003), but with items relating to "the use of crack" and "sexual intercourse" omitted due to population relevance and ethical concerns. Each of the eight items was ranked on a 7-point scale ranging from "not well at all" to "very well" and individual items were summed to generate total scores ranging from 0 to 48 with higher scores representing higher resistive self-regulatory efficacy.

For all scale scores (knowledge, normative perceptions, attitudes, self-efficacy to resist peer pressure), the total scores were calculated using a prorated approach, meaning that any student who had completed 80% or more of the items were assigned a total score (either the full number of items was summed or the mean score on the other items was allocated in place of missing items prior to summing). In the instance where less than 80% of the items were missing, the total score of that participant would be coded as missing.

Statistical Analysis

Causal multiple mediation analysis was conducted via structural equation modelling. The models were estimated using a robust maximum likelihood (MLR) estimator with a probit link (suitable for the binary outcome variables) (detailed more in Nguyen et al., 2016). Separate models examined the effects associated with: (1) any alcohol use (full standard drink) in the past 6 months at the 24-month follow-up time point and (2) binge drinking in the past 6 months at the 24-month follow-up time point. All mediators were measured at the 12-month follow-up timepoint. Group assignment to either the climate group or control group at baseline was included as the exposure variable. All four mediators were included in a single mediation analysis to determine the combined effects. The mediators and outcome models controlled for sex, age, school type, personality scores (as measured by the Substance Use Risk Profile Scale; Woicik et al., 2009), Kessler 6 psychological distress scores (Kessler et al., 2002), and other drug use at baseline. Using a method described in Nguyen et al. (2016), the combined natural direct and indirect effects of the multiple mediators, as well as the total effect, were calculated on the risk difference (RD) scale with standard errors and 95% confidence intervals estimated in 500 bootstrap samples.

The causal mediation analysis implemented in the current study generates several direct and indirect effect measures based on the potential outcomes or counterfactual framework. Causal mediation models differ from traditional mediation models by the inclusion of an exposure-mediator (XM) interaction. Therefore, the magnitude of the direct effect is dependent on the mediator values and the magnitude of the indirect effect is dependent on the exposure values. The pure natural direct effect (PNDE) is interpreted as the direct effect of the exposure variable (e.g., climate vs control) on the outcome but holding the mediators at a constant value equal to what they would naturally be observed in the control group. The total natural indirect effect (TNIE) is interpreted as the indirect effect of exposure variable on the outcomes due to changing the mediators as if by changing from control to intervention but at the same time fixing the exposure variable to the climate group. Finally, the total effect is calculated as the intervention effect on the outcome that comes both directly and indirectly through the mediators, i.e., the sum the PNDE and TNIE.

For the results to be interpreted as causal, several strong assumptions are required: (1) no unmeasured treatment-mediator confounding, (2) no unmeasured treatment-outcome confounding, (3) no unmeasured mediator-outcome confounding, (4) no mediator-outcome confounder that is influenced by the treatment, and (5) no mediator-mediator interaction in influence the outcome (in the case of multiple mediators). It can be argued that the first and second assumptions can be handled by the randomised assignment of the sample to intervention and control conditions. However, to increase the plausibility of the no unmeasured confounding assumptions, models controlled the mediator variables at 12-month follow-up for the respective mediator at baseline and controlled the outcome at 24-month follow-up for the respective outcome at baseline (as well as additional covariates described previously). Moreover, each mediator was allowed to be predicted by each of the other mediator values at baseline. All mediation models were estimated in Mplus version 8.1. The marginal means, variances, and covariances of the mediation model were estimated by correcting standard errors for clustering of students in schools using the type = COMPLEX feature of Mplus.

Sensitivity Analysis

Traditional sensitivity analysis, proposed by Imai et al. (2010), for causal mediation with more than two mediators is not currently available (Nguyen et al., 2016). However, it is possible that some potential unmeasured confounders were not controlled for in the analysis, despite including an extensive list of potential covariates in the mediation models. To identify the robustness of the results, *E*-values were calculated that represent the required strength of an association between an unmeasured confounder and the treatment, mediators and outcomes that would make the identified associations statistically non-significant (VenderWeele & Ding, 2017). *E*-values are presented on an odds ratio or rate ratio scale with values close to 1 indicating less confidence that the results are robust against unmeasured confounders.

Results

Any Alcohol Use (Standard Drink)

The unstandardized parameter estimates from the hypothesized multiple mediation model of the intervention on alcohol use are provided in Fig. 2. The estimates generated in this model were used to estimate the prevalence derived from the interaction between outcome and mediators that results in four estimates under different hypothetical situations, e.g., p00 = prevalence of use for the control group with mediators set at the control levels, p11 = prevalence of use for the intervention group with mediators set at the intervention levels, p10 = prevalence of use for the intervention group with mediators set at the control levels, p01 = prevalence of use for the control group with mediators set at the intervention levels.

The potential prevalence of any alcohol use in the past 6 months at 24-month follow-up is estimated to be p00 = 36.3% (95% CI = 32.1, 41.3) had the whole sample been in the control condition and p11 = 26.2% (95% CI = 22.4, 30.6) had the whole sample been in the climate condition. Under the hypothetical situation that the whole sample participated in the intervention, but the mediators were kept at control levels, the potential prevalence was

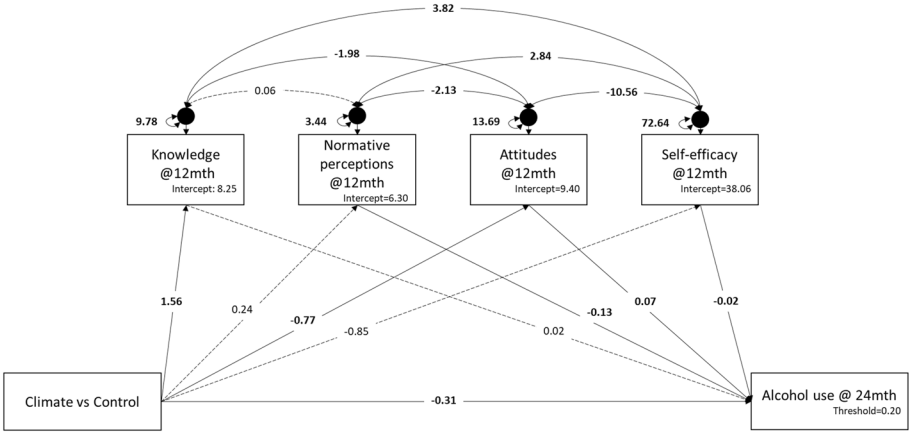

Fig. 2 Unstandardized coefficients for hypothesized multiple mediation model of intervention on alcohol use. Bold estimates and solid lines signify significance at $p < 0.05$. Model also include covariates that are excluded from the figure for simplicity (sex, age, school type, personality, psychological distress, other drug use at baseline, alcohol use at baseline, mediator values at baseline)

p10 = 27.4% (95% CI = 23.3, 32.0). Finally, under the hypothetical situation that the whole sample participated in the control, but the mediators were kept at the intervention levels, the potential prevalence was p01 = 34.9 (95% CI = 29.9, 40–1).

Based on the potential outcomes described above, the total effect of the climate intervention on this sample resulted in a decreased prevalence of past 6-month alcohol use at 24-month follow-up of 10.1% (95% CI = 3.8, 16.4) via both direct and indirect pathways. Of this total effect, the PNDE indicates that the prevalence of past 6-month alcohol use was 8.9% (95% CI = 2.5, 15.1) lower for the climate group than control group fixing the values of the mediators to that of the control group, i.e., the effects of the mediators were blocked and the influence of intervention on alcohol use occurred directly. The TNIE indicates that the prevalence of 6-month alcohol use was 1.2% (95% CI = − 1.4, 3.5) lower for participants allocated to climate group allowing the mediators to change in a manner that they would from control to climate groups, i.e., the indirect effect on the outcomes due to the influence of the climate intervention via the four mediators. Given the 95% confidence intervals for the TNIE contain zero, there was no evidence of a significant combined mediation effect of knowledge, normative perceptions, attitudes, and peer pressure on any alcohol use.

Binge Drinking

The unstandardized parameter estimates from the hypothesized multiple mediation model of the intervention on binge drinking are provided in Fig. 3. The potential prevalence of binge drinking in the past 6 months at 24 month follow-up is estimated to be p00 = 22.5% (95% CI = 18.3, 26.4) had the whole sample been in the control condition and p11 = 13.5% (95% CI = 10.1, 17.4) had the whole sample been in the climate condition. Under the hypothetical situation that the whole sample participated in the intervention, but the mediators were kept at control levels, the potential prevalence was p10 = 15.2% (95% CI = 11.2, 19.7). Finally, under the hypothetical situation that the whole sample participated in the

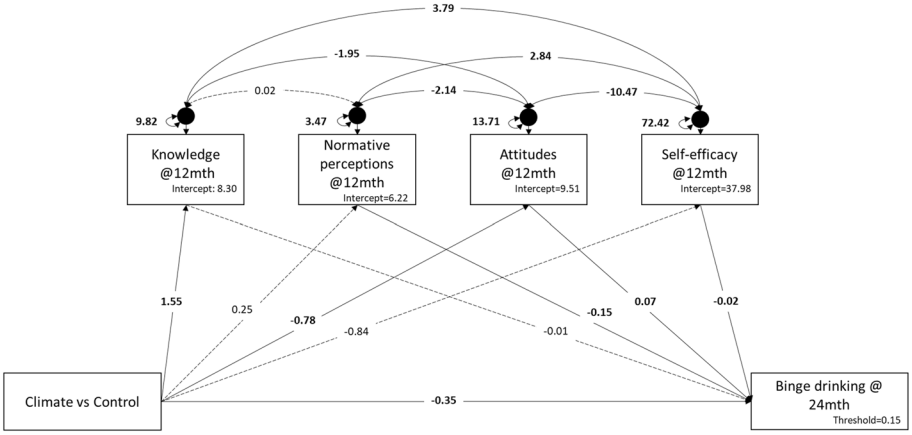

Fig. 3 Unstandardized coefficients for hypothesized multiple mediation model of intervention on binge drinking. Bold estimates and solid lines signify significance at $p < 0.05$. Model also include covariates that are excluded from the graph for simplicity (sex, age, school type, personality, psychological distress, other drug use at baseline, alcohol use at baseline, mediator values at baseline)

control, but the mediators were kept at the intervention levels, the potential prevalence was p01 = 20.3% (95% CI = 16.2, 24.8).

Based on the above potential outcomes, the total effect of the climate intervention on this sample resulted in a significantly decreased prevalence of past 6-month binge drinking at 24-month follow-up by 9.1% (95% CI = 3.5, 14.5) via both direct and indirect pathways. Of this total effect, the PNDE indicates that the prevalence of past 6-month binge drinking was 7.4% (95% CI = 1.5, 12.7) lower for the climate group than control group, i.e., the direct effect of the intervention on outcome blocking out the potential indirect effects of the mediators. The TNIE indicates that the prevalence of 6-month binge drinking was 1.7% (95% CI = −0.1,3.4) lower for participants in the climate group allowing the mediators to change in a manner that they would from control to climate groups, i.e., the indirect effect of climate on the outcomes via the influence of four mediators. Like the findings for alcohol use, there was no evidence of a significant combined mediation effect of the four mediators on binge drinking due to the 95% confidence intervals of TNIE containing zero.

Assuming the plausibility of the no unmeasured confounding assumptions, these effects could be interpreted as causal. That is, the direct effect of the intervention on students results in a significant decrease in alcohol use and binge drinking at the 24-month period by 8.9% and 7.4%, respectively. The remaining, albeit non-significant, indirect effect could be causally attributable to the combined effects of the four mediators; however, inspection of the mediation models in Figs. 2 and 3 suggests that changes in alcohol attitudes may be predominately driving this remaining indirect effect.

Sensitivity Analysis

The *E*-values for significant associations in the mediation models are presented in Table 1 and provide some indication regarding the plausibility of the no unmeasured confounding assumptions. For the direct effect of the intervention on alcohol use and binge drinking, the *E*-values were 2.07 and 2.17, respectively. Therefore, an unmeasured confounder that is associated with both the climate intervention and alcohol outcomes by a risk ratio of

Table 1 *E*-values for the mediation models of alcohol use and binge drinking

Alcohol use model			Binge drinking model		
IV	DV	*E*-value	IV	DV	*E*-value
Intervention	Knowledge	2.38	Intervention	Knowledge	2.38
Intervention	Normative	NA	Intervention	Normative	NA
Intervention	Self-efficacy	NA	Intervention	Self-efficacy	NA
Intervention	Attitudes	1.65	Intervention	Attitudes	1.66
Intervention	Alcohol use	2.07	Intervention	Binge drinking	2.17
Knowledge	Alcohol use	NA	Knowledge	Binge drinking	NA
Normative	Alcohol use	1.54	Normative	Binge drinking	1.59
Self-efficacy	Alcohol use	1.14	Self-efficacy	Binge drinking	1.14
Attitudes	Alcohol use	1.37	Attitudes	Binge drinking	1.34

Note: NA indicates associations that were not significant at the $p < 0.05$ level. Models also adjusted for sex, age, school type, personality, psychological distress, other drug use at baseline, alcohol use at baseline, and mediator values at baseline

2.07 and 2.17, above and beyond the measured covariates, could explain away the observed association but weaker confounding could not. Given the inclusion of several strong measured covariates, we anticipate the unmeasured confounders of this magnitude to be unlikely. The remaining significant associations between exposure and mediators and mediators and outcomes demonstrated *E*-values close to 1, except for those association with the intervention and knowledge (*E*-value = 2.38), potentially reducing confidence that the models have adequately accounted for potential confounders of the mediating relationships.

Discussion

The current manuscript reports on the first study to use a *potential outcomes framework* to investigate multiple, theoretically guided, mediators of the *Climate Schools* program. Overall, there was an 8.9% and 7.4% reduction in past 6-month alcohol use and past 6-month binge drinking attributed directly to the intervention. Given some degree of caution based on the strict assumptions of causal inference and the modest *E*-values, these reductions in alcohol use could be considered causal. However, the study did not find sufficient evidence of the hypothesized joint mediation model of knowledge, attitudes, normative perceptions, and resistance self-efficacy indirectly mediating the association between intervention and alcohol use outcomes. Inspection of the individual mediating pathways provided in Figs. 2 and 3 provides some indication of a small indirect association via attitudes towards alcohol that is harmful attitudes towards alcohol leads to higher rates of drinking and the intervention is associated with reductions in harmful attitudes. However, the relatively small *E*-values generated from these associations suggest that this result should be interpreted with caution as it is plausible that small associations with unmeasured confounders could account for these observable associations.

The other significant association between the intervention and the mediators that emerged in the current study are related to that of improved knowledge. As can be seen in Figs. 2 and 3, the intervention was associated with a mean increase of approximately 1.5 correct answers to the knowledge scale in comparison to the control. However, there

was no evidence that this increase in knowledge of alcohol-related harms significantly reduced alcohol use outcomes, that is, increased knowledge did not translate into changes in behaviour. These findings suggest that, at least in terms of the *Climate Schools: Alcohol and Cannabis course*, increases in knowledge may represent a proxy for attention or comprehension of the key messages in the program, but these increases cannot explain the observed intervention effect. Indeed, a previous survey of 1381 young people aged 16–29 indicated that despite having knowledge of alcohol-related risks, many young people continued to consume alcohol at harmful levels (Bowring et al., 2012). The study concluded that factors such as social norms, environment, self-efficacy, and cues to action might be additional modifiers of alcohol use outcomes, as well as external contextual factors such as non-standardised serving sizes, price, marketing, setting, and variations in alcohol availability acting as potential barriers to behaviour change (Bowring et al., 2012). Similarly, mass media campaigns that seek to reduce alcohol consumption have often demonstrated changes in knowledge about alcohol but offer little evidence of corresponding reductions in alcohol consumption (Young et al., 2018). These prior studies provide further evidence of the importance that different contexts and drinking settings might have on the ability to translate improvements in knowledge into behaviour change.

Although the study did not find evidence for normative perceptions and self-efficacy to resist peer pressure as mediators, the individual path diagrams provide a more nuanced picture and revealed there was some evidence that normative perceptions and ability to resist peer pressure were significantly related to alcohol use outcomes (i.e., increases in normative perceptions and ability to resist peer pressure were significantly associated with decreased alcohol use and binge drinking). However, there was no evidence to suggest the intervention had a significant influence on changing normative perceptions and the ability to resist peer pressure. As such, it is possible that the intervention components may not have targeted these domains with sufficient intensity to have any substantive benefit at the 12-month follow-up occasion. The current study potentially suggests that improvements to the intervention that result in additional targeting of normative perceptions and ability to resist peer pressure may have downstream effects of reducing alcohol use and binge drinking at a greater rate than currently observed.

The primary question then remains, if the hypothesized mediators are not significantly and jointly mediating the total effect of the *Climate Schools* intervention on alcohol use outcomes, then what is? One additional hypothesis could be the influence of friends and social/peer circles as well as the broader social and cultural context in which students and schools are situated. Indeed, recent evidence has emerged from social network analysis that suggests drinking outcomes can be influenced by both selection and influence (Henneberger et al., 2021). For example, an individual might actively seek out peers with similar drinking levels and/or might be influenced by existing peers drinking levels. Whilst the current study did measure subjective judgements of normative drinking, more refined, nuanced, and objective measures of the dynamics of social networks are required in a potential mediation model. Further research would benefit from investigating if an intervention could alter the dynamics of social networks and the broader context of those social networks that could then have additional impact on drinking outcomes, possibly via both influence and selection hypotheses (McCann et al., 2019). This potential hypothesis is supported by previous evidence that have found a "herd" effect in prevention programs suggesting that targeted interventions can translate from a high-risk group who received the intervention to the broader school environment, including school children who did not receive the intervention (Conrod et al., 2013).

An additional hypothesis centres around *Climate Schools* focus on social connectedness and the building of a universal supportive environment regarding substance use rather than a punitive and abstinence-based approach. The educational component of *Climate Schools* seeks to develop literacy around alcohol and other drug use, for example, putting a language around the problems faced by young people who use alcohol and other drugs and provide awareness that it is helpful to talk about these issues with trusted adults, teachers, and peers. Yet despite these significant components of the *Climate Schools* program, the current study did not sufficiently measure these broader constructs of social support, connectedness, and culture. Future research could investigate the impact of school-culture, alcohol and other drug literacy, and supportive environments as potential mediators, moderators, or in moderated mediation analyses. For example, the influence of improved alcohol and other drug knowledge may have a greater impact on drinking behaviours in supportive vs non-supportive environments. Alternatively, the influence of the intervention may alter help-seeking or other harm minimisation behaviours that result in decreased alcohol consumption, which may also be moderated by the overall context and peer/parental factors that provide an open and supportive dialogue regarding substance use rather than a closed and punitive environment.

The current study has several strengths, including a large school-based sample, multiple longitudinal measures over a 24-month period, and the use of modern casual mediation methods to examine the impact of a joint mediation model. However, there are notable limitations that require further consideration. First, the primary outcomes and mediating variables were all measured using self-report scales. Previous evidence, particularly for measures of adolescent alcohol use and externalizing behaviours, have suggested that self-report biases and errors may influence reporting (Koning et al., 2010). Hence, future studies would benefit from inclusion of more objective measure or peer-, teacher-, or parent-rated measures to supplement self-report. However, the measures selected for the current study all represent highly validated and reliable measures of the constructs of interest. Self-report measures also provide a highly feasible method to obtain information from students in large samples whilst keeping response burden at a minimum. Second, despite inclusion of an extensive list of covariates, there is the possibility of unmeasured confounding that could influence the results of the current study and bring into question the causal nature of the associations. Indeed, the *E*-value analysis highlighted that some of the associations between the mediating variables and the outcomes could be particularly susceptible to unmeasured confounding. However, the direct associations between the intervention and outcomes were relatively robust and with some degree of caution could be interpreted as causal in nature. Third, extensive efforts were made to accurately measure the mediating variables based on theoretical and hypothesized model of harm minimisation and social influence, however the quality of the measurement for some of the mediators, e.g., normative perceptions, may not have adequately captured the targeted constructs and possibly resulted in the null findings demonstrated here. Additional studies would benefit from use of more objective and informative measures, particularly for constructs that represent social connectedness and peer support structures.

The current study demonstrated that a universal school-based prevention program for alcohol and cannabis use had a significant and potentially direct causal influence on alcohol use and binge drinking behaviours at 24-month follow-up. However, the study did not find sufficient evidence for a joint mediation model representing knowledge, attitudes, normative perceptions, and self-efficacy to resist peer pressure accounting for any indirect associations. Despite the promising results in reductions in use of alcohol, more research

is needed to examine how the *Climate Schools* interventions, and similar school-based programs, are working.

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Declarations

Conflict of Interest Nicola Newton and Maree Teesson have reported they are two of the developers of the Climate Schools programs and have reported they are directors of Climate Schools Pty Ltd., a social enterprise established in 2015 to distribute the Climate Schools programs and maximise social well-being. All other authors declare no competing interests.

Consent to Participate All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all participants for being included in the study.

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