

Understanding Youth Trajectories of Alcohol Use: Evaluating
the Impact of a Policy of Authorizing Alcohol Sales in Some
Grocery Stores in Ontario

by

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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Doctor of Philosophy
in
Public Health and Health Systems

Waterloo, Ontario, Canada, 2019

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This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

This thesis consists in part of three manuscripts that have been submitted for publication.

Exceptions to sole authorship:

Chapter 6: Gohari MR, Cook RJ, Dubin JA, Leatherdale ST. (Under review). Identifying patterns of alcohol use among secondary school students in Canada: a multilevel latent class analysis. *Addictive Behaviors*.

Chapter 7. Gohari MR, Dubin JA, Cook RJ, Leatherdale ST. (Accepted). Identifying trajectories of alcohol use among a sample of secondary-school students in Ontario and Alberta: longitudinal evidence from the COMPASS study. *Health Promotion and Chronic Disease Prevention*.

Chapter 8. Gohari MR, Cook RJ, Dubin JA, Leatherdale ST. (under review). The impact of an alcohol policy change on developmental trajectories of youth alcohol use: examination of a natural experiment in Canada. *Canadian Journal of Public Health*.

As lead author of these three chapters, I was responsible for conceptualizing the study design, contributing to the data collection, conducting the data analysis, and drafting and submitting manuscripts. My co-authors provided guidance during each step of the research and provided feedback on draft manuscripts. Dr. Leatherdale provided significant direction throughout.

Under Dr. Scott Leatherdale's supervision, I also prepared the remaining chapters in this thesis, which were not written for publication.

Abstract

The latest change in the policy of the Liquor Control Board of Ontario (LCBO), enacted in December 2015, authorizes the sale of alcohol in 450 grocery stores that previously had not sold alcohol. This policy change increased the availability of alcohol to the province's population in terms of the number of off-premise alcohol outlets, hours and days of sale. Since alcohol consumption is highly prevalent among Canadian youth, the new LCBO policy may result in a change in youth alcohol use patterns. The youth population is heterogeneous with respect to alcohol use patterns, and there exist several distinct patterns of alcohol use among youth each representing a subgroup of the population. As these subgroups differ in patterns of use, their responses to changes in alcohol-related policies could likewise differ. Given the numerous immediate and long-term adverse health outcomes associated with alcohol consumption, evaluation of the impact of the new LCBO policy on each subgroup of the population is a public health priority.

The research presented in this dissertation research used longitudinal data to examine the impact of the new LCBO policy on youth alcohol use patterns in a quasi-experimental setting with two control groups, one in Ontario and the other in Alberta. The objectives were to (1) identify patterns of alcohol consumption among the youth population, (2) investigate differences in alcohol use patterns across secondary schools, (3) estimate the probabilities of transitioning between drinking patterns over time, (4) examine how individual- and school-level covariates predict patterns of alcohol use and transitioning between the patterns, and (5) evaluate any impact of the new LCBO policy on changes in the alcohol use patterns of youth in the exposed jurisdictions by means of pre- and post-policy assessment. Three manuscripts served these objectives all using student- and school-level data from the COMPASS study.

The first manuscript identified latent classes (patterns) of youth alcohol consumption and investigated whether the size of latent classes vary by school. The multilevel latent class analysis identified four student-level latent classes and two school-level latent classes. Student-level classes of youth alcohol use were characterized as non-drinkers (had never consumed alcohol or did not drink in past year, 44.2% of the sample), light drinkers (initiated alcohol consumption at

age 14 or later and consumed alcohol up to 3 times a month, with one time binge drinking, 41.8% of the sample), regular drinkers (initiated drinking before age 14 and consumed alcohol 1 to 3 times a week and undertook binge drinking 2 to 4 times a month, 11.1% of the sample), and heavy drinkers (initiated drinking before age 14 and consumed alcohol on a nearly everyday basis, with binge drinking more than once a week, 2.9% of the sample). Two groups of schools were characterized, one as low-use [schools with a relatively large number of non-drinkers (n=40, 44.9% of schools)] and the other as high-use [schools with higher rates of regular and heavy drinkers (n=49, 55.1%)]. Male students (OR=1.30) and upper grades (OR=1.93) were significantly associated with membership in higher use groups. The number of off-premise alcohol outlets and the median household income was not significantly associated with membership in school-level latent classes.

The second manuscript estimated the probabilities of maintenance or change between the identified drinking patterns two years before the LCBO policy change. Latent transition analysis of longitudinal data identified a similar number of latent classes with slightly different structures. LTA identified four latent classes: non-drinker, periodic drinker (reported drinking up to 3 times a month and no binge drinking), lower risk drinker (reported drinking up to 3 times a month and once or less than a month binge drinking), and high-risk regular drinker (reported drinking 1-3 times a week and binge drinking 2-4 times a month). The results of the second manuscript suggest that alcohol consumption tends to increase among those who start, but the volume of increase is not the same across all populations of youth. The greatest risk of increasing consumption was observed among the periodic drinker group: 40% of periodic drinkers demonstrated not only an increase in their consumption but also reported occasions of binge drinking at the follow-up year, when previously they had not engaged in binge drinking at all. Overall, the proportion of individuals engaged in some level of binge drinking rose from 21.2% at baseline to 33.9% at follow-up. The manuscript suggests that some youth do quit drinking or reduce the level of their consumption over time. Nearly 10% of low risk or high-risk regular drinkers were likely to have stopped drinking one year later at the follow-up. The results indicate that the use of either cigarettes or cannabis is markedly associated with greater risk of membership in higher risk drinking classes.

The third manuscript examined changes in probabilities of transitioning between the four identified patterns of alcohol use among subpopulations in the exposed jurisdiction, using the two control cohorts (respectively in Ontario and Alberta) before and after the new LCBO policy. The transition probabilities estimated by latent transition analysis suggest that the new LCBO policy has no negative impact on the periodic and low-risk drinker groups that comprise 57% of the population. In contrast, there is a negative impact among non-drinker and high-risk regular drinker groups as the lowest and highest risk groups, respectively. In communities with alcohol available in grocery stores, the lowest risk group (non-drinker) were more likely to transition to the highest risk group (high-risk regular drinker), and individuals in the highest risk group indicated a higher likelihood of maintaining their behaviour. Comparison of the prevalence of high-risk regular drinking among the three cohorts indicated that youth in the exposed jurisdictions had the highest rate of increase during the follow-up years.

This dissertation enhances our knowledge of alcohol use patterns in Canadian youth, the developmental stages of alcohol use over time, and the impact of the new LCBO policy on alcohol use patterns of the youth population. This work signals the need for continued efforts to delay alcohol initiation of abstainers as the primary prevention and to promote the transition from drinking to reducing or quitting among drinkers. This dissertation illustrates that following the increase in physical availability of alcohol in the jurisdictions exposed to the new LCBO policy, the probability of high-risk regular drinking among youth has increased. Abstainers in the exposed jurisdictions had a higher risk of being regularly engaged in high-risk drinking compared to youth in unexposed jurisdictions. Further, high-risk regular drinkers are more likely to maintain their behaviours following the policy change. This research provides scientific, documentary and timely evidence on the impact of the new alcohol policy on specific subgroups of the youth population separately. This evidence can fuel and support initiatives to reduce harm of youth alcohol consumption. Moreover, the analytic approach used offers a template for future evaluations of the impacts of public policy changes, for instance, to examine patterns of cannabis use in view of federal Cannabis legalization.

Acknowledgements

The COMPASS study was supported by a bridge grant from the Canadian Institutes of Health Research (CIHR) Institute of Nutrition, Metabolism and Diabetes (INMD) through the “Obesity – Interventions to Prevent or Treat” priority funding awards (OOP-110788; grant awarded to S. Leatherdale) and an operating grant from the Canadian Institutes of Health Research (CIHR) Institute of Population and Public Health (IPPH) (MOP-114875; grant awarded to S. Leatherdale), a CIHR Project Grant (PJT-148562; grant awarded to S. Leatherdale), a CIHR Project Grant (PJT-149092; grant awarded to K. Patte), and by a research funding arrangement with Health Canada (#1617-HQ-000012; contract awarded to S. Leatherdale).

I would like to express my deepest appreciation to my supervisor, Dr. Scott Leatherdale, for four years of support, encouragement, and help. Scott, you are the ultimate role model of a supervisor. You believed in me and gave me the opportunity to be part of your amazing research team. Not only did your support help me achievement the best work I am capable of, it allowed me to settle into my new community and country with confidence and optimism for a productive future.

Thank you!

My sincere thanks are due to Dr. Richard Cook whose expertise was invaluable in formulating the research analyses, so that I could proceed with confidence. I would also like to extend my gratitude to Dr. Joel Dubin for sharing his valuable insights and critical feedback through many manuscript drafts.

Throughout the writing of this dissertation, I have received a great deal of support and assistance from the Writing and Communicating Centre at the University of Waterloo. In particular, thank you Jane Russwurm and Mary McPherson.

Thank you Dr. Katelyn Godin for the many office chats to talk through papers, projects, and life. I feel incredibly lucky to have you as an officemate/lab-sister. Thank you Dr. Alex Zuckerman, for your feedback throughout the manuscripts of this dissertation and for the many times we

talked through ideas. Thank you Chad Bredin for your ongoing efforts to keep the project supplied with reliable and valid data. I have been fortunate to be a part of the COMPASS team and to work with this amazing group of graduate students and postdocs. Thank you all for wonderful emotional support, brilliant research ideas, and parties!

Now to thank my dear family. First of all, an enormous thanks to my parents, whose love and guidance are always with me. Thank you for the sacrifices you made to ensure I had the best education possible. Most importantly, I'm deeply indebted to Raheleh, my wife, for her continued support and nurturing. It was she who suggested that I start this amazing journey. I could not have completed my studies if she had not lightened my burdens by taking them on herself. A huge thanks to Baran, our wonderful daughter, and Kian, our little son, for giving unending inspiration and providing some of the best moments during the times we played together. Words cannot express how much I love you all.

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List of Terms

Alcohol use

In this study, consistent with other research, alcohol use means a drink of alcohol that was more than just a sip. The frequency of alcohol consumption during past year of each wave of the study was measured through a self-reported questionnaire.

Binge drinking

The binge drinking in the present study is defined as five drinks of alcohol or more on one occasion. The frequency of binge drinking during past year of each wave of the study is measured through a self-reported questionnaire.

Youth

This study focuses on youth that is defined as secondary-school students in grades 9 to 12.

The Liquor Control Board of Ontario

The Liquor Control Board of Ontario (LCBO) refers to a Crown corporation that controls and regulates production, distribution, and sales of alcohol across the province of Ontario.

The new Liquor Control Board of Ontario (LCBO) policy

The latest change in the liquor control board of Ontario (LCBO) policy that took place in December 2015 authorized up to 450 stores across the province to sell alcohol.

On-premise alcohol outlet

In this study, on-premise alcohol outlet refers to a store that you can purchase alcoholic beverages and consume there, including bars and restaurants.

Off-premise alcohol outlet

A store that you can purchase alcoholic beverages, but you cannot consume there, including Liquor Control Board of Ontario (LCBO) stores, The Beer stores, and The Wine Stores.

Natural experiment

Natural experiment is an experiment when an intervention is implemented but the circumstances around the intervention are not under the control of researcher.

Chapter 1

Background

Youth consumption of alcohol is a critical public health concern in Canada with several immediate and long-term outcomes. The prevalence of drinking among Canadian youth 15 to 19 years old is 60%, and among them nearly 46% are binge drinkers (more than five drinks per occasion) (Public Health Agency of Canada, 2016). According to world health organization (WHO), Canadian youth aged 15-19 are responsible for an estimated 12.3% of consumption in Canada, with specific gender rates of 18.3% for males and 6.3% for females (Public Health Agency of Canada, 2016; World Health Organization, 2015). Many Canadians begin drinking before age 15 (Public Health Agency of Canada, 2016). Fifty percent of the high school students in Canada who have consumed alcohol at least once report having had their first drink between the ages of 12 and 14; among them, 73% reported having been drunk (Asbridge, Cartwright, Wilson, & Langille, 2016; Public Health Agency of Canada, 2016).

Alcohol consumption imposes significant costs to the individual and society from both a health and financial perspective. In response, many policies and programs have been developed and implemented to prevent youth from alcohol initiation or to decrease the levels of consumption using various approaches. One common key factor among all approaches is reducing the availability of and accessibility to alcohol through strictly regulating the production, distribution, and sale of alcohol (Gruenewald, Johnson, & Treno, 2002; Wagenaar, 1995). Past research indicates that physical availability of alcohol in terms of number of alcohol outlets in both on- and off-premises forms is a key contributor to alcohol consumption and alcohol-related harm (Campbell et al., 2009; Jackson et al., 2014; Thern et al., 2017; Treno et al., 2013). For example, the results of study by Rowland et al. (2016) suggested that a 10% increase in alcohol outlet density is related to a 17% increase in youth alcohol consumption. The results showed that increase in the number of alcohol outlets was associated with higher likelihood of early initiation of drinking. Previously, Stockwell and colleagues (2009) had found the number of alcohol stores to be positively associated with per capita sales across 89 regions of British Columbia. Further, following privatization of off-premise alcohol sales in British Columbia, the rate of alcohol-related deaths significantly increased by 3.25% for each 20% increase in private store density (Stockwell et al., 2011).

The latest change in the liquor control board of Ontario (LCBO) policy (henceforth this policy will be referred to as the LCBO policy) that took place in December 2015 authorized up to 450 stores across the province to sell alcohol. This has increased the physical availability of alcohol to the youth population (as well as all other age groups), in terms of the number of off-premise alcohol stores and days and hours of sale. Irrespective of clear and rigorous regulation accompaniment, the new LCBO policy brought a new source of alcohol to youth that may change their patterns of alcohol consumption. As past research has shown, the harm of alcohol use depends not only on the volume of consumption but also drinking patterns. How frequently and how much an individual drinks can increase or decrease the alcohol-related consequences (Degenhardt, Stockings, Patton, Hall, & Lynskey, 2016; Gilmore et al., 2016). As a result, the potential impact of the policy change on public health warrants the need for an evidence-based evaluation of the latest change on LCBO policy.

There is growing evidence that the youth population is heterogeneous with respect to alcohol use patterns (Auerbach & Collins, 2006; Peterson, Davis, & Smith, 2018; Romelsjö, 2010). Accordingly, the youth population can be classified into distinct subgroups, such as low frequency, low quantity, no heavy episode drinkers and high frequency, high quantity, heavy episode drinkers. Moreover, despite the virtually-universal shift toward a rapid increase in alcohol use during adolescence, the timing and developmental trajectories of use differ greatly among subgroups of the youth population (Hix-Small, Duncan, Duncan, & Okut, 2004; Malone, Northrup, Masyn, Lamis, & Lamont, 2012; McBride, Adamson, Cheng, & Slade, 2014). As these subgroups differ in patterns of alcohol consumption, their responses to changes in alcohol-related policies could likewise differ (Snowden, 2016). For example, one can expect that in response to an increase in the physical availability of alcohol, individuals who begin alcohol consumption in early adolescence will be more likely to be engaged in heavy drinking compared to individuals who begin drinking in late adolescence.

This dissertation evaluated the impact of the new LCBO policy on youth alcohol use patterns in jurisdictions with alcohol in grocery stores within a natural experiment context. Specifically, alcohol use trajectories of distinct subgroups of the youth population in the exposed jurisdictions were compared to the trajectories of their peers in two control cohorts in Ontario and Alberta. Using three longitudinal cohorts of youth in Ontario and Alberta, this research (1) identified alcohol use patterns among a sample of Canadian youth populations; (2) estimated

probabilities of maintenance or transitioning between drinking patterns over time; and (3) examined the difference in transition probabilities between alcohol use patterns of three cohorts of secondary school students before and after the new LCBO policy. This large-scale study is among the first studies that evaluates the impact of the new LCBO policy. Further, the research fills a knowledge gap in Canada and internationally with respect to the effects of an alcohol policy change on patterns of alcohol consumption by youth.

This dissertation is composed of nine chapters. Chapter 1 provides a summary of relevant background information. Chapter 2 presents a review of literature pertaining to distinct patterns of alcohol use, trajectories of alcohol use, and the impact of the alcohol-related policy changes on alcohol consumption and harm. Chapter 3 provides the research rationale and questions. Chapter 4 overviews the general methods of the COMPASS host study and the specific methods used in the three studies of this dissertation, including participants, linkage data, statistical methods. The overall results of the research are presented in Chapter 5, and the specific results of each study are presented in Chapter 6, Chapter 7, and Chapter 8 as they were published/submitted to peer-reviewed journals. Chapter 9 provides a general discussion, presenting a summary of key findings, overall strengths and limitations, and implications for policy and directions for future research.

1.1 Vulnerability of youth to alcohol

Adolescence represents a critical age of extensive and rapid transition in nearly every domain of physical and mental human development (Windle, 2016). This period is the peak time for initiation of substance use, typically beginning with alcohol and tobacco, and continuing to other substances (Kirby & Barry, 2012). Existing evidence shows that alcohol consumption reduces educational attainment and has impacts on quality of learning (Renna, 2008), school completion (Dee & Evans, 2003), school grades (Singleton & Wolfson, 2009), and academic rigor (Patte, Qian, & Leatherdale, 2017). Longitudinal research has indicated that alcohol behaviours established during adolescence have long-term impact; youth who initiate drinking earlier tend to drink more as an adult (Lee, Corte, & Stein, 2018), and have higher propensity to use other substances as an adult (Kirby & Barry, 2012). Moreover, youth who drink heavily may have trouble with attention, memory and decision-making (Hanson, Medina, Padula, Tapert, & Brown, 2011; Sneider, Cohen-Gilbert, Crowley, Paul, & Silveri, 2013) and typically experience

social, emotional, and behavioural problems (Blakemore & Robbins, 2012; Peeters, Vollebergh, Wiers, & Field, 2013). These students are also at a higher risk of social isolation and having poorer job positions in future (Henkel, 2011; Jeynes, 2002; Neighbors, Lee, Lewis, Fossos, & Larimer, 2007).

Although the long-term effects of early alcohol use are consistent in the literature, the causal relationship with adverse outcomes in adulthood is still a debate. A few studies have attempted to relate early drinking consequences to other developmental domains (Brown et al., 2008). For example, the results of the study by Wells et al. (2004) suggested that by controlling some demographic variables, the early alcohol use was not a predictor for much later behaviour. They found that early alcohol use was an exclusive predictor for non-cannabis substance use at 25 years of age, the number of sexual partners, and violence, but was not a predictor for other developmentally important outcomes, such as substance dependence, mental health, and sexual outcomes. Therefore, Wells et al. (2004) concluded that alcohol might have been an important, but non-unique contributing factor. In another study, Peel et al. (2007) indicated that the relationship between early alcohol (or other substances) use and associated problems in adulthood is not a causal relationship. The authors suggested that youth who initiate substance use early are not equivalent to their peers, as they are more likely to have a problematic childhood, which itself is a strong predictor for problematic outcomes in adulthood. Irrespective of a true or false causal relationship, given the strong evidence of the association between underage alcohol consumption and various adverse individual and societal consequences, efforts to delay alcohol consumption as long as possible is a critical public health priority (Cullen et al., 1999).

1.2 The Liquor Control Act of Ontario

The Liquor Control Act of Ontario is a provincial act that regulates all aspects of sale, service, and consumption of alcohol in the province. The Liquor Control Board of Ontario that administrates the act has authority to:

- buy, import, and sell liquor and other products containing alcohol,
- control and provision of sale, transportation and delivery of liquor,
- determine the classes, varieties and brands of liquor to be kept for sale at government stores,

- establish governmental stores or authorize the private sector to sell the alcoholic beverages,
- make regulations about the purchase, distribution and sale of liquor.

The Liquor Control Act was introduced by the government of Canada in 1926 when alcohol was deemed illegal and alcohol control policies were implemented in North America to manage alcohol production, distribution, and sales (Malleck, 2012). Several revisions to the act have been made to reflect changes to liquor laws in Ontario. In the latest change, the liquor control board of Ontario authorized 450 grocery stores across the province to sell beer, wine, and cider from December 15, 2015. Prior to this change, in Ontario liquor was only permitted to be sold in licensed alcohol-only retailers, including “LCBO”, “Beer Stores”, and Winery Retail stores (WRS). The main objectives for the proposed change were stated as creating additional market opportunities for Ontario alcoholic beverage producers and improving consumer access to alcohol and their convenience by modernizing alcohol retailing and distribution across the province (Premier’s Advisory Council on Government Assets, 2016). The change aims to introduce competition into the beverage alcohol sector in Ontario through adding a new sales channel to the existence primary channels for wine, i.e., LCBO and a network of WRS outlets, and for beer, i.e., LCBO and The Beer stores.

Corresponding to this change, three classes of authorization were established. The first class authorizes sale of beer (including cider) only, the second class permits the sale of both beer and wine. The third class is a restricted authorization, which for the first three years has additional restrictions about the types of beer and wine that can be sold. After three years, the restricted authorization becomes a class 2 beer and wine authorization.

The council clearly expressed that changes to the system should improve convenience and access in a controlled and socially responsible way. Therefore, strict controls and restrictions within a range of provisions, including permitted pricing, stocking, and displaying of alcohol, were created. Grocery stores must follow the proposed rules when selling alcohol, and some highlights of the rules are as follows (Liquor Control Act, Revised statute of ON (1990, 2019):

- Beer, cider, and wine are not sold to anyone under Ontario's legal drinking age of 19 or to intoxicated adults. In situations when a customer is appears under the age of 19 years, the store must inspect the person’s identification to ensure that he/she is over 19

- All aspects of the sale of beer and wine, including ordering and payment, must be conducted in person at the grocery store
- The alcoholic drinks are sold between 9 a.m. and 11 p.m. Monday to Saturday and from 11 a.m. to 6 p.m. on Sunday
- Alcoholic drinks are only available in a designated section of each store. The store must ensure that the beer, wine, or cider is displayed in a single contiguous product display area
- All staff selling the alcoholic beverages are fully trained to ensure that Ontario's standards for social responsibility are always met
- The types of beer that are allowed to be sold are to be constrained to meet the following rules:
 - Beer with an alcohol content less than 7.1% by volume.
 - Beer containing alcohol must have been obtained by the fermentation of an infusion or decoction of barley.
 - Coolers that are non-malt based.
- Grocery store must not offer beer in containers with a volume of more than 750 ml or beer in packages with more than six containers.
- Grocery store must not offer wine with an alcohol content greater than 18% by volume or wine priced below \$10.95 per 750 mL bottle.
- Grocery store must not offer cream wine, wine beverages, and fortified wine

1.3 Availability of Alcohol

The new LCBO policy took place in December 2015, and the initial rollout included 58 participating grocery stores across Ontario. The number of grocery stores with alcohol increased to 200 stores by July 2017, and it is been targeted that ultimately 450 grocery stores will be added to the established alcohol retail network (Premier's Advisory Council on Government Assets, 2015). According to the change, the existing winery retail stores, already located next to grocery stores, will also be able to move inside the sales floor and use the same checkout of that grocery store (Premier's Advisory Council on Government Assets, 2016). The new grocery stores sell alcohol in addition to the existing alcohol retailers across Ontario, including 651 LCBO, 217 LCBO agency stores (independent local retailers in locations with no access to

LCBOs that are authorized to sell alcohol), 447 Beer Stores, 113 on site brewery retail stores (Premier's Advisory Council on Government Assets, 2015), and 491 winery retail store (WRS) (292 off-site and 199 on-site stores). These represent an increase in alcohol availability of approximately 30% (Premier's Advisory Council on Government Assets, 2015).

Physical availability of alcohol is a key factor among a long list of predictors of alcohol consumption and alcohol harms (Speer, Gorman, Labouvie, & Ontkush, 1998; World Health Organization, 2015). Research suggests that physical availability of alcohol in the form of greater number of alcohol outlets per geographic area or population is associated with increased alcohol sales and consequently more occurrence of alcohol-related harms (Gruenewald et al., 2002; Gruenewald, Remer, & LaScala, 2014; Rowland et al., 2016). Specifically, studies have shown that density of alcohol outlets is related to: alcohol sale (Stockwell et al., 2009), alcohol consumption (Campbell et al., 2009; Jackson et al., 2014; Thern et al., 2017), binge drinking (Larsen et al., 2017). Density of alcohol outlets has also been associated with a number of alcohol-related harms, including: alcohol-related hospitalization (Livingston, 2011; Stockwell et al., 2013; Tatlow, Clapp, & Hohman, 2000), traffic crashes (Gruenewald & Ponicki, 1995), suicide (Giesbrecht et al., 2015), violent assaults (Reid, Hughey, & Andrew Peterson, 2003), and long-term health outcomes (Popova, Giesbrecht, Bekmuradov, & Patra, 2009; Stockwell et al., 2011; Thern et al., 2017). Given the positive association between alcohol availability and alcohol consumption (and related harms), research suggests that reducing the physical availability of alcohol, in the form of reducing off-premise outlets (i.e., liquor, grocery, and convenience stores where alcohol is purchased but not consumed) and on-premise outlets (i.e., bars, restaurants where alcohol purchased and consumed), is one of the most effective strategies for reducing alcohol consequences in the population (Jackson et al., 2014; World Health Organization, 2015).

Chapter 2

Literature review

This chapter comprises a review of the literature for relevant studies of youth alcohol use patterns, developmental trajectories of alcohol consumption, and impact of change to an alcohol-related policy on alcohol use trajectories of youth.

2.1 Patterns of alcohol use among youth population

2.1.1 Overview of the literature

There is growing evidence that the youth population is heterogeneous with respect to individual drinking patterns, including the level, type, and sequences of consumption (Romelsjö, 2010). Several cross-sectional and longitudinal studies identified the subgroups of youth with the same patterns of alcohol use. Cross-sectional studies typically identified the number of alcohol patterns in a range of three to six groups (Bräker, Göbel, Scheithauer, & Soellner, 2015; Diestelkamp et al., 2015; Jackson et al., 2014). Longitudinal research concur that three to six patterns tend to best present the alcohol-use behaviours of youth (Brunborg, Norström, & Storvoll, 2017; Chan et al., 2013; Dauber, Paulson, & Leiferman, 2011; Malone et al., 2012). For example, Shin et al. (2016) found three subpopulations: non-drinkers, light drinkers (high probability for current drinking), and heavy drinkers (average 3+ drinks/day). Chan and colleagues (2017) identified five groups of students with distinct patterns of stable moderate, early high drinkers, slow increasers, steep escalation, and nonusers. The most prevalent pattern of drinking among the youth population that is identified in nearly all of the cross-sectional and longitudinal studies is a non-user group (Chan et al., 2013; Colder, Campbell, Ruel, Richardson, & Flay, 2003; Malone, Northrup, Masyn, Lamis, & Lamont, 2012; Shin, Lee, Lu, & Hecht, 2016).

The heterogeneity in populations means that the effect of any program or policy change may be different in subpopulations. Moreover, the nature of alcohol-attributable consequences varies between subpopulations (Degenhardt, Stockings, Patton, Hall, & Lynskey, 2016; Gilmore et al., 2016; Studer et al., 2014). Therefore, developing effective intervention strategies and evaluating their results depend on understanding and identifying the subgroups of the youth population. Alcohol-related behaviour, like many other constructs in social and health studies, is

a multidimensional behaviour that is difficult to measure directly from a single quantitative dimension; instead it is considered as a latent variable and is inferred from several manifest variables (Cleveland, Lanza, Ray, Turrisi, & Mallett, 2012). Alcohol drinking has typically been operationalized by the frequency and quantity of alcohol consumption, in addition to the frequency of heavy episode drinking. Based on these underlying drinking-related characteristics, the population can be classified into some finite distinct groups.

A large body of research indicated a gender difference in alcohol drinking patterns; it is consistently reported that male students consume more alcohol compared to their peer females in terms of frequency of drinks and binge drinking (Ajilore, Amialchuk, & Egan, 2016; Jacobs et al., 2017; Lebreton, Peralta, Allen-Collinson, Wiley, & Routier, 2017). For instance, Jackson and colleagues (2014) demonstrated that male students compared to their female peers have higher odds of belonging to alcohol drinking high-risk groups. They reported that being a member of the very high-risk class for male students was approximately double the odds for females. In addition to alcohol consumption, alcohol-related harm may differ in male and female (Danzo, Connell, & Stormshak, 2017; Perkins, 2002). For example, Perkins (2002) indicated that while personal and private consequences caused by alcohol drinking are similar for males and females, male drinking produces more consequences for self and others that involve social problems compared with those females produce.

The impact of density of alcohol outlets on patterns of alcohol use has been examined in several studies (Chaloupka & Wechsler, 1996; Jackson, Denny, Sheridan, Zhao, & Ameratunga, 2016). In the study by Jackson et al. (2016) on a nationally representative sample of youth in New Zealand, researchers found a positive association between neighborhood type and alcohol consumption and alcohol related-harm. The frequencies of binge drinking and high typical consumption were significantly higher among students who live in areas with high outlet density and economic deprivation. In another study, the levels of drinking and binge drinking were significantly higher among all college students where a high number of alcohol outlets existed near their campus (Chaloupka & Wechsler, 1996). The students in the areas with higher density of alcohol stores indicated greater likelihood of experiencing alcohol-related consequences, including alcohol-related hospitalization (Livingston, 2011; Stockwell et al., 2013; Tatlow et al., 2000), suicide (Giesbrecht et al., 2015), violent assaults (Reid, Hughey, & Andrew Peterson, 2003; Wechsler, Lee, Hall, Wagenaar, & Lee, 2002), and female criminal victimization

(Campbell et al., 2009; Chaloupka & Wechsler, 1996; Larsen et al., 2017; Snowden, Hockin, & Pridemore, 2017). However, some studies reported contrary results. For example, Larsen et al. (2017) studied 6142 high school students across Ontario to examine whether the high accessibility to alcohol around the school is associated with higher odds of binge drinking. The researchers found no significant correlation between the number of neighborhood retail stores and binge drinking.

2.1.2 Summary and identified gaps

Due to the heterogeneity of youth, several researchers investigated this subpopulation with respect to alcohol consumption. Because a change in alcohol-related policies, like Ontario's changes to where alcohol can be purchased, may affect different subpopulations in different ways, it is valuable to explore the differences in how members of one subpopulation respond. The findings can be used to design effective programs and policies. Previous research assumed that alcohol use patterns are constant across the youth population, ignoring possible variation due to differences in sociodemographic, political, and physical characteristics of the communities in which individuals spend their time. Since students within the same school are more likely to share common characteristics (i.e., they are not independent), individuals in certain schools are also more likely to belong to higher risk drinking groups than students attending other schools. This dissertation seeks to identify distinct subpopulations of students that are engaged in particular patterns of alcohol drinking using a large-scale database of participating students in Year 2 of the COMPASS study.

2.2 Trajectories of alcohol use among the youth population

2.2.1 Overview of the literature

Studies of developmental trajectories of alcohol drinking have used longitudinal data to track alcohol behaviours of individuals over time. Identifying trajectories of alcohol use is important because it can explain the factors that contribute to divergent developmental trajectories (Tucker, Orlando, & Ellickson, 2003). During the last two decades, as the longitudinal data have become more available, changes in patterns of alcohol use over time have been increasingly investigated (Chan et al., 2013; Malone et al., 2012; Modecki, Barber, & Eccles, 2014; Shin et al., 2016; Tucker, Orlando, & Ellickson, 2003). Although the

operationalization of alcohol use and the number of identified clusters differed between studies, the following trajectories were found in most: non-users (the youth in this cluster are those youth who never drunk alcohol or did not consumed in the past year), low/moderate users (comprises those youth drinking alcohol occasionally or less than two times per month), early high users (youth in this trajectory were those with a high consumption of alcohol at their early youth ages and who remained frequent drinkers during the follow-up times), and escalators (this trajectory comprises those youth with no drinking or very low drinking at the younger age but increased their consumption over the follow-up time).

Youth tend to increase their alcohol consumption over time. Therefore, in addition to identified alcohol trajectories and their prevalence, probabilities of transitioning between stages of alcohol use is important information that can be estimated in the longitudinal studies. Several studies have estimated the transition probabilities between different patterns of alcohol use (Dauber, Paulson, & Leiferman, 2011; Guo, Collins, Hill, & Hawkins, 2000; Jackson & Schulenberg, 2013; McBride, Adamson, Cheng, & Slade, 2014; Shin et al., 2016), between alcohol and marijuana use (Green et al., 2016), between alcohol and tobacco use (Orlando et al., 2005), and between the three substances of alcohol, tobacco, and marijuana use (Chung, Kim, Hipwell, & Stepp, 2013; Graham, Collins, Wugalter, Chung, & Hansen, 1991; Mistry et al., 2015). For example, Shin and colleagues (2016) explored trajectories of drinking among students of 29 secondary public schools in the US using a three-wave longitudinal study. Four drinker classes emerged at Wave 1: non-drinker (59%), potential drinker, experimenter (20%), and regular drinker (9%). The researchers found that only 61% of non-drinker at Wave 1 did not drink by Wave 2 and the remaining 39% moved to groups of potential drinker, experimenter, and regular drinker with the probability of 0.129, 0.186, and 0.071, respectively (Shin et al., 2016).

A variety of sociodemographic and behavioural characteristics have been identified in the literature that can be used to differentiate between trajectory groups. Sociodemographic characteristics include gender (Green et al., 2016; McBride et al., 2014; Modecki, Barber, & Eccles, 2014; Schuckit et al., 2014; Tucker et al., 2003), age at initiating alcohol use (Ellickson, Tucker, Klein, & McGuigan, 2001; McBride et al., 2014), ethnicity (Chung et al., 2013; Green et al., 2016), socioeconomic status (Modecki et al., 2014). Behavioural characteristics include parental drinking (McBride et al., 2014; Poelen, Engels, Scholte, Boomsma, & Willemsen, 2009; Seljamo et al., 2006; Vermeulen-Smit et al., 2012), parents approval and monitoring of drinking

(Shin et al., 2016; Tucker et al., 2003), peers drinking (Ajilore et al., 2016), emotional distress (Colder, Campbell, Ruel, Richardson, & Flay, 2002), smoking and marijuana use (Hix-Small, Duncan, Duncan, & Okut, 2004; Orlando, Tucker, Ellickson, & Klein, 2005).

Several studies showed the gender of youth as a predictor factor for increased alcohol use over time (Modecki et al., 2014; Schuckit et al., 2014; Tucker et al., 2003). The results suggest that males are more likely than females to transition to and remain in higher levels of alcohol consumption. For example, in the study by Tucker et al. (2003) five alcohol groups were identified among youth. The researchers found that men were largely overrepresented in the group of binge drinkers. In another study, Schuckit et al. (2014) reported that 60.1% of female students were in the least alcohol consumption class and only 11.5% were in the most extreme alcohol use class, as compared to 81.5% of males in this class.

2.2.2 Summary and identified gaps

The studies support that the timing and developmental trajectories of use differ greatly among youth. Identifying alcohol use trajectories and probability of transition into other groups is informative to characterize distinct alcohol use trajectories. Most of the literature is filled with US and European research and there is a big gap in the Canadian context. Given that alcohol use trajectories are extremely dependent on cultural factors, identifying the changes in drinking patterns of Canadian youth is important for evaluating the impact of the new LCBO policy. By identifying trajectories of alcohol use, content, delivery, and timing of alcohol prevention programs could be improved and could be matched to particular stages of alcohol use.

2.3 The impact of an alcohol policy change on trajectories of alcohol use

2.3.1 Overview of the literature

Following repeal of national prohibition in 1933, some states in the U.S and later in Europe and Canada started to decrease the involvement of government in sales of alcohol by deregulations of alcohol policies. In response to public and commercial pressures, at the next wave of liberalization in the early 1980s, a broad movement occurred to reduce government involvement in alcohol production, sale, and distribution and to privatize the monopolies (Holder & Griffith, 1995; Wagenaar et al., 1996). The liberalizations include allowing liquor sales at bars, beer and wine sales in grocery stores, and closing the governmental stores. These changes

ultimately lead to increases in the overall number of outlets, longer opening hours, and increased promotions of alcoholic beverages (Holder & Griffith, 1995; Wagenaar et al., 1996). Many researchers investigated the impacts of the changes on consumption of alcohol in the US (Hoadley, Fuchs, & Holder, 1984; Holder & Griffith, 1995; Ornstein & Hanssens, 1985) Holder and Wagenaar 1990; Wagenaar and Holder 1991, 1995; (Gruenewald, Johnson, & Treno, 2002; Gruenewald, 2011)), Europe (Gustafsson, 2010; Herttua, Mäkelä, & Martikainen, 2009), and Canada (Sen, 2016; Smart & Mann, 1998; Treno et al., 2013; Trollid, 2005; Zalcman & Mann, 2007). The results of this research demonstrated that following the increase in physical availability in the form of increase in the number of on- and off-premise alcohol outlets, alcohol consumption and related harm increased. In the US, the results of longitudinal studies by Ornstein & Hanssens (1985) indicated that population living in the states with more liberal policies drank higher amounts and experienced a higher rate of alcohol consequences. In a study of over 14 states in the US showed that higher off-premises alcohol outlet densities were associated with greater proportions of alcohol-related suicides among men (Giesbrecht et al., 2015).

In Europe, Thern et al. (2017) examined the effect of change to the Sweden alcohol policy in the late 1960s that temporarily authorized grocery stores in two regions of Sweden to sell strong beer and decreased the minimum legal age to 16. The results of this natural-experimental study with a 43-year follow-up suggested that the exposed group experienced more alcohol use disorders and mental disorders.

In the Canadian context, a few studies reported the impact of change to provincial policies on sale, consumption, and consequences of alcohol. Smart et al. (1986) evaluated effects of the change in Quebec that introduced wine into grocery stores in 1978. The researchers compared the trend of wine consumption in Quebec and Ontario (as a control group) from 1963 to 1984. The study indicated that selling wine in grocery stores had no impact on wine sales or total alcohol sales in Quebec. The researchers explained that the reasons for the lack of impact could include depressed economic circumstances, low percentage of wine consumption relative to other alcoholic beverages, and the long-term declining trend in alcohol consumption across the country. In another study, Stockwell and colleagues (2011) showed that the number of private stores was positively associated with per capita sales in BC; per capita alcohol sales increased from 8.04 litres in 2003/04 to 8.63 litres in 2007/08.

The study by Stockwell et al. (2011) indicated that after the privatization of off-premise alcohol sales in British Columbia, the rates of alcohol-related death significantly increased by 3.25% for each 20% increase in private liquor store density. In the study by Zalcman and Mann (2007), it was shown that privatization of retail sale of alcohol in Alberta between 1985 and 1995 significantly increased the mortality rates from suicide compared to Ontario for the same period of time (Zalcman & Mann, 2007). In a contrary study, Sen (2016) investigated the effects of differences in retail alcohol distribution systems on trends of violent crime and crime rates across six Canadian provinces from 1993 to 2011. The results of the study suggest no significant difference between per capita alcohol sales and different types of crimes or violent. The researcher concluded that provinces with more liberalized alcohol sale systems do not experience more consequences than the provinces with more controlled availability. The study by Trollidal (2005) indicated that number of traffic accidents related to alcohol was not significantly associated with the 1994 privatization of retail sales in Alberta.

To the best of my knowledge, during the last three years after the change to the Ontario alcohol liquor act, there is only one study and few commentaries that discussed the health outcomes of the new LCBO policy. Myran and colleagues (2019) examined the association between increase in alcohol availability after the new LCBO policy and alcohol-attributable emergency department visits in Ontario one year after the policy change. The researchers compared the number of emergency department (ED) visits between pre-policy (2013-14) and post-policy (2016–17) for 513 geographic regions in Forward Sortation Areas (FSAs), Ontario, Canada. The outcome measure in this study was the age-standardized rates of alcohol-attributable ED visits. The results of this study showed that alcohol-attributed ED visits increased by 17.8% after the policy change: more than twice the rate of increase for all ED visits. They suggested that increased hours of operation and the numbers of alcohol outlets were positively associated with higher rates of alcohol-related ED visits.

The commentary letter from the Wellington-Dufferin-Guelph Public Health Unit (Campbell, McCorrison, & Sethi, 2017) in 2017 called on the provincial government to develop a comprehensive strategy for alcohol market to ensure they were not putting the health of the Ontario population at risk. The report suggested some actions that needed to take place, including analysis of surveillance data related to alcohol and its outcomes, monitoring the trends of consumption, and identifying priority populations. The authors also recommended

collaboration between municipalities and boards of Health to develop regional/local public health programs to create or enhance the supportive environments, to increase public awareness about alcohol consequences, and engage people in community programs and services on alcohol use. In another commentary letter by the authors at the Centre of Addiction and Mental Health (CAMH) (Rehm & Wells, 2019) suggests the recognition of alcohol as an invisible drug that can cause various health consequences in the society, rather than looking at alcohol as a commodity that can raise government revenues. The CAMH commentary recommends that Ontario consult widely with stakeholders to create a scientific, comprehensive alcohol strategy to ensure Ontarians have the information to reduce the alcohol-related consequences.

2.3.2 Summary and identified gaps

Past research suggests that increasing the physical availability of alcohol through off-premise alcohol outlets increases alcohol consumption and alcohol-related consequences. These studies support the importance of limiting alcohol availability through restricting the number of alcohol outlets and reducing the hours and days of sale (Gruenewald, 2011; Shield, Monteiro, Roerecke, Smith, & Rehm, 2015). The recent change in the Ontario Liquor Control Board policy has authorized some grocery stores to sell alcohol, but the impact of this policy change on alcohol-use behaviours of the population in exposed jurisdictions has not been studied yet. Furthermore, most studies that have evaluated the impact of policy changes investigate only the impact on adults and ignore youth. This dissertation supplies the first contemporary youth-specific evaluation of whether increased physical availability of alcohol affects youth alcohol use trajectories. The findings of this dissertation research would contribute useful evidence-based knowledge to inform relevant decision makers and public policies.

Chapter 3

Study rationale and research questions

This dissertation research was undertaken to extend our knowledge about the development of alcohol consumption among the youth population and the impact of changes in one public policy on youth alcohol use trajectories through three studies. The aims of these studies are to

- *Identify dominant patterns of youth alcohol use;*
- *Estimate probabilities of transitioning among different patterns of alcohol use over time;*
- *Evaluate the impact of the change to the LCBO policy allowing alcohol sales in select grocery stores on youth alcohol use trajectories.*

3.1 Study 1: Identifying patterns of alcohol use among secondary school students in Canada: a multilevel latent class analysis

Evidence suggests that the short- and long-term effects of policy changes may differ among distinct subgroups of the population. For example, some research suggests that individuals consuming alcohol in early adolescence are more vulnerable to the long-term health consequences than individuals who begin consuming alcohol in late adolescence. Therefore, identifying potential subpopulations can aid in the evaluation of the new LCBO policy on specific subpopulations of youth. In addition, empirical evidence (Cleveland, Collins, Lanza, Greenberg, & Feinberg, 2010; Duncan, Duncan, & Strycker, 2002; Van Horn et al., 2008) and socioecological models (Gruenewald et al., 2014) suggest a substantial influence of contextual factors on alcohol use among the youth population.

Socioecological models suggest that alcohol use patterns are best understood as embedded within social contexts, ranging from the proximal in terms of individuals (e.g., early initiation of alcohol consumption, gender), family (parental disciplines and family bonding) and peer groups (rates of use and attitude to alcohol) to more distal levels of schools (school environment and academic achievement), community (neighbourhood norms and average household income), and provincial and national (taxation and minimum legal drinking age) (Brooks-Russell, Simons-Morton, Haynie, Farhat, & Wang, 2014; Liang & Chikritzhs, 2015; Nash, McQueen, & Bray, 2005; Soloski, Kale Monk, & Durtschi, 2016). According to these models, individuals in certain

schools are more likely to belong to higher risk drinking groups than students attending other schools. Ignoring the clustering structure of individuals within schools may lead to misclassification of individuals into latent classes of alcohol use (Finch & French, 2014; Kaplan & Keller, 2011).

By identifying the specific alcohol-use patterns among subgroups of students, this dissertation provides information on how heterogeneous the youth population is and how interventions can target specific subgroups according to the needs of each: for some subgroups delaying alcohol use initiation may be the priority, for others the priority may be reducing levels of consumption. Identifying these distinct subpopulations in study 1 sets a ground for Study 2 to investigate how individuals engaged in certain patterns of alcohol use develop their consumption over time.

3.1.1 Study 1 Research Questions

The objective of Study 1 was to investigate whether there are distinct patterns (classes) of alcohol use among youth participating in the COMPASS study (described in detail in Chapter 4). The first study answered the following research questions:

1. Is there a latent class structure that represents the heterogeneity in alcohol use patterns among a sample of Canadian youth in Ontario and Alberta participating in the COMPASS study?
2. Do patterns of alcohol use differ between schools? Is there a latent class structure that represents the heterogeneity in students' alcohol use patterns among schools?
3. Which individual characteristics are associated with engagement in alcohol use patterns?
4. Which neighbourhood characteristics are associated with school-level latent class membership?

3.1.2 Study 1 Hypotheses

The following results were hypothesized relative to the individual research questions:

1. The youth population would consist of a mixture of subpopulations, each representing a pattern of alcohol use. Based on past research, I anticipated at least three subpopulations, with the most prevalent group being non-drinkers.

2. Patterns of alcohol use differ among schools. I expected membership probability of high-risk groups for students in some schools would be significantly higher than that of students in other schools.
3. Male and female students have different alcohol use patterns. I predicted seeing more male students involved in higher levels of drinking than female students.
4. The number of alcohol outlets would be a significant factor on alcohol use patterns of students. I expected that students in areas with a higher density of outlets would have increased risk of engagement in patterns with higher levels of alcohol consumption.

3.2 Study 2: Identifying trajectories of alcohol use among a sample of secondary-school students in Ontario and Alberta: longitudinal evidence from the COMPASS study

As documented in the literature, the patterns of alcohol use identified in study 1 do not remain stable over time but change as youth age. Despite the virtually universal shifts toward a rapid increase in alcohol use during adolescence, the timing and developmental trajectories of use differ among youth (Hix-Small et al., 2004; McBride et al., 2014). Identifying alcohol use trajectories and probabilities of transitioning among trajectories is important in informing interventions for the subgroups of individuals with high risk of alcohol consumption and alcohol-related problems. This information in turn can help in the development, implementation, and evaluation of interventions.

3.2.1 Implications

By identifying the probability of transitioning among distinct patterns of alcohol use during the two years before the implantation of the new alcohol policy, this study showed how alcohol-use behaviours of the youth population develop over time. It also showed that what subpopulations are more likely to maintain their patterns of consumption, to progress to latent classes with higher levels of consumption, or to revert to latent classes with lower levels of consumption. The findings of Study 2 provided knowledge about alcohol-consumption development later set against new findings obtained after before the new LCBO policy was enacted.

3.2.2 Study 2 Research Questions

The objective of Study 2 was to describe drinking development and identify distinct developmental trajectories of alcohol consumption patterns among a sample of Canadian youth using longitudinal two-year linked data from secondary school students in Ontario and Alberta participating in the COMPASS study. The study also aimed to estimate the probability of transitioning among patterns of alcohol use over time. Specifically, Study 2 answered the following research questions:

1. What are the dominant alcohol use patterns among a sample of Canadian youth in Ontario and Alberta participating in the COMPASS study? What is the prevalence of the patterns among the population?
2. What is the probability of youth transitioning among the patterns of alcohol use over time?
3. What individual characteristics are associated with engagement in different alcohol use patterns? What individual characteristics are associated with transitioning between alcohol use patterns over time?

3.2.3 Study 2 Hypotheses

The following results were hypothesized relative to the individual research questions:

1. There would be a finite number of alcohol use patterns among the youth population. I expected to find the similar number and similar patterns of alcohol use identified in Study 1, supporting the robustness of patterns using both cross-sectional and longitudinal data.
2. A large proportion of the youth population transition into/out of different patterns of alcohol use, particularly the transitioning of non-drinkers into a drinking pattern. I expected that most individuals would move to further alcohol consumption, but that some individuals would remain at their current levels of alcohol consumption.
3. Different development patterns for alcohol use between male and female youth with higher levels of consumption among males. In addition, I expected that males would be more likely to transition into high consumption patterns. Furthermore, given the interrelationships between alcohol use and use of tobacco and cannabis (Green et al., 2016; Herttua, Mäkelä, & Martikainen, 2009; Mistry et al., 2015; Orlando, et al., 2005), I expected tobacco and cannabis users would be more likely to drink more.

3.3 Study 3: The impact of an alcohol policy change on developmental trajectories of youth alcohol use: examination of a natural experiment in Canada

Restricting availability of alcohol is one of the key factors suggested for public policies to reduce alcohol consumption. Past research has indicated that greater physical availability of alcohol in the form of greater numbers of alcohol outlets per geographic area or population is associated with a rise in alcohol consumption and alcohol-related problems (Foster et al., 2017; Treno et al., 2013). Because the new LCBO policy introduced a new source of alcohol to the youth population, it is essential to evaluate to what extent this policy change affects the alcohol-use behaviours of youth in the exposed jurisdictions. The knowledge provided by this dissertation can inform any adjustments to the policy that may be required to promote population health.

3.3.1 Implications

By evaluating the impact of the new LCBO policy on the alcohol-use behaviour of the youth population, I can provide decision makers with evidence from a longitudinal, large sample of the population for further policy modification and/or development. This study informs decision makers on the impact of their decision on the vulnerable subgroups most influenced by the policy change. Accordingly, further actions can take place to reduce any negative effects of the new LCBO policy and promote its positive effects, which may result in a positive population-level impact on youth alcohol use. The results of this study can be used by other national and international jurisdictions to develop alcohol or other substance use policies.

3.3.2 Study 3 Research Questions

1. What are the dominant alcohol use trajectories of the youth population?
2. Does the new LCBO policy have an effect on the developmental trajectories of youth alcohol use in the exposed jurisdictions in the province?

3.3.3 Study 3 Hypotheses

The following results were hypothesized relative to the individual research questions:

1. The youth population would be heterogonous in terms of alcohol use and that trajectories of use would differ among groups youth. I predicted that finite distinct subgroups of the

population characterized by alcohol use trajectories would be identified. As these subgroups differed in their alcohol consumption patterns, their responses to the new LCBO policy could likewise differ.

2. Those youth who have been exposed to the increased alcohol availability due to changed LCBO policy would demonstrate an increased risk of alcohol consumption. I predicted that the exposed cohort of students would have greater odds of transitioning into latent classes with higher levels of alcohol consumption compared to the unexposed cohorts of students in Ontario and Alberta.

Chapter 4

Methodology

This chapter details the methodology that was used to answer the described research questions (see chapter 2) using data from the COMPASS host study. Study 1 used cross-sectional data from Year 2 (school year 2013-14) of the COMPASS study. Study 2 analyzed two-year linked data from Year 2 (2013-14) and Year 3 (2014-15) of the COMPASS study. The four-year linked data from Year 2 to Year 5 (school year 2016-17) were used in Study 3.

4.1 Natural experiment and quasi experimental designs

Public policies and programs are developed and implemented on an ongoing basis across various fields, including public health, economics, education, etc. Evaluation of these policies is key to improve policy implementation and assess successes and failures with respect to policy objectives. From a research perspective, the implementation of public policies can be considered as a natural experiment, in which the circumstances surrounding the research intervention are not under the control of the researchers (Leatherdale, 2019). Three key features of a natural experiment are (1) lack of control on the intervention by researcher; (2) inability of manipulation of subject exposure to the intervention by researcher; (3) the intervention would occur with or without subsequent research evaluating the impact of the intervention.

As public policy has the potential for considerable impact on the population, decision makers increasingly need scientific evidence to support their decisions. However, in many cases, there is a lack of this evidence, or available evidence is not relevant to real-world experience (Brownson, Fielding, & Maylahn, 2009). In fact, a large portion of the evidence available to decision makers is derived from highly controlled studies that do not reflect real world conditions. In a clinical context, the randomized controlled trial (RCT) is generally considered the most robust design to examine causality. In public health, however, an RCT is typically not a feasible design for evaluating program and policy changes, since interventions usually cannot be randomized for ethical reasons. For example, exposing youth to higher levels of alcohol availability when there is large evidence that more availability is associated with a higher risk of alcohol harm would be unethical, therefore an RCT is not possible. Instead, quasi-experimental studies can be used to evaluate natural experiments. A robust quasi experimental design differs

from an RCT only with respect to the inability for random allocation of individuals to intervention or control group(s). Similar to randomized control trials, quasi-experiments aim to establish a causal relationship between intervention and changes in the outcome (Eliopoulos et al., 2004). Quasi-experiments, are among the most credible designs for use in public health. These designs can be divided into three categories (Shadish, Cook, & Campbell, 2002): (1) single group quasi-experimental study with no control group. This is a commonly used 1-group pre- and post-test design, in which pre-test observations are measured, then after an intervention, post-test observations are measured; (2) Multiple group quasi-experimental study with no pre-test. This is a 2-group post-test study design, in which outcomes of an intervention are compared among the exposed and unexposed (control) group(s); and (3) Multiple group quasi-experimental study with both pre- and post-test measurements. Obtaining pretest measurements for both the exposed and control groups allows one to assess the initial comparability of the groups. The use of both a pretest group and a comparison group make avoiding certain threats to internal validity easy. This design is more likely than the other two designs to establish a causal relationship.

Quasi-experimental studies are important in the policy evaluation context because they can create scientific evidence situated in real world contexts to inform policy makers about the outcomes of their decisions. The information generated can help improve policy implementation moving forward as well as reduce prohibitive costs, since sustaining ineffective or harmful interventions or continuing interventions not implemented as intended is costly (Brownson et al., 2009; Leatherdale, 2019). This dissertation uses a longitudinal quasi-experimental design with two control groups across Ontario and Alberta (Canada) to evaluate the new LCBO policy.

Natural experiments have some limitations. First, they are observational rather than true experiments, thus it is difficult to establish a causal effect (Dunning, 2008). Further, because of the long list of factors influencing the association between the intervention and outcome in the real world, the internal validity of the results is questionable, and the way that the intervention influences the outcome may not be known. Moreover, natural experiments occur once, and later it is difficult to replicate them and to test their reliability. In addition, natural experiments are context specific, so it is difficult to generalize the impact of an intervention from one experiment to other contexts (DiNardo, 2016).

4.2 Theoretical model

Youth alcohol use is a complex, multidimensional behaviour caused by the interactions of many proximal and distal factors. Several theories, such as the socioecological health model (McLeroy, Bibeau, Steckler & Glanz, 1988), common liability model (Vanyukov et al., 2003), and problem behaviour theory (Jessor & Jessor, 1977), have been developed to help in determining significant personal and contextual factors and their interactions that direct individuals to consume alcohol. Among the many, the socio-ecological framework is well established in the literature, and researchers have employed it to explain the etiology of alcohol use and to understand the mechanisms by which macro-ecological factors of drinking influence the micro-ecology of individual behaviours) (Brenner, Bauermeister, & Zimmerman, 2011; Sudhinaraset, Wigglesworth, & Takeuchi, 2016; Gruenwald et al, 2014). This theoretical model describes how individuals' behaviours, here alcohol consumption, are influenced by various aspects of social influences, ranging from intrapersonal and interpersonal to more distal ones: organizational, community, and public policies (Figure 4.1).

Intrapersonal factors include biological ones, knowledge, and attitudes toward alcohol. Many studies have found a significant association of gender, age, grade, ethnicity with alcohol consumption and related harm. Interpersonal factors include parent's alcohol-use behaviours, family bonding, and family monitoring, as well as peer's attitudes and consumption patterns. Organizational factors include school setting, rules, and norms. Schools represent an important organization context because youth spend much of their time at school, interacting with people and being exposed to programs and policies that may influence their alcohol-use behaviours. Community factors include the number of alcohol retailers, bars and restaurants in a neighbourhood, plus social and cultural norms. Features of the community and greater availability of alcohol may impact youth alcohol-use behaviours through greater accessibility to alcohol and the normalizing of alcohol consumption. Public policy includes local, provincial, and federal laws that regulate production, sale, access, and consumption. Public policies shape the more proximal levels of the socioecological model.

The socioecological framework is centred on two principals (1) multiple levels shape alcohol-use behaviours, and (2) these levels dynamically interact (Bronfenbrenner, 1979).

According to these core principals, the models suggest that interventions to prevent or reduce alcohol harm should account for these different levels of influence.

Socioecological health models have been found to validly describe different risk behaviours of the youth population, including alcohol use (Brenner et al., 2011, Gruenwald et al., 2014), cannabis use (Berg et al., 2018), and cigarette smoking (Sawdey, 2017). In the alcohol use context, socio-ecological models suggest that greater community alcohol availability is associated with individuals' drinking behaviour. This association means that community and individual characteristics jointly affect drinking patterns of the population, suggesting that increased availability of alcohol due to the recent change to Ontario's alcohol policy can lead to changes in individuals' alcohol use patterns. Therefore, the socio-ecology theory best applies to this dissertation research to determining describe any impacts of the new LCBO policy on the alcohol-use patterns of the youth population. The research also investigates the impact of the number of off-premise alcohol outlets, as a community level factor, with youth alcohol use patterns. Moreover, the association of alcohol use patterns and several other modifiable or non-modifiable factors across various levels of the socioecological framework have been investigated. These factors include gender, ethnicity/race, and grade (intrapersonal level) and neighbourhood average household income (community level). Possible impacts of the new LCBO policy on family alcohol-use behaviours and peers' alcohol consumption and attitudes toward alcohol (interpersonal level) and change in community norms (community level) are discussed throughout the dissertation.



Figure 4.1. The levels of influence from the socioecological health model (Mcleroy et al.,1988)

4.3 The COMPASS host study

COMPASS is a nine-year longitudinal study (2012-2021) designed to understand how the impact of changes in school environment characteristics and provincial/national policies are associated with changes in health behaviours among the youth population. The compass survey collects data on different domains of students' health behaviours, including physical activity, diet, substance use behaviours, and mental health indicators. COMPASS follows students in grade 9 to 12 attending a convenience sample of secondary schools across Ontario, Alberta, British Columbia, Quebec, and Nunavut (Patte et al., 2018). The COMPASS study provides a multiple large-scale school-based dataset by collecting and linking data from students in over 100 participating secondary schools across the country every year.

The COMPASS study also facilitates knowledge transfer to help schools to put the evidence-based recommendations into action by annually delivering each participating school with a school-specific feedback report. The annual reports (1) highlight the school specific prevalence of health behaviours of the students (e.g., smoking rates, daily physical activity, and mental health indicators), (2) compare school measures to provincial and national norms or guidelines, and (3) provide evidence-based suggestions for school-based interventions.

4.3.1 School-level sampling

Participating schools in the COMPASS study were a convenience sample that were sampled through school boards; school boards that met inclusion criteria were approached for participation. The criteria were (1) English speaking, (2) had secondary schools with grades 9 through 12 inclusive, and (3) belonged to a school board that permitted use of active-information passive-consent protocol. At the first stage of sampling in the baseline year, out of 83 school boards in Ontario, 40 boards had met the criteria and were contacted via courier mail or email. Out of the 40 eligible boards, 37 public secondary schools and 51 Catholic secondary schools met the COMPASS criteria.

Sampling protocol (and inclusion criteria) for private schools was similar, except that in Ontario these schools are not part of a school board (Thompson-Haile; Bredin, & Leatherdale, 2013). Therefore, the eligible schools were approached directly by sending the COMPASS recruitment package, which included a school invitation letter, brochure of the project, and a copy of the student-level questionnaire. This process resulted in a final sample of 49 recruited

secondary schools in Ontario who participated the COMPASS study in the first year (2012-13). In year 2 of the study (2013-14), an additional 36 sampled schools across Ontario and 9 schools in Alberta were added to the sample (Bredin, Thompson-Haile, & Leatherdale, 2015). In the school year 2015-2016, the COMPASS study recruited secondary schools in Quebec (n=11), British Columbia (n=5), Nunavut (n=2) for two years of data collection. In this dissertation, however, I only used data from Ontario and Alberta.

4.3.2 Student-level recruitment

COMPASS uses an in-class whole-school sampling data collection method, meaning that all students in grade 9 to 12 in participating schools were eligible to participate in the study and to complete the student questionnaire. An active-information passive-consent protocol was used to recruit the students. In this protocol, parent(s) or guardian(s) of students were sent an information letter about the COMPASS study and were asked to inform the COMPASS recruitment coordinator by email or a toll free call if they did not want their child to participate in the survey (Thompson-Haile et al., 2013). All students whose parents did not contact to COMPASS coordinator were deemed eligible to participate. Parent(s) or students had the opportunity to decline participation in the survey at any time.

4.3.3 Ethics

The COMPASS study protocol and all student-level and school-level questionnaires used in the study were approved by participating school boards, Canadian Institutes of Health Research (CIHR) for funding the study, and the University of Waterloo Office of Research Ethics.

4.4 Data source

The research questions (see section 3) were investigated using the linked student longitudinal data from Year 2 to Year 5 of the COMPASS study and neighbourhood spatial information databases which contain information about the built environment surrounding each school. The COMPASS collects data using three data collection tools: student-level questionnaire (Cq), School Policies and Practices (SPP) questionnaire, and a mobile application that records school's facilities and built environment.

4.4.1 Student questionnaire

Participating students in grades 9 to 12 were administered student-level questionnaires (Cq) once annually. The Cq is a 12-page machine-readable scantron-based paper questionnaire that is completed by participating students in the classroom setting on the day of data collection (Bredin & Leatherdale, 2014). The Cq takes about 30 to 40 minutes to complete. The Cq includes several questions about various types of individual behaviour and health outcomes such as questions related to body weight, use of three main substances (tobacco, alcohol, and cannabis), physical activity, sedentary activity, and mental health. The questionnaire also includes questions related to eating behaviours, bullying, education outcomes, school connectedness, and consumption of energy drinks (Bredin & Leatherdale, 2014).

4.4.1.1 Survey protocols

The student-level questionnaire was administered by classroom teachers on the day of data collection (Thompson-Haile, Bredin, & Leatherdale, 2013). Teachers were provided with detailed instructions for implementing the survey to ensure consistency across sites (Thompson-Haile et al., 2013). All students who were not on the “No permission list” (which contains individuals whose parents opted-out of the survey based on the passive consent protocol), and attended school on the day of data collection, were eligible to complete the questionnaire. The participation rate for four years of the study were 79.2% (2013-14), 78.7% (2014-15), 79.9 (2015-16), and 76.0 (2016-17). The main reasons for non-participation were absenteeism, classroom spares, and a small number of parental or student refusals (average of 1.2%). For the sake of protecting student confidentiality, students were asked to seal their questionnaires into blank envelopes once they were completed. The teacher collected the completed Cq envelopes and placed them into a larger classroom envelope (Thompson-Haile et al., 2013). Each classroom envelope was then sent to the data collector in school’s main office. The schools’ data were returned to the University of Waterloo for processing.

4.4.1.2 Data linkage

The longitudinal student-level dataset was created by linking student data from the Cq over Year 2 to Year 5 of the COMPASS study through a unique 6-digit code generated from student response to the gender question on the questionnaire, as well as responses to a set of five questions: the first letter of student middle name, the name of the month in which student was

born, the second letter of student's full first name, the last letter of student's last name, and the first initial of the student's mother's first name (Bredin & Leatherdale, 2013). These five questions were presented on the front page of the student Cq to increase likelihood that students complete them. To further increase the quality of the linkage, data from students over time were matched within schools rather than across schools (Bredin & Leatherdale, 2013). Moreover, to reduce the false-linkage error, the linkage data were checked by the linkage process using information from reported grade, age, and ethnicity of each student. The record was removed from the dataset if: (1) the difference in grade between two consecutive years was negative or greater than one, or (2) the difference in age was greater than two. Figure 4-2 illustrates the linkage procedure for two consecutive years. This procedure can be generalized to link multiple years.

4.5 Measures

This dissertation used four indicators to quantify patterns of individuals' alcohol consumption and used a variety of individual and neighbourhood factors to examine influences on the patterns of alcohol consumption. The alcohol measures were used to: (1) identify patterns of alcohol consumption (Study 1), (2) determine trajectories of alcohol consumption (Study 2), and (3) investigate the association between the new LCBO policy and changes to patterns of alcohol consumption in the population (Study 3).

4.5.1 Measures assessing alcohol consumption

Alcohol consumption measures used in the Cq are consistent with those have been used nationally (Canadian Student Tobacco, Alcohol and Drug Survey, 2017). Students participating in the COMPASS survey were asked to report their alcohol consumption through three questions: (1) "In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?". The response categories were on a 10-point scale (never, not in the last 12 months, only a sip, less than once a month, once a month, 2 or 3 times a month, once a week, 2 or 3 times a week, 4 to 6 times a week, every day); (2) "In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?" The response categories were on an 8-point scale (never, not in the last 12 months, less than once a month, once a month, 2 to 3 times a month, once a week, 2 to 5 times a week, daily or almost daily); and (3) "How old were you when you first had a drink of alcohol that was more than just a sip?" Responses range from 8

years or younger to 18 years or older. Then, age of alcohol initiation for the students who indicated alcohol consumption was dichotomized as occurring at before age 14, the age at which students, generally, begin secondary school.

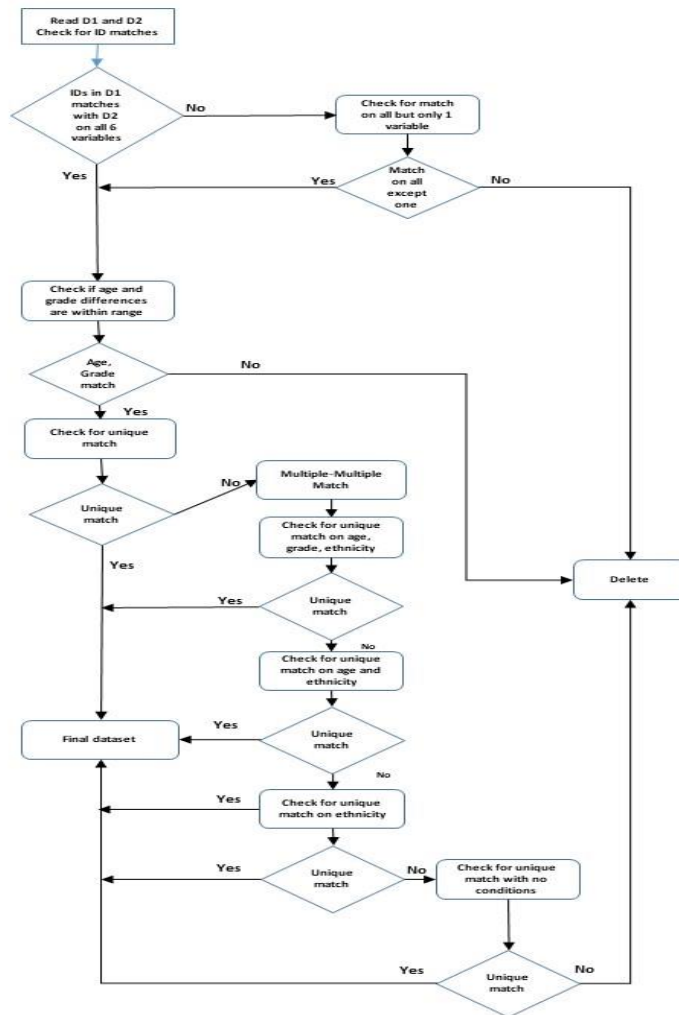


Figure 4-2. The linkage procedure for linking two years of data from students in grade 9 to 12 participating in the COMPASS study

4.5.2 Individual-level variables

Research indicates that various individual-level characteristics, such as age (Freeman, King, & Picket, 2016), gender (Jackson & Schulenberg, 2013), ethnicity (Malone et al., 2012), and age of initiation (Kim et al., 2017), are associated with youth alcohol consumption. The study examined effects of school grade, gender, ethnicity, tobacco use, and cannabis use on probability of engagement in certain alcohol use patterns, and also on transition probabilities between alcohol use patterns. These variables measured by Cq as follows:

Gender: the question “Are you female or male?” followed by a female and male response option measured the gender of participants.

Ethnicity: Detailed information about Ethnicity was recorded based on a student’s response to the question “how do you describe yourself?” The listed options for this question were White, Black, Aboriginal (First Nations, Métis, Inuit), Latin American/Hispanic, Asian, and Other.

Grade: One question asked about the grade of students: “What grade are you in?” followed by the response options of grade 9 to grade 12.

Cigarette use: Students’ cigarette use was assessed by asking students, “On how many of the last 30 days did you smoke one or more cigarettes?” Responses were recorded for analysis into a binary variable (None=0, use in any day during the past 30 days=1).

Cannabis use: student’s cannabis use was assessed by asking students, “In the last 12 months, how often did you use marijuana or cannabis?” Similar to cigarette use, responses were classified into a binary variable (None=0, use in any day during the last year=1).

4.5.3 School-level (neighborhood) variables

Locations of off-premise alcohol outlets: The Enhanced Points of Interest (EPOI) databases were used to locate the alcohol retailers. EPOI is a vector GIS database that provides data on the location of specific services and business for all province/territories of Canada, including the Standard Industrial Classification (SIC) codes, name of business, and phone numbers.

The number of off-premise alcohol outlets: The number of alcohol retailers was quantified by the number of off-premise alcohol outlets (namely, The Beer stores, LCBOs, and Winery

Retail stores) located within a 10 km buffer of the schools. The buffer radius of 10 km was selected because this buffer represents a distance that individuals can drive to within 10-15 minutes to purchase alcohol. In the current study, only the number of off-premise alcohol outlets surrounding a school was extracted, transformed, and included for the analyses and the number of on-premise alcohol outlets (i.e., restaurants and bars) were not included.

Median household income (MHI): This variable was generated using the census divisions that corresponded with school postal codes according to data from the 2011 National Household Survey (Statistics Canada, 2013).

Exposure to the new LCBO policy: The list of all authorized stores was retrieved from the Ontario Ministry of Finance (The Ontario Ministry of Finance, 2018). Distances of the participating COMPASS schools from the grocery stores were obtained by entering the coordinates of the schools and stores manually into Google Maps. A dummy variable is used to represent whether schools were exposed to the policy change. This dummy variable took 1 if at least one grocery store with alcohol was within the 10 km buffer of the school at December 2015, otherwise zero.

4.5.4 Study specific sample & measures

The research questions of each study within this thesis were explored using the student and built environment data as follows:

4.5.4.1 Study 1: Identifying patterns of alcohol use among secondary school students in Canada: a multilevel latent class analysis

Sample size & participants: Participants in this study were 45,298 students in grade 9 to 12 within participating schools across Ontario (n=79) and Alberta (n=10) in Year 2 (Y₂:2013-2014).

Alcohol measures: Three measures were used for assessing alcohol use among this study sample: the frequency of alcohol consumption, the frequency of binge drinking, and age of initiation of alcohol consumption.

4.5.4.2 Study 2: Identifying trajectories of alcohol use among a sample of secondary-school students in Ontario and Alberta: longitudinal evidence from the COMPASS study

Sample size and participants: Participants in this study were 19,492 students in grade 9 in Year 2 (Y2:2013-2014) across Ontario (n=79) and Alberta (n=10) who had linked data from Year 2 and Year 3 (i.e. those who had participate in both year 2 and year 3).

Alcohol measures: Two measures were used for assessing alcohol use among this study sample: the frequency of past year alcohol consumption, and the frequency of past year binge drinking.

4.5.4.3 Study 3: Identifying trajectories of alcohol use among a sample of secondary-school students in Ontario and Alberta: longitudinal evidence from the COMPASS study

Sample size & participants: Participants in this study were 2,267 students in grade 9 at Year 2 (Y2:2013-2014) across Ontario (n=56) and Alberta (n=4) who had linked data from Year 2 to Year 5 (2016-2017) (i.e. those who had participated in years 2, 3, 4, and 5, inclusively). Participants in study 3 were considered to be in three cohorts. Cohort 1 included 652 students within 13 schools in Ontario who were exposed to the new LCBO policy. Cohort 2 included 1,527 students that were not exposed to the policy change. Cohort 3 included 88 students from 4 participating schools in Alberta. Cohort 2 and 3 are considered as control groups for the exposed cohort 1.

Alcohol measures: Two measures were used for assessing alcohol use among this study sample: the frequency of alcohol consumption and the frequency of binge drinking.

4.6 Statistical analysis

Multiple statistical methods were used to answer the various research questions of the dissertation. The statistical methods that were employed for each study are described in the following section.

4.6.1 Study 1: Identifying patterns of alcohol use among secondary school students in Canada: a multilevel latent class analysis

The objective of Study 1 was to explore the patterns of youth alcohol consumption. The variables used to identify alcohol consumption patterns were defined as follows (1) the frequency of alcohol consumption (with 4 possible categories: 1= none, 2= up to 3 times a month, 3= between 1 to 3 times a week, and 4=more than 3 times a week; (2) the frequency of binge drinking (with 4 possible categories: 1= none, 2=less than or once a month, 3= between 2 to 4 times a month, and 4=more than once a week); and (3) the age of alcohol use initiation (with two possible categories for consumers: <14 and >=14 years). These responses can form 4*4*3=48 distinct empirical patterns, meaning that the alcohol data can be classified into a contingency table with 48 cells (patterns). From these 48, a limited number of dominant patterns are extracted that sufficiently explain the observed data, and other patterns may be disregarded because of the low likelihood of occurrence and small cell count. The classic log-linear methods usually employed for these types of discrete data yield serious concerns about the expected frequency of cells and the complexity of the interpretation of such a large number of possible patterns. To address these concerns, Study 1 used latent class analysis (LCA) to find the most likely patterns of youth alcohol consumption. LCA is a person-centred approach that assumes individuals can be classified into distinct classes of an underlying categorical variable, each class here representing a pattern of alcohol consumption (Collins & Lanza, 2013). All individuals in the same class are considered similar and share common characteristics with respect to their alcohol-consumption behaviour. LCA enables researchers to represent a complex array of data, forming large contingency tables in a concise manner while revealing the important information. In this case, LCA was used to find the number of alcohol use patterns that best represent the main patterns in the sample population. LCA can be described as follows (Collins & Lanza, 2013):

Let Y_{ijk} denote the response of individual i , $1, 2, \dots, n$, within a cluster k , $1, 2, \dots, K$, on the j th question, and let each question j , $1, 2, \dots, M$, have a possible discrete response r_j , $1, 2, \dots, R_j$. The latent class model can be written as follows:

$$p(Y_{ik1} = r_1, Y_{ik2} = r_2, \dots, Y_{ikM} = r_M | X_{ik}) = \sum_{c=1}^L p(C_{ik} = c | X_{ik}) \prod_{j=1}^M \prod_{r_j=1}^{R_j} p(Y_{ikj} = r_j | C_{ik} = c)^{I(Y_{ikj}=r_j)}$$

where C_{ij} is the latent class membership, c is used to refer to a particular latent class, $C_{ik} = 1, 2, \dots, L$, $I(y_{ikj} = r_j)$ is an indicator function that equals 1 if the response to question $j = r_j$ and equals zero otherwise, and X_{ik} is a vector of individual covariates. The parameters of the model are estimated using the expectation-maximization (EM) algorithm. Traditional LCA assumes that observations are independent of one another. In the current research, however, students are classified into schools and the independent assumption is violated. As such, a multilevel LCA was used.

Multilevel LCA (MLCA) considers the two-level structure of data and allows latent class memberships to vary across schools (Finch & French, 2014; Henry & Muthén, 2010). For the nonparametric approach of MLCA used in this dissertation, between-cluster variations are expressed through assuming an additional latent structure for level 2 units. That is, similar to the level 1 latent structure that is defined using observed indicator variables, the between-cluster structure is created using the prevalence of level 1 class memberships. Thus, clusters belong to one of T cluster-level mixture components, and each class of level 2 consists of clusters with similar prevalence of within-cluster level 1 classes. The MLCA can be now be expressed as

$$p(Y_{ik1} = r_1, Y_{ik2} = r_2, \dots, Y_{ikM} = r_M | W_k, X_{ik}, Z_k) \\ = \sum_{c=1}^L p(C_{ik} = c | W_k = w, X_{ik}, Z_k) \prod_{j=1}^M \prod_{r_j=1}^{R_j} p(Y_{ikj} = r_j | C_{ik} = c)$$

where Z_j denotes the vector of level 2 covariates, W_k represents the level 2 class membership for cluster k , and $w, 1, 2, \dots, T$ is a particular level 2 class. In this representation, the probability of class membership can be defined as follows:

$$p(C_{ik} = c | W_k = w, X_{ik}, Z_k) = \frac{\exp(\gamma_c + \beta_c x_{ik} + \alpha_c z_k + \alpha_{cw})}{1 + \sum_{r=2}^L \exp(\gamma_r + \beta_r x_{ik} + \alpha_r z_k + \alpha_{rw})}$$

where $c = 2, 3, \dots, L$, and α_{cw} , is a random latent variable associated with clusters in class w . LCA uses multinomial logistic regression to incorporate covariates into the model. The outcome variable in the multinomial regression is membership in identified classes with one class

considered as the reference. Multilevel LCA was performed in Mplus 8.0 (Muthen & Muthen, 2017).

4.6.2 Study 2: Identifying trajectories of alcohol use among a sample of secondary-school students in Ontario and Alberta: longitudinal evidence from the COMPASS study

Study 2 employed latent transition analysis (LTA) to explore trajectories of alcohol consumption over the two years before the new LCBO policy. LTA is a longitudinal extension of LCA (see previous section) that can be used to model a stage-developmental process over a period of time and to estimate probabilities of transitioning between stages. Since the development of substance use is often considered stage-sequential (as a discrete-time process), Study 2 employed LTA to identify youth alcohol-use trajectories. Compared to traditional approaches, such as repeated measures analysis of variance and growth curve modeling, LTA is more appropriate when development is conceptualized as discrete and the substance-use behaviour (e.g., alcohol consumption) is multifaceted, requiring measurements through multiple indicators. In contrast to a traditional modelling approach that describes the variability of a single variable, LCA provides a framework for describing heterogeneity in the population based on the variations between individuals on a set of variables or characteristics (Lanza, 2016). In addition, classic clustering methods are mainly variable-centred, which create clusters based on the association among variables, compared to LTA which is a person-centred that creates clusters based on similar patterns of individuals' behaviours (Laursen, 2006). The goal of variable-centred models is to identify significant predictors of outcomes, and relation between dependent and independent variables. In comparison, the goal of person-centred models is to classify individuals into distinct clusters based on individual response patterns in a way that individuals within a cluster are more similar than individuals between clusters (Muthen & Muthen, 2000). Similar to LCA, LTA highlights dominant classes that are essential to explain the observed behaviours in a population; additionally, LTA enables researchers to estimate the probabilities of transitioning among patterns (classes) over time. In a longitudinal study, summarizing all possible responses of individuals efficiently is much more important than in cross-sectional studies, because the contingency table created by longitudinal data grows dramatically over time. For example, the contingency table of Study 2, created from two alcohol use indicators measured

twice over time, consists of $4^2 \cdot 4^2 = 256$ different possible patterns (compared to 48 patterns in Study 1). Building on the LCA model, LTA describes the probability of observing a particular vector of responses of y can be represented as follows (Collins & Lanza, 2013) :

$$p(Y = y) = \sum_{c_1=1}^K \cdots \sum_{c_T=1}^K \gamma_{c_1} \tau_{c_2|c_1} \cdots \tau_{c_t|c_{t-1}} \cdots \tau_{c_T|c_{T-1}} \prod_{t=1}^T \prod_{j=1}^J \prod_{r_{j,t}=1}^{R_j} \rho_{j,r_{j,t}|c_t} I(y_{j,t}=r_{j,t}) \quad t = 1, 2, \dots, T$$

where $\rho_{j,r_{j,t}|c_t} = p(Y_{jt} = r_{jt} | C_t = c)$ is the conditional item response probability that represents the probability of response r_j to question j at time t given being in class c at time t ($\sum_{r_{j,t}=1}^{R_j} \rho_{j,r_{j,t}|c_t} = 1$), $I(y_{j,t} = r_{j,t})$ is an indicator function that equals 1 when the response to question $j = r_j$ and zero otherwise, $\tau_{c_t|c_{t-1}} = p(C_t = c_t | C_{t-1} = c_{t-1})$ is the conditional probability of transition from latent class c_{t-1} at time $t - 1$ to latent class c_t at time t ($\sum_{c_t=1}^K \tau_{c_t|c_{t-1}} = 1$), and γ_{c_1} is the probability of membership in class c_1 at time one. The parameters are estimated via the expectation-maximum (EM) algorithm. The transition probabilities are the elements of the transition matrix in the form of

$$p = \begin{bmatrix} \tau_{1_{t+1}|1_t} & \tau_{2_{t+1}|1_t} & \tau_{3_{t+1}|1_t} & \cdots & \tau_{c_{t+1}|1_t} \\ \tau_{1_{t+1}|2_t} & \tau_{2_{t+1}|2_t} & \tau_{3_{t+1}|2_t} & \cdots & \tau_{c_{t+1}|2_t} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \tau_{1_{t+1}|c_t} & \tau_{2_{t+1}|c_t} & \tau_{3_{t+1}|c_t} & \cdots & \tau_{c_{t+1}|c_t} \end{bmatrix}$$

where, for example, $\tau_{3_{t+1}|1_t}$ is the probability of being in class 3 at time $t+1$ given being in class 1 at time t .

The item-response probabilities are often constrained to be equal in LTA. Thus, only the clusters are explored, based on the first wave of the longitudinal study, and the structure is assumed to be stable over time. However, the prevalence of clusters may vary over time due to transitioning of individuals among different classes.

To examine the effect of covariates on the class membership or on the transitioning among the classes, LTA uses multinomial logistic regression. Similar to LCA the outcome variable in the regression is class membership. To test the effect of the covariates on the transition probabilities, a set of multinomial logistic regressions are fitted; each model corresponding to a row of the transition matrix that models belonging to a certain class at follow-up based on the

covariates and the latent class at the previous time (Collins and Lanza, 2013). The nested structure of students within schools is accounted for in the LTA models used in Study 2 and Study 3. The effects of the baseline covariates were examined by correcting the variance of estimated parameters in latent classes extracted in the baseline using LCA (PROC LCA & PROC LTA, 2015).

4.6.3 Study 3: The impact of an alcohol policy change on developmental trajectories

Study 3 used four-year linked data from the COMPASS host study in a natural experiment context to explore to what extent the alcohol use trajectories of youth in jurisdictions exposed to the new LCBO policy differed from the trajectories of youth in the two unexposed jurisdictions in Ontario and Alberta. Analyses of this study were performed in three stages. First, LTA was used to identify the most reasonable number of latent alcohol patterns among the participating youth. The model building was started with a two-class model and successively the number of latent classes were added. Each model was refitted with 50 random sets of starting values to provide greater confidence that the model would locate the global maximum and that the estimated parameters were the best maximum likelihood estimates (Nylund, Asparouhov, & Muthén, 2007). Then, the relative fit of all models was evaluated using the widely used goodness-of-fit statistics of the Bayesian information criterion (BIC) (Schartz, 1978), Akaike information criterion (AIC) (Akaike, 1987), and likelihood-ratio statistic (G²) (Agresti 1990). After the most reasonable number of latent classes had been determined, the identified classes were labelled based on the values of conditional item-response probabilities (IRP). The IRPs indicate the strength of association between every level of alcohol item and the class. At the next step, the stability of the structure of latent classes across the four waves of the study were examined by comparing the fit of the two latent transition model: one with item-response probabilities were constrained to be identical over years (M1) and another model with freely estimated item-response probabilities across the four waves (M2). The equivalence of these models indicates that the structure of the latent classes (and consequently their interpretation) are stable over time (Collins & Lanza, 2013).

Second, the multi-group LTA was fitted to data from two years pre-policy change (Y2 and Y3) to examine (a) the stability of the latent structure (measurement invariance) across the three cohorts, and (b) to examine the similarity of transitioning probabilities among the three cohorts during the two years before the new LCBO policy was enacted. If the grouping variable G has $q=1,2,\dots,Q$ groups, then the multiple-group LTM is expressed as follows:

$$p(Y = y|G = q) = \sum_{c_1=1}^K \dots \sum_{c_T=1}^K \gamma_{c_1|q} \tau_{c_2|c_1,q} \dots \tau_{c_t|c_{t-1},q} \prod_{t=1}^T \prod_{j=1}^J \prod_{r_{j,t}=1}^{R_j} \rho_{j,r_{j,t}|c_t,q}$$

Using the above notation, the stability of classes over the three groups of this study mean that: $\rho_{j,r_{j,1}|c_1,q} = \rho_{j,r_{j,1}|c_1,q'} \quad q \neq q', \quad q = 1,2,3$. The equivalence of transition probabilities between the three cohorts was examined by fitting a model with the following constraints:

$$\tau_{c_2|c_1,q} = \tau_{c_2|c_1,q'} \quad q \neq q'$$

Third, a multiple-group LTA was fitted to the whole sample of students in the four years of the study (Y2 and Y5) to test the fit of the model with equal transition probabilities among the three cohorts (M3) with the one that transition probabilities are not equal across the three cohorts (M4):

$$\text{M3:} \quad \tau_{c_4|c_3,q} = \tau_{c_4|c_3,q'} \quad q \neq q'$$

$$\text{M4:} \quad \tau_{c_4|c_3,q} \neq \tau_{c_4|c_3,q'} \quad q \neq q'$$

To evaluate the impact of the new LCBO policy, this dissertation research has compared changes in the transition probabilities of youth in the exposed jurisdictions with the transition probabilities of students in the unexposed jurisdictions. The LCA and LTA were performed by PROC LTA (PROC LC & PROC LTA, 2015). EM algorithm was used to estimate the latent class membership probabilities, and transition probabilities.

4.6.4 Missing data

Missing data are inevitable in longitudinal survey studies and must be accounted for in the data analysis. Attrition in longitudinal studies can occur for a variety of reasons, and can result in missing data. In school-based studies that use a self-reporting questionnaire (like this study), missing data could be a result of item non-response (students do not answer particular questions), unit non-response (students miss a particular data collection time point), dropout (grade 12 students graduate from the study or students change schools). Within the COMPASS study, item non-response rates for alcohol items are relatively low. The unit non-response items in the COMPASS study are due to parental refusal, and the remainder due to absenteeism, classroom spares, or student refusal. Both PROC LCA and LTA treat missing values as missing at random and use the full information maximum likelihood (FIML) approach (Collins, Schafer, & Kam, 2001; Schafer, 1997), in which subjects with missing values on alcohol indicator variables were retained but cases with missing covariates were removed from the analysis.

Chapter 5

General Results

This chapter presents the results of this dissertation research according to the studies' research questions. The detailed results are presented in Chapters 6 to 8 in three manuscripts that have been submitted to the journals.

5.1 Study 1. Identifying patterns of alcohol use among secondary school students in Canada: a multilevel latent class analysis

In study 1, data from a sample of 45,298 students participating in Year 2 (Y2: 2013-2014) of the COMPASS study across 89 secondary schools in Ontario (n=79) and Alberta (n=10) were analyzed to explore the heterogeneity of alcohol use in the youth population. The sample was evenly split in terms of gender (49.4% female) and school grades (26.2% (n=11,793) in Grade 9, 26.2% (n=11,817) in Grade 10, 24.9% (n=11,229) in Grade 11, and 22.7% (n=10,233) in Grade 12). Of the sample, 92.1% (n=41,734) participated from schools in Ontario and 7.9% (n=3,564) from Alberta.

5.1.1 Research question 1: Is there a latent class structure that represents the heterogeneity in alcohol use patterns of the youth population?

Latent class analysis identified four distinct patterns of alcohol use:

- 1- *non-drinker* (had never drunk or did not use alcohol in past year, 44.2% of the sample),
- 2- *light drinker* (initiated alcohol consumption after age 13 with a frequency of up to three drinks and one binge drinking episode per month, 41.8% of the sample),
- 3- *regular drinker* (initiated alcohol consumption before age 13, drink alcohol one to three times a week, and undertook binge drinking two to four times a month, 11.1% of the sample), and
- 4- *heavy drinker* (initiated alcohol consumption before age 14 and drink alcohol more than 3 times a week with binge drinking more than once a week, 2.9% of the sample).

5.1.2 Research question 2: Do patterns of alcohol use differ between schools? Is there a latent class structure that represents the heterogeneity in student's alcohol use patterns among schools?

The nonparametric multilevel LCA classified schools into two groups: low-use schools (n=40, 44.9% of schools) with a relatively large number of non-drinkers and high-use schools (n=49, 55.1% of schools). Students attending high-use schools were more likely to belong to regular or heavy drinker classes than the individuals attending low-use schools ($p < 0.001$). The proportions of regular and heavy drinkers in high-use schools were nearly double the proportions in low use schools, 11.8% and 7.2% compared to 6.0% and 4.6%, respectively.

5.1.3 Research question 3: Which individual characteristics are associated with engagement in alcohol use patterns?

Multinomial logistic regression in multilevel latent class analysis indicated significant associations between both gender and grade of individuals with student-level latent class membership. The likelihood of being a heavy drinker compared to a non-drinker was 1.3-fold higher for male students. As expected, students in upper grades were engaged in higher levels of drinking.

5.1.4 Which neighbourhood characteristics are associated with school-level latent class membership?

The results indicated that neither of the school-level covariates (i.e., number of off-premise outlets and median household income) had a significant association with membership in level 2 latent classes. Odds ratio of being a high-use school compared to low-use school for increase in any unit number of off-premise alcohol outlets was estimated as OR=1.01 (0.98, 1.03) and for median household income was estimated as OR=1.56 (0.64, 3.70).

5.2 Study 2: Identifying trajectories of alcohol use among a sample of secondary-school students in Ontario and Alberta: longitudinal evidence from the COMPASS study

In Study 2, latent transition analysis (LTA) was used to estimate probabilities of transitioning between patterns of alcohol use over two years before the new LCBO policy took

Table 5-1. Transition probabilities for the four-latent class model of youth alcohol consumptions in baseline (school year 2013-14) and follow-up (school year 2014-15) of the COMPASS study (n=19 124) adjusted for the school year, cigarette and cannabis use

Baseline class	Follow-up class			
	Non-drinker	Periodic drinker	Low risk drinker	High-risk regular drinker
Non-drinker	0.64	0.24	0.09	0.03
Periodic drinker	0.01	0.54	0.40	0.05
Low risk drinker	0.08	0.02	0.69	0.20
High-risk regular drinker	0.08	0.09	0.18	0.65

place (school year 2013-14 and 2014-15). The two-year linked data of 19,492 students that were in grade 9 to grade 11 at baseline year were analyzed.

5.2.1 Research question 1: What are the dominant alcohol use patterns among a sample of Canadian youth in Ontario and Alberta participating in the COMPASS study? What is the prevalence of the patterns among the population?

Consistent with the results of the cross-sectional Study 1, LTA identified four latent classes of alcohol use patterns, but with slightly different characteristics of each class. The four classes are

1. *non-drinker* (had never drunk or did not use alcohol in past year),
2. *periodic drinker* (reported drinking up to 3 times a month and no binge drinking),
3. *low risk drinker* (reported drinking up to 3 times a month and once or less than a month binge drinking),
4. *high-risk regular drinker* (reported drinking 1 to 3 times a week and binge drinking 2 to 4 times a month).

Non-drinkers were the largest subgroup in both waves (55.9% baseline to 39.8% follow-up), though, the proportion was reduced at follow-up. The number of periodic drinkers increased slightly from 22.9% of the sample at baseline to 26.3% at follow-up. The prevalence of the low risk drinkers and high-risk regular drinkers increased nearly 50% at follow-up.

Table 5-2. Estimated Odds ratios reflecting the effects of covariates on membership and transitions between latent classes of youth alcohol drinking in baseline (school year 2013-14) and follow-up (school year 2014-15) of the COMPASS study (n=19 124)

Covariate	Non-drinker	Periodic drinker	Low risk drinker	High-risk regular drinker
Class membership covariate				
Males	Reference	0.85 (0.79,0.93)	0.86 (0.80, 0.93)	1.20 (1.04,1.36)
White ethnicity	Reference	1.51 (1.37,1.65)	1.72 (1.57, 1.89)	1.26 (1.08, 1.49)
Smoking	Reference	4.44 (3.50, 5.63)	12.63 (10.31,15.47)	22.85 (14.24, 33.62)
Cannabis	Reference	5.98 (5.17, 6.91)	10.88 (8.34, 13.75)	19.24 (9.81, 30.47)
Transition covariates				
Males				
Non-drinker	Reference	0.83 (0.76, 0.90)	1.15 (0.89, 1.49)	2.40 (1.76, 3.27)
Periodic drinker	1.64 (1.21, 2.22)	Reference	1.00 (0.87, 1.16)	1.90 (1.33, 2.71)
Low risk drinker	1.42 (0.80, 2.51)	0.00 ^a	Reference	1.77 (1.51, 2.08)
High-risk regular drinker	1.33 (0.78, 2.28)	0.75 (0.38, 1.48)	0.80 (0.57, 1.14)	Reference
Grade 9 (relative to Grade 11)				
Non-drinker	Reference	0.84 (0.77, 0.91)	0.95 (0.74, 1.22)	0.87 (0.65, 1.16)
Periodic drinker	1.11 (0.80, 1.55)	Reference	1.47 (1.26, 1.71)	1.91 (1.34, 2.74)
Low risk drinker	1.52 (0.80, 2.89)	0.00 ^a	Reference	1.37 (1.14, 1.65)
High-risk regular drinker	2.56 (1.42,4.61)	2.06 (0.94, 4.53)	1.14 (0.71, 1.83)	Reference
Grade 10 (relative to Grade 11)				
Non-drinker	Reference	1.11 (1.02, 1.22)	1.12 (0.83, 1.52)	1.01 (0.77, 1.33)
Periodic drinker	0.92 (0.67, 1.26)	Reference	0.98 (0.84, 1.13)	0.84 (0.58, 1.22)
Low risk drinker	0.82 (0.45, 1.49)	0.00 ^a	Reference	0.97 (0.83, 1.15)
High-risk regular drinker	0.91 (0.52, 1.58)	0.68 (0.32, 1.43)	1.21 (0.85, 1.72)	Reference

^aThere was no transitioning from the low risk to periodic class.

5.2.2 Research question 2: What is the probability of youth transitioning among the patterns of alcohol use over time?

Table 5-1 presents latent transition probabilities based on the LTA model adjusted for the school year and cigarette and cannabis use. Low risk drinkers and high-risk regular drinkers indicated a higher likelihood of maintaining the same class at follow-up relative to non-drinkers and periodic drinkers. In contrast, the periodic drinkers were most likely to transition to low-risk drinker class. In particular, 40% of the students in the periodic drinker class at baseline moved to the low-risk drinker class at follow-up. Non-drinkers demonstrated a 24% chance of transitioning to periodic drinking. The results also show that, despite 65% of high-risk regular drinkers maintaining their class at follow-up, 18% of high-risk regular drinkers moved to low-risk class, and 8% reported complete cessation of alcohol drinking (Table 5-1).

5.2.3 Research question 3. What individual characteristics are associate with engagement in different alcohol use patterns? What individual characteristics are associated with transitioning between alcohol use patterns over time?

Odds ratios (OR) in Table 5-2 suggest that male students were more likely to be in the high-risk regular drinker class than females (OR=1.2, 95% CI: 1.04-1.36). Ethnicity was also found to be a significant predictor of class membership ($2(\text{likelihood}_{\text{without ethnicity}} - \text{likelihood}_{\text{with ethnicity}}) = 37.2$, $df=3$, $p<.001$), indicating White students were significantly at a higher risk of being engaged in a level of alcohol use compared to their peers from other ethnic groups.

Table 6 presents the odds ratios associated with transitions from each latent class relative to remaining in the same class. Male non-drinkers indicated 2.4 (95% CI: 1.76–3.27) times greater chance of being engaged in high-risk regular drinking. The back transition from the high-risk drinking to abstinence was also higher for male students (OR = 1.33, 95% CI: 0.78–2.28). Grade 9 students were more likely to move to higher risk drinking classes than Grade 11 students, while there were no significant differences between Grade 10 and Grade 11 students in transitioning to higher risk drinking classes.

Cigarette and cannabis use increased the probability of membership in the higher risk drinking classes. Odds ratio of membership in the periodic drinker class for cigarette smokers was more than four times that of non-smokers (OR=4.44, 95% CI= 3.50-5.63). Similar patterns were observed for cannabis users, in which odds of engaging in higher levels of drinking was greater for cannabis users relative to non-drinkers. The results of multinomial latent transition analysis Table 5-2 indicated that the number of off-premise alcohol outlets and the median household income of families were not significantly associated with the membership of latent classes.

Table 5-3. Characteristics of individuals participating at baseline year (2013-14) of the COMPASS study (n=2,267) by exposure to the new LCBO policy

Characteristic	Exposed (%)	Ontario- unexposed (%)	Alberta (%)
Gender (male)	282 (43.2)	746 (49.0)	41 (46.6)
Ethnicity (white)	440 (67.9)	1225 (80.7)	69 (78.4)
Median household income < \$68,830 ^a	265 (40.6)	812 (53.2)	88 (100)
Total # of off-premise alcohol outlets >8 ^{a,b}	630 (96.6)	511 (33.5)	0 (0.0)
Urbanicity			
Small	0 (0.0)	416 (27.2)	88 (100)
Medium	39 (6.0)	434 (28.4)	0 (0.0)
Large	613 (94.0)	677 (44.3)	0 (0.0)

^a median of the sample, ^b within 10 km buffer zone around schools

5.3 Study 3: The impact of an alcohol policy change on developmental trajectories of youth alcohol use: examination of a natural experiment in Canada

Study 3 evaluated the impact of the new LCBO policy on trajectories of alcohol use among youth in different jurisdictions of Ontario and Alberta. For this purpose, probabilities of transitioning among the four identified patterns of alcohol use were within the exposed jurisdictions in Ontario were compared with those of unexposed jurisdictions in Ontario and Alberta.

Table 5-3 represents the characteristics of the youth population in the three cohorts of the study. The majority of secondary students (96.6%) within the exposed jurisdictions have already been close to more than 8 off-premise outlets compared to students in jurisdictions in Ontario not exposed to the new policy (33.5%) and in Alberta (0.0). The four schools in Alberta were in a rural area that had less than eight outlets around. Table 5-4 reports the frequency of substance use in four waves (school year 2013-14 to 2016-17) of the COMPASS study according to the three groups of jurisdictions that are exposed or unexposed to the new LCBO policy. Figure 5-1 illustrates the distribution of off-premise alcohol outlets within the 10 km buffer around the COMPASS schools in Ontario.

Table 5-4. The frequency of substance use in four waves (school year 2013-14 to 2016-17) of the COMPASS study according to the three cohorts in the exposed or unexposed to the new LCBO policy (n=2,267)

Variable	Cohort	Wave 1 (%)	Wave 2 (%)	Wave 3 (%)	Wave 4 (%)
Alcohol drinking					
Non-user	Exposed	490 (75.7)	370 (56.8)	279 (43.1)	224 (34.8)
	Ontario-Unexposed	1128 (75.3)	843 (56.1)	588 (38.8)	459 (30.3)
	Alberta	52 (59.8)	35 (39.8)	28 (32.2)	21 (24.1)
Up to 3 times a month	Exposed	144 (22.3)	252 (38.7)	316 (48.7)	322 (50.0)
	Ontario-Unexposed	340 (22.7)	565 (37.5)	790 (52.1)	852 (56.2)
	Alberta	33 (37.9)	52 (59.1)	49 (56.3)	56 (64.4)
1 to 3 times a week	Exposed	11 (1.7)	27 (4.1)	44 (6.8)	81 (12.6)
	Ontario-Unexposed	25 (1.7)	82 (5.4)	122 (8.0)	176 (11.6)
	Alberta	2 (2.3)	1 (1.1)	9 (10.3)	10 (11.5)
3+ times a week	Exposed	2 (0.3)	2 (0.4)	9 (1.4)	17 (2.6)
	Ontario-Unexposed	5 (0.3)	15 (1.0)	17 (1.1)	30 (2.0)
	Alberta	0 (0.0)	0 (0.0)	1 (1.1)	0 (0.0)
Binge drinking					
No binge drinking	Exposed	581 (89.1)	495 (75.9)	393 (60.5)	339 (52.1)
	Ontario-Unexposed	1359 (89.1)	1129 (74.0)	913 (59.9)	746 (48.9)
	Alberta	75 (85.2)	53 (60.2)	40 (45.4)	29 (32.9)
Less or once a month	Exposed	59 (9.0)	128 (19.6)	178 (27.4)	187 (28.8)
	Ontario-Unexposed	138 (9.0)	275 (18.0)	434 (28.5)	518 (33.9)
	Alberta	10 (11.4)	25 (28.4)	36 (40.9)	39 (44.3)
2-4 times a month	Exposed	10 (1.5)	25 (3.8)	71 (10.9)	106 (16.3)
	Ontario-Unexposed	24 (1.6)	105 (6.9)	145 (9.5)	216 (14.2)
	Alberta	3 (3.4)	10 (11.4)	10 (12.5)	20 (22.7)
More than once a week	Exposed	5 (0.3)	4 (0.6)	7 (1.1)	18 (2.8)
	Ontario-Unexposed	2 (0.3)	17 (1.1)	32 (2.1)	45 (2.9)
	Alberta	0 (0.0)	0 (0.0)	1 (1.1)	0 (0.0)
Cigarette use	Exposed	12 (1.8)	24 (3.7)	34 (5.2)	581 (89.5)
	Ontario-Unexposed	29 (1.9)	71 (4.6)	129 (8.4)	1353 (88.8)
	Alberta	5 (5.7)	8 (9.1)	13 (14.8)	77 (87.5)
Cannabis use	Exposed	34 (5.3)	85 (13.1)	159 (24.6)	232 (35.9)
	Ontario-Unexposed	68 (4.5)	213 (14.1)	354 (23.4)	494 (32.6)
	Alberta	6 (7.0)	10 (11.6)	25 (28.7)	32 (36.8)

Alcohol off-premise retailers within 10km buffer of COMPASS schools

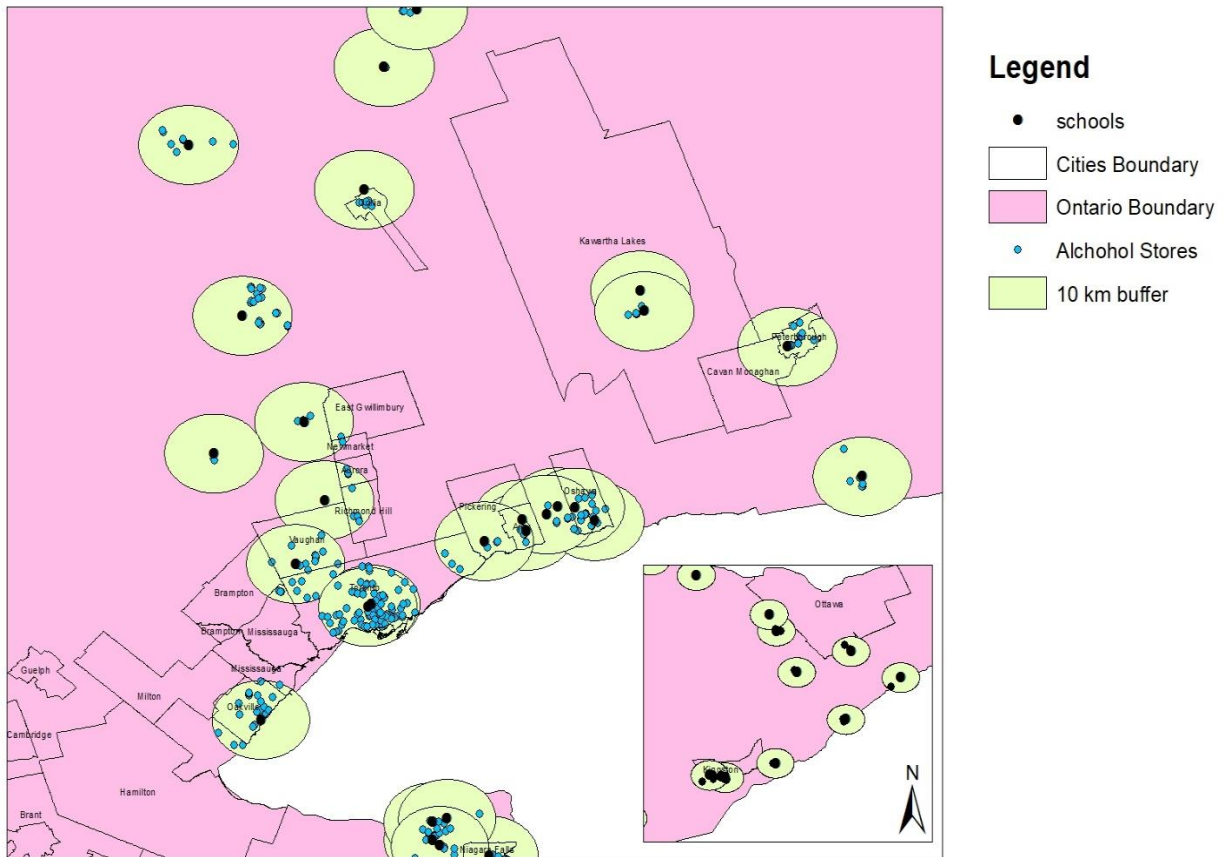


Figure 5-1. Distribution of off-premise alcohol outlets within the 10 km buffer around the COMPASS schools in Ontario in 2015

Grocery stores selling alcohol within 10km of the COMPASS schools

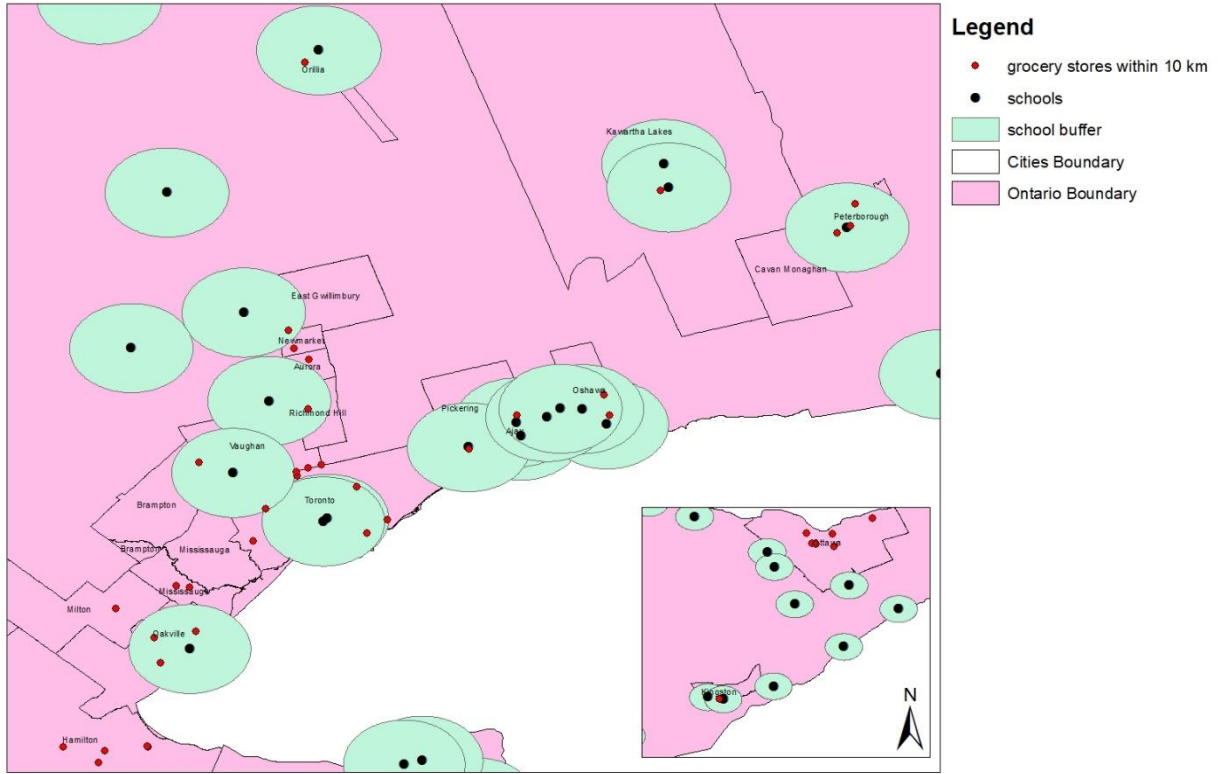


Figure 5-2. Distribution of the grocery stores selling alcohol in Ontario within the 10 km buffer around the COMPASS schools in 2015

Table 5-5. The prevalence of latent classes of youth alcohol-use behaviours in four waves (school year 2013-14 to 2016-17) of the COMPASS study (n=2,267)

Prevalence	Non-drinker	Periodic drinker	Low risk drinker	High-risk regular drinker
Wave 1 (%)	71	18	10	1
Wave 2 (%)	50	24	21	5
Wave 3 (%)	34	24	33	9
Wave 4 (%)	26	21	38	15

5.3.1 Research question 1: What are alcohol use trajectories among youth in the three cohorts in Ontario and Alberta?

Consistent with the results of Study 1 and Study 2, LTA identified four latent trajectories of alcohol use over the four years of follow-up as: non-drinker (had never consumed alcohol or did not drink alcohol in past year, baseline prevalence 71%), periodic drinker (reported monthly drinking and no binge drinking, baseline prevalence 17%), low-risk drinker (reported some steady monthly drinking but limited binge drinking, baseline prevalence 10%), and high-risk regular drinker (reported drinking 1 to 3 times a week and binge drinking 2 to 4 times a month, baseline prevalence 1%). Table 5-5 presents changes in the size of trajectories over four years of secondary school.

5.3.2 Research question 2: Does the new LCBO policy have an effect on the developmental trajectories of youth alcohol use in the exposed jurisdictions?

The results of LTA show substantial changes in alcohol-use behaviour of students over the years of secondary school. The periodic drinker and low-risk drinker classes among the three cohorts illustrated similar changes, particularly among exposed and Ontario-unexposed cohorts (Figure 5-3). Despite this similarity, the probability of transitioning from the low-risk drinker to high-risk regular drinker class decreased among Ontario-unexposed students while remaining stable for students in the exposed jurisdictions. Nonetheless, the covariate cohort was not significant in the LTA model, indicating that, in general, the alcohol policy did not have a significant influence on the probability of transitioning between different classes of alcohol consumption. Though, changes in transition probabilities in/out of the two extreme classes of abstainers and high-risk regular drinkers indicated a difference between the three cohorts (Figure 5-3) (the probabilities are shown in Table C-4).

Results of Figure 5-3 indicate that the probability of transitioning from abstainer class to high-risk regular class for the exposed cohort was 0.007 during the two years before the policy change but doubled afterwards, reaching 0.011. This probability decreased from 0.02 to 0.01 among Ontario-unexposed students and remained stable at 0.001 among Alberta students. The estimated transition probabilities suggest that after the policy change, risk of transitioning to high-risk regular class among abstainers in the exposed jurisdictions was 1.71 times that before the policy change, compared to 0.50 and 1.00 among Ontario-unexposed and Alberta cohorts, respectively.

Moreover, after the policy change, the chance of staying in the high-risk regular drinker class increased by 40.3% for the exposed cohort to reach 92.3%. In contrast, the probability increased by only 13.0% for the Ontario-unexposed cohort and decreased by 10.6% in the Alberta cohort. Among the exposed cohort, the risk of maintaining high-risk regular drinking after the policy change relative to before increased by a factor of 1.77 compared to the 1.13-fold and 0.89-fold change among Ontario-unexposed and Alberta cohorts. Appendix C reports the transition probabilities of the three cohorts according to individual characteristics of gender and ethnicity, in addition to community characteristics of median household income and the number of alcohol off-premise outlets.

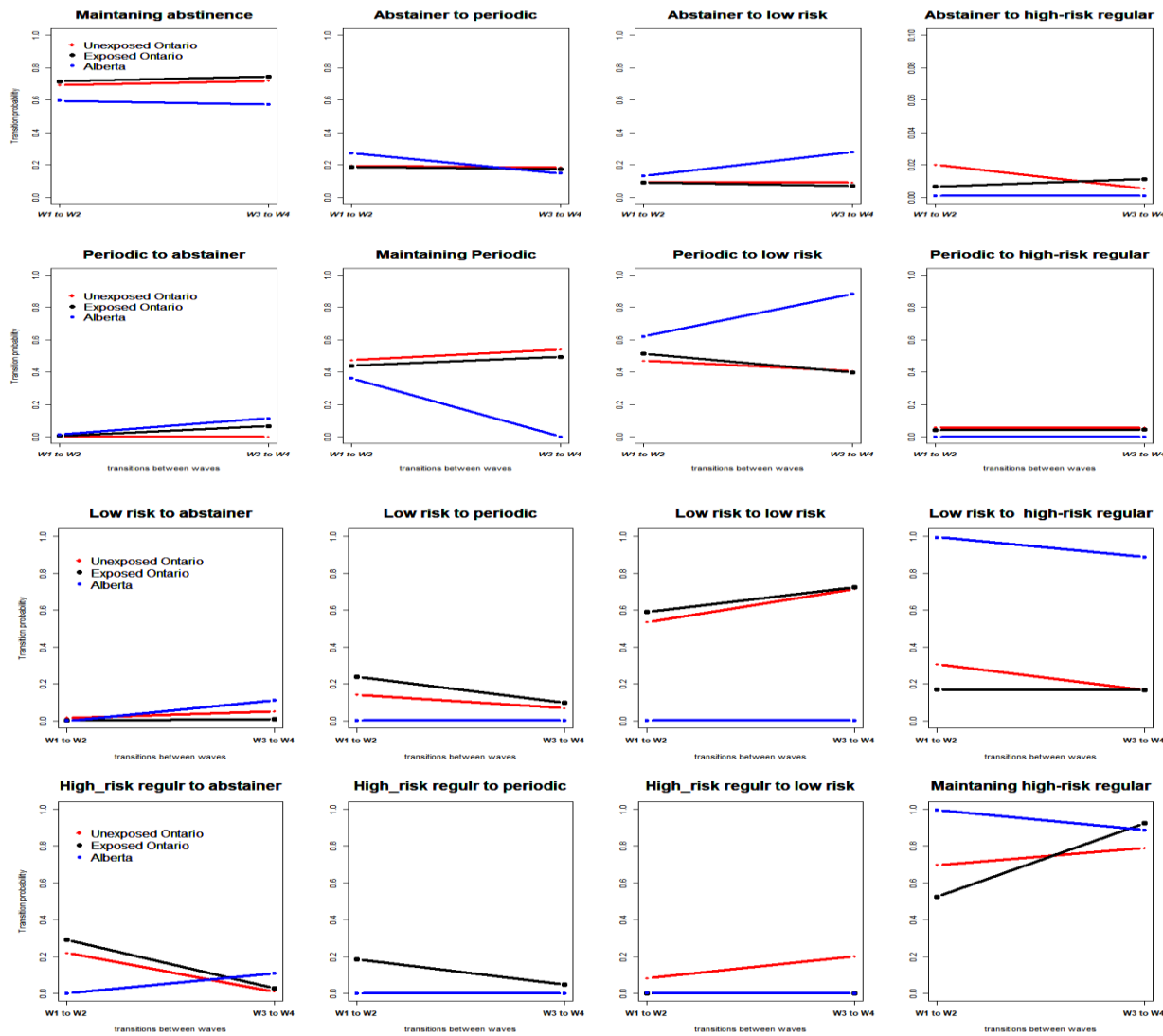


Figure 5-3. Comparison of transitions probabilities between latent classes of youth alcohol consumption among three cohorts during two years before selling alcohol in Ontario grocery stores (w1: school year 2013-14 and w2: school year 2014-15) and two years after (w3: school year 2015-16 and w4: school year 2016-17). The sample consisted of participating students in COMPASS study (n=2,267).

Chapter 6
Manuscript 1

**Identifying patterns of alcohol use among secondary school students in
Canada: a multilevel latent class analysis**

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Status: under review by journal of Addictive behaviors

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6.1 Brief overview and purpose

The following chapter includes a copy of the manuscript submitted to the journal “Addictive Behaviors”. The manuscript answered the following research questions:

1. Is there a latent class structure that represents the heterogeneity in alcohol use patterns of the youth population?
2. Do patterns of alcohol use differ between schools? Is there a latent class structure that represents the heterogeneity in student’s alcohol use patterns among schools?
3. Which individual or neighbourhood characteristics are associated with engagement in alcohol use patterns?

6.2 Overview

Introduction: Harms from alcohol use depend not only on the volume of consumption but also on drinking patterns. This study identifies patterns of alcohol consumption in youth and investigates how these patterns vary across schools and whether individual- and school-level factors are associated with engagement in patterns of alcohol consumption.

Methods: The sample consists of 45,298 grade 9 to 12 students attending 89 secondary schools across Ontario and Alberta (Canada), who participated in the COMPASS study during the school year 2013-14. The frequency of drinking and binge drinking in the past year and age of alcohol-use initiation were used to characterize alcohol use patterns.

Results: The multilevel latent class analysis identified 4 student-level latent groups and 2 school-level latent groups. Student-level groups of youth were characterized as *non-drinkers* (44.2%), *light drinkers* (41.8%), *regular drinkers* (11.1%), and *heavy drinkers* (2.9%). Two groups of schools were characterized as either *low-use schools* (44.9%) or *high-use schools* (55.1%), with significantly different probability of membership in each student-level group. Male students (OR 1.30) and upper grades (OR 1.93) were significantly associated with membership in higher use groups of individuals. The median household income and number of off-premise alcohol outlets had no significant association with patterns of alcohol consumption within schools.

Conclusions: A large proportion of students reported a level of drinking, suggesting that interventions need to encourage drinker students to quit drinking or lower their consumption. Significant differences in patterns of alcohol use among schools indicate that schools may need

to select and/or alter external interventions according to the dominant patterns of alcohol use among their students.

Key words: Youth, alcohol consumption, substance use, school

6.3 Introduction

Youth consumption of alcohol is widely recognized as a critical public health concern globally (World Health Organization, 2018). In Canada, the prevalence of drinking among youth 15 to 19 years old is 60%, of drinkers 46% undertake binge drinking (Public Health Agency of Canada, 2016). Numerous consequences associated with underage drinking, including traffic accidents (Brubacher et al., 2016), unprotected sexual activity (Ellickson, Tucker, & Klein, 2003), suicide (Landberg, 2009), mental health disorders (Brière, Rohde, Seeley, Klein, & Lewinsohn, 2014), and poor academic performance (Patte et al., 2017), and impose significant costs on individuals and society. Moreover, the age at which youth start drinking is associated with subsequent trajectories; the earlier an individual starts to drink, the greater the risk of higher levels of consumption later (Lee, Corte, & Stein, 2018).

The harms of alcohol consumption depend not only on the volume of consumption but also on drinking patterns (Degenhardt et al., 2016; Gilmore et al., 2016). How frequently and how much an individual drink can increase or decrease alcohol-related consequences. Past research identified between 3 to 6 distinct patterns of alcohol use among youth, including non-drinkers, light drinkers, and heavy/binge drinkers (Auerbach & Collins, 2006; Peterson, Davis, & Smith, 2018; Romelsjö, 2010), indicating that the youth population is heterogeneous with respect to drinking patterns. Therefore, this population can be classified into distinct subgroups, each representing a pattern of alcohol consumption, such as low frequency, low quantity, no heavy episode drinkers and high frequency, high quantity, heavy episode drinkers (Maldonado-Molina & Lanza, 2010).

Socioecological models suggest that alcohol use patterns are best understood as embedded within social contexts. These contexts can be proximal in terms of individual (e.g., early initiation of alcohol consumption), family (parental disciplines and family bonding) and peer groups (rates of use and attitude to alcohol). However, others are more distal, including schools (school environment and academic achievement), community (neighbourhood norms and

average household income), and provincial and national (taxation and minimum legal drinking age) (Brooks-Russell et al., 2014; Liang & Chikritzhs, 2015; Nash et al., 2005; Soloski et al., 2016). According to these models, students within the same school often share common socioeconomic and cultural characteristics that may increase (or decrease) the likelihood of engagement in certain patterns of alcohol use compared to students attending other schools. Ignoring the clustering structure of individuals within schools may lead to misclassification of individuals into latent classes of alcohol use (Finch & French, 2014; Kaplan & Keller, 2011). To account for the clustering structure, past researchers either employed multilevel models (Chan et al., 2017; Duncan et al., 2002; Rowland, Bosco, Toumbourou, & Livingston, 2015; Stockwell et al., 2009) or included neighbourhood factors such as density of alcohol outlets in their modelling approach (Larsen et al., 2017; Ransome, Luan, Shi, Duncan, & Subramanian, 2018). For example, Rowland et al. (Rowland et al., 2015) used a multilevel regression model to explore the association between alcohol outlet density and youth purchasing and consumption of alcohol. In another study, Larsen et al. (Larsen et al., 2017) examined the link between access to alcohol in school neighbourhoods and binge drinking among youth in Ontario (Canada) using GIS data to measure the density of outlets and distance to outlets. However, few studies have accounted for the nested structure of students within schools when identifying latent classes of alcohol use. Moreover, there is a dearth of research on the effects of neighbourhood factors, such as the number of alcohol outlets and median household income, on membership in alcohol use latent classes.

In this study, to address this knowledge gap, we used latent class analysis (LCA) to determine whether there is a latent structure that represents the heterogeneity in the drinking patterns of a sample of Canadian secondary school students. LCA is a person-centred approach that assumes individuals can be classified into distinct classes of an underlying categorical variable (Collins & Lanza, 2013). Individuals in the same class of this latent variable are similar and share common characteristics in terms of, in this study, their alcohol use. Understanding distinct patterns of alcohol use is important to public health interventions to reduce alcohol-related harm by targeting the highest-risk groups (Craig et al., 2012; Kaplan & Keller, 2011; Lanza & Rhoades, 2013). Specifically, the present study seeks to address research gaps by applying multilevel latent class analysis to a large sample of cross-sectional data from secondary school students in Ontario and Alberta, Canada to (1) identify distinct patterns (classes) of

alcohol use among the youth population; (2) investigate the patterns of alcohol use among schools and classify schools according to students' alcohol use patterns; and (3) examine the effects of individual- and neighbourhood-level covariates on alcohol-use class memberships.

6.4 Materials and methods

6.4.1 Participants and procedures

Study participants were drawn from Year 2 (Y2: 2013-2014) of the COMPASS (Cannabis, Obesity, Mental health, Physical activity, Alcohol use, Smoking, and Sedentary behaviour) study. This longitudinal study was designed to collect hierarchical longitudinal data from a cohort of students in grades 9 through 12 in Ontario and Alberta, Canada. A full description of the COMPASS study can be found elsewhere (Leatherdale et al., 2014). In Y2, 45,298 students, representing an average participation rate of 70.2%, were recruited from 89 secondary schools across Ontario (n=79) and Alberta (n=10). The recruiting employed an active-information passive-consent procedure then used to recruit participants from the schools. The students completed the self-reported questionnaire during school time. The sample was evenly split in terms of gender (49.4% female) and school grades 26.2% (n=11,793) in Grade 9, 26.2% (n=11,817) in Grade 10, 24.9% (n=11,229) in Grade 11, and 22.7% (n=10,233) in Grade 12).

6.4.2 Instruments

Consistent with measures used in national surveillance tools for the youth population (Canadian Student Tobacco, Alcohol and Drug Survey, 2017), the study used three variables to quantify individuals' alcohol use patterns: (1) frequency of alcohol consumption in the past year, (2) frequency of binge drinking in the past year, and (3) age of alcohol initiation. The frequency of drinking was measured by responses to the question "In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?" The frequency of binge drinking was assessed by the question "In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?" Because of a skewed distribution of responses and in keeping with the WHO alcohol use identification test (AUDIT) system of recording the frequency of drinking (World Health Organization, 2001), the responses were coded into four outcomes: nonuser, up to 3 times a month, 1 to 3 times a week, and more than 3 times a week. Responses on binge drinking in the past year were also categorized into four outcomes: no binge drinking, once a

month or less, 2 to 4 times a month, and more than once a week. The age of alcohol initiation, for the students who indicated alcohol consumption, was defined as occurring at before age 14, the age at which students generally begin secondary school, and age 14 or after.

The study included student-level characteristics of gender and grade (grade 9 to 12), as well as neighbourhood-level correlates of median household income (MHI), as a proxy for the socioeconomic status of families, and the number of off-premise alcohol outlets. MHIs were generated using the census divisions that corresponded with school postal codes according to data from the 2011 National Household Survey (Statistics Canada, 2013). The median of MHI within the COMPASS school communities was \$61,830, with a range of \$29,171 to \$114,271. The number of alcohol outlets was quantified by the number of off-premise alcohol outlets within a 10 km buffer zone around schools. This buffer was chosen to reflect proximity in the sense of accessibility by driving. Locations of off-premise alcohol outlets were obtained from Enhanced Points of Interest (EPOI) databases; these vector GIS databases provide information on the location of specific services and businesses for all provinces/territories of Canada.

6.4.3 Data Analysis

Analyses proceeded through three phases. In Phase 1, we ignored the nested structure of students within schools and used traditional latent class analysis (LCA) to explore the number of patterns of alcohol consumption among the participating students. We began model building by determining the optimum number of classes, starting with a one-class model. At each subsequent step, we fitted successive models with an increasing number of classes. Each model was refitted using 50 random sets of starting values to ensure that we found the global maximizer for the likelihood function (Nylund et al., 2007). The relative fit of models was evaluated using the Bayesian information criterion (BIC) (Nylund et al., 2007). The quality of class separation was measured by the entropy statistics, the weighted average of class membership probabilities on the (0,1] scale (Ramaswamy, Desarbo, Reibstein, & Robinson, 1993). The closer the value of the entropy statistics is to 1 the more accurately each student can be classified into one of the classes.

In Phase 2 of the analysis, we used a nonparametric multilevel LCA (MLCA) to account for the hierarchy of students within schools. The nonparametric MLCA poses an additional between-school (Level 2) latent structure that is created using the prevalence of within-school (Level 1) latent classes. A brief description of the nonparametric MLCA is provided in the

Appendix. To find the optimum number of Level 2 latent classes, a series of latent class models was fitted to the prevalence values of Level 1 latent classes estimated in the previous phase.

In Phase 3, we extended the MLCA to account for student- and school-level factors and evaluate their effect on membership of student- and school-level groups. Adjusted odds ratios and confidence intervals were used to summarize the effect of covariates. Nonparametric MLCA was performed in Mplus version 8.0 (Muthen & Muthen, 2017). The rates of non-response were 3.2%, 0.3%, and 5.7%, for the frequency of drinking, frequency of binge drinking, and age of drinking initiation, respectively. Mplus uses the full information maximum likelihood (FIML) (Schafer, 1997) and retains subjects with non-response items on the three alcohol variables, but cases with missing covariates are removed from the analysis. No values were missing for the two school-level variables of MHI and the number of the off-premise outlets. The missing rates for the student-level covariates of age (0.4%), grade (0.5%), and gender (0.1%) were very low, with no pattern, so removing the cases from the analysis would not change the results.

6.5 Results

Among participants in the study, 26,503 (58.5%) students reported some level of alcohol drinking during the past year, of which 9,512 students (35.9%) had consumed their first drink before age 14. Binge drinking was reported by 28,774 (63.5%) students. Table 1 indicates the distribution of alcohol items within school years. Alcohol consumption was reported by 7,587 (75.7%) of students in Grade 12, which is more than double the alcohol consumption of Grade 9 students (34.9%). Nearly 60% of Grade 12 students reported binge drinking during the past year, compared to 19.3% of students in Grade 9. A high proportion of Grade 9 students did not report alcohol consumption; however, a small group of these students reported binge drinking more than once a week (1.7%). Table 1 indicates that almost one in four Grade 12 students (24.3%) had remained non-drinkers up to the time of graduation.

Table 6-1. Characteristics of secondary school students in Year 2 (school year 2013-14) of the COMPASS study (n=45,298)

Characteristic	N	Frequency of alcohol consumption				Frequency of binge drinking			
		None	3- times a month	1-3 times a week	3+ times a week	None	1- times a month	2-4 times a month	2+ a week
Gender									
Female	22,149	9260 (42.5)	10541 (48.3)	1742 (8.0)	271 (1.2)	13309 (60.3)	5786 (26.2)	2554 (11.6)	434 (2.0)
Male	22,712	9384 (42.6)	9382 (42.6)	2489 (11.3)	781 (3.5)	13279 (58.7)	5274 (23.3)	367 (13.6)	998 (4.4)
Grade									
9	11,793	7482 (65.1)	3396 (29.5)	424 (3.7)	199 (1.7)	9485 (80.7)	1549 (13.2)	515 (4.4)	199 (1.7)
10	11,817	5215 (45.1)	5,204 (45.0)	903 (7.8)	238 (2.1)	7442 (63.2)	2809 (23.9)	1224 (10.4)	296 (2.5)
11	11,229	3597 (32.8)	5,707 (51.9)	1346 (12.3)	330 (3.0)	5642 (50.4)	3269 (29.2)	1800 (16.1)	479 (4.3)
12	10,233	2432 (24.3)	5,695 (56.9)	1577 (15.7)	313 (3.1)	4136 (40.6)	3463 (33.9)	2108 (20.7)	494 (4.8)
Province									
Ontario	41,734	17,592 (43.2)	18322 (45.0)	3837 (9.4)	975 (2.4)	25070 (60.3)	10103 (24.3)	5099 (12.3)	1305 (3.1)
Alberta	3,564	1203 (34.2)	1750 (49.8)	442 (12.6)	118 (3.4)	1771 (49.8)	1030 (29.0)	579 (16.3)	175 (4.9)
Household income									
<=\$61,830 ^a	22,350	9377 (43.0)	9930 (45.5)	1996 (9.2)	500 (2.3)	13277 (59.6)	5553 (24.9)	2754 (12.4)	686 (3.1)
>\$61,830	22,948	9418 (42.0)	10142 (45.2)	2283 (10.2)	593 (2.6)	13564 (59.3)	5580 (24.4)	2924 (12.8)	794 (3.5)
Alcohol outlets									
<=8 ^b	23,457	9031 (39.4)	10749 (46.8)	2555 (11.1)	611 (2.7)	13077 (56.0)	6042 (25.9)	3345 (14.3)	890 (3.8)
>8	21,841	9764 (45.9)	9323 (43.8)	1724 (8.1)	482 (2.2)	13764 (63.2)	5091 (23.4)	2333 (10.7)	590 (2.7)

^a the median of household income, ^b the median number of off-premise alcohol outlets within 10 km buffer of schools

Latent class identification began with examining the 1-through 5-class models. Table 2 represents the overall fit statistics and model comparisons. BIC decreased substantially from the 1-class model to the 4-class model, and then began to increase. Entropy of the 4-class model was 0.93 compared to 0.87 for the 5-class model. The mean posterior probabilities for the 4-class model were 0.94, 0.96, 0.96, and 0.82, showing a high separation of latent classes. According to the fit indices, as well as considerations of model interpretability and parsimony, we selected the 4-latent class model as the best representation of alcohol patterns of participating youth in the study.

Table 6-2 Fit statistics for latent class models at Level 1 and Level 2 for alcohol use of youth participating in Year 2 (school year 2013-14) of the COMPASS study (n=45,298)

	Log-Likelihood	Degrees of Freedom	AIC	BIC	Entropy
Level 1 models					
1	-138,298	40	276,613.2	276,683.1	1.00
2	-103,749	30	207,532.8	207,681.1	0.97
3	-98,727	21	197,506.1	197,732.8	0.94
4	-97,931	12	195,932.5	196,237.7	0.93
5	-98,341	3	196,770.7	197,154.5	0.87
Level 2 models (nonparametric model with 4 Level 1 classes)					
2	-97,566	8	195210.3	195550.4	0.91
3	-114,480	4	229047.5	229422.5	0.91

Table 3 shows the item-response probabilities and the size of each pattern in the 4-class model. We labeled the latent classes as: non-drinkers (had never consumed alcohol or did not drink in past year, size 44.2%), light drinkers (initiated alcohol consumption at age 14 or later and consumed alcohol up to 3 times a month with one time binge drinking, size 41.8%), regular drinkers (initiated drinking before age 14 and consumed alcohol 1 to 3 times a week and undertook binge drinking 2 to 4 times a month, size 11.1%), heavy drinkers (initiated drinking before age 14 and consumed alcohol more than three times a week with binge drinking more than once a week, size 2.9%).

Figure 1 describes how the four identified alcohol patterns were distributed across schools. The schools were sorted by median-household income (MHI) to reveal any possible association between MHI and alcohol use classes. Although, the heavy-drinker class was the smallest of the four classes, this class was identified in all schools, with a range of 2.2% to 9.3%. In Figure 1, there is no association between prevalence of classes and MHI; schools with lower rates of heavy drinking are equally distributed across MHI levels.

In the next step, we conducted a nonparametric multilevel LCA to account for the nested structure of students within schools. In this model, a Level 2 latent variable was added based on

Table 6-3 Conditional item-response probabilities and the prevalence of latent classes of youth alcohol-use behaviours in Y2 (school year 2013-14) of the COMPASS study (n=45,298)

	Non-drinker	Light	Regular	Heavy
Prevalence	44.2%	41.8%	11.1%	2.9%
Alcohol consumption				
Non-user	0.988	0.004	0.000	0.001
Up to 3 times a month	0.012	0.996	0.199	0.000
1 to 3 times a week	0.000	0.000	0.780	0.269
3+ times a week	0.000	0.000	0.021	0.730
Binge drinking				
No binge drinking	0.998	0.348	0.056	0.024
Once or less than a month	0.002	0.531	0.209	0.047
2-4 times a month	0.000	0.121	0.646	0.135
More than once a week	0.000	0.000	0.089	0.794
Age of alcohol initiation				
No use	0.991	0.060	0.052	0.102
Age 13 or before	0.009	0.323	0.485	0.808
After age 13	0.000	0.617	0.462	0.090

the prevalence of Level 1 latent classes. Comparison of BIC between the 2-class and 3-class nonparametric models (Table 2) indicates that the 2-class model adequately represents the school-level latent classes. With the addition of Level 2 latent classes, the BIC of model declined by $\Delta_{BIC} = 687$, and the entropy of the model improved from 0.89 to 0.91.

Furthermore, the average posterior probabilities for eight combinations of classes (four individual classes and two school classes) were greater than 0.76. All of these measures suggested that adding the Level 2 latent classes improved the fit of the model and produced fairly robust results with a high degree of latent structure recognition.

Figure 2 illustrates the distribution of individual-level latent classes within the two school-level classes. The class of low-use schools (n=40, 44.9% of schools) is comprised of schools with a relatively large number of nonusers. The average of non-drinkers in this group of schools is 14% higher than the average of high-use schools. In contrast, the class of high-use schools (n=49, 55.1% of schools) is comprised of schools that have higher rates of regular and heavy drinkers. The proportions of regular and heavy drinkers in high-use schools were nearly double the proportions in low-use schools: 11.8% and 7.2% compared to 6.0% and 4.6%, respectively.

Table 6-4 Estimated Odds ratios from a multilevel latent class analysis reflecting the effects of covariates on membership of latent classes of youth alcohol drinking in Y 2 (school year 2013-14) of the COMPASS study (n=45,298)

Characteristic		Latent class		
Individual-Level	Non-drinkers	Light drinkers	Regular drinkers	Heavy drinkers
Gender (male)	Reference class	2.82 (2.38, 3.36)	1.24 (1.18, 1.31)	1.30 (1.19, 1.42)
Grade	Reference class	1.44 (1.29, 1.61)	1.07 (0.98, 1.18)	1.93 (1.77, 2.10)
School-Level	Low use	High use		
Median household income	Reference class	1.53 (0.64, 3.70)		
Number of alcohol outlets	Reference class	1.01 (0.98, 1.03)		

We then extended the MLCA model to incorporate the student-level (i.e., gender and grade) and school-level covariates (i.e., median household income and the number of off-premise alcohol outlets). Table 4 shows the estimates of odds ratios that compare the baseline group of non-drinkers with the other three groups at Level 1 (individual-level classes) and compare the baseline group of low-use schools with that of the high-use schools at Level 2 (school-level classes). As can be seen, both the gender and grade of individuals significantly were associated with student-level latent class membership. The likelihood of being a heavy drinker compared to a non-drinker for male students was 1.3 (95% CI:1.19-1.42) greater than that of female students. Grade comparisons indicate that the odds of the membership in light drinker class (OR=1.44, 95% CI:1.29-1.61) and heavy drinker class (OR=1.93, 95% CI: 1.77-2.10) increased as students moved to upper grades. However, the difference in the odds of membership in the regular drinker class was not significant (OR=1.07, 95% CI:0.98-1.18). The results of Table 4 indicate that neither the number of off-premise alcohol outlets (OR=1.01, 95% CI:0.98-1.03) nor the median household income (OR=1.53, 95% CI:0.64-3.70) were significantly associated with latent class memberships.

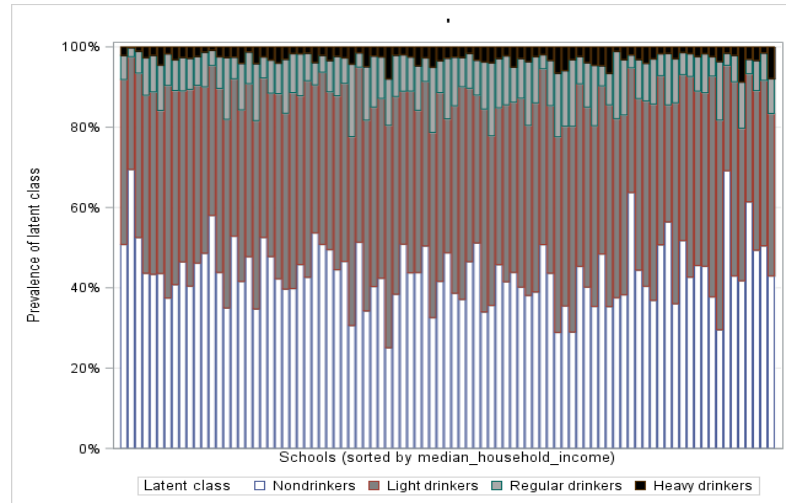


Figure 6-1. The proportion of latent classes of youth alcohol drinking (n=45,298) across schools participating in the COMPASS study in Ontario (n=70) and Alberta (n=10). Schools are sorted by median household income, from lowest (Left) to highest (Right)

6.6 Discussion

This study has explored the patterns of alcohol consumption among a sample of Canadian secondary school students from Ontario and Alberta. Employing multilevel latent class analysis, the study identified four subpopulations of individuals characterized as non-drinkers, light drinkers, regular drinkers, or heavy drinkers. Male and upper grade students had greater likelihood of engaging in high-level patterns of alcohol consumption. The model also identified two groups of schools: low-use (schools with a relatively large number of non-drinkers) and high-use (schools with higher rates of regular and heavy drinkers). Neighborhood factors of median household income and number of off-premise alcohol outlets had no significant association with patterns of alcohol consumption.

In line with previous studies, the largest proportion of youth consisted of non-drinkers (Dauber, Paulson, & Leiferman, 2011; Huh & Leventhal, 2016). Levels of alcohol consumption and binge drinking show that three out of four groups are engaged in binge drinking. This finding supports previous research indicating that binge drinking is a common pattern of alcohol use among youth who drink and accounts for large proportion of drinking occasions among Canadian youth (Flewelling, Paschall, & Ringwalt, 2004; Miller, Naimi, Brewer, & Jones, 2007).

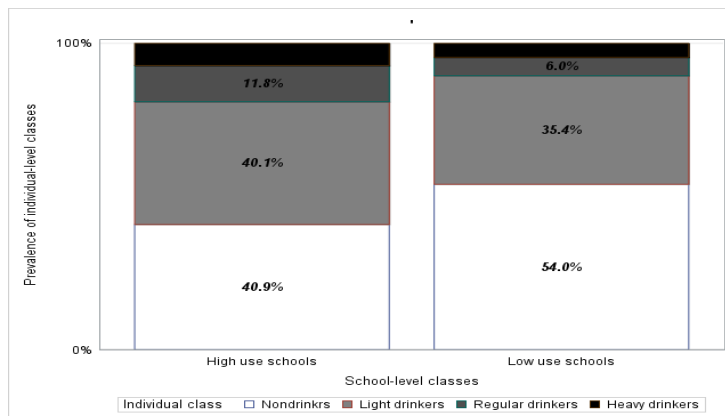


Figure 6-2. The proportion of latent classes of youth alcohol drinking (n=45,298) across schools participating in the COMPASS schools in Ontario (n=70) and Alberta (n=10) within the two classes of schools identified by nonparametric multilevel latent class analysis

Past research suggests that youth drinking is likely to be binge drinking for different reasons, including unmatured impulse control, peer pressure, and unawareness of consequences (Deas, Riggs, Langenbucher, Goldman, & Brown, 2000; Gray, 2017; Soloski et al., 2016), and is associated with a high risk of immediate and long-term harms. Therefore, for a large proportion of youth drinkers, we can expect alcohol-related consequences that could be prevented or at least limited if alcohol consumption was delayed as long as possible.

Consistent with past research addressing a direct association between early initiation of alcohol consumption and an increased likelihood of heavy drinking (Gruber, DiClemente, Anderson, & Lodico, 1996; Kim et al., 2017; Liang & Chikritzhs, 2015), this study found that the heavy drinker group is characterized by alcohol-consumption initiation before age 14. This finding indicates that early initiation to alcohol consumption increases the risk of later engagement in heavy drinking. This increased risk could be because early drinkers have more time to increase their consumption, or because early drinkers are more likely to become involved with other substances (e.g., tobacco and cannabis) that often leads to greater alcohol consumption (Gruber et al., 1996; Peleg-Oren, Saint-Jean, Cardenas, Tammara, & Pierre, 2009). This result underscores the need for screening for alcohol consumption in early adolescence, even before youth start secondary school, to reduce alcohol-related harm (Peleg-Oren et al., 2009). Although the majority of regular drinkers began drinking before secondary school, the

high proportion of regular drinkers who started drinking at age 14 or after suggests that even those who start later are at risk of heavy drinking.

Similar to previous research (Jackson & Schulenberg, 2013), we found a significant association between gender and alcohol class membership, where being male was associated with increased odds of membership in risky drinking groups; nonetheless, there are still a considerable number of females in the heavier drinking groups. Our study also confirms the significant increase in rates of heavy drinking from grade 9 to grade 12 reported by others (Freeman et al., 2016; Leatherdale & Rynard, 2013).

In addition to the individual-level latent classes, the study identified two groups of schools (i.e., low-use schools and high-use schools), indicating that the probability of engagement in a certain pattern of alcohol use significantly differed between schools. This finding suggests that those initiating prevention programs may require more intensive efforts in high-use schools.

To describe part of the variation across schools, we incorporated the median household income and the number of off-premise alcohol outlets into the model. Household income was not significantly associated with group membership across schools. This finding supports past research that indicated a null association between the amount of alcohol consumption among youth and family socioeconomic status (Åslund & Nilsson, 2013; Brenner, Bauermeister, & Zimmerman, 2011; Cambron, Kosterman, Catalano, Guttmanova, & Hawkins, 2018). This nonsignificant association may be explained by the high variability of family income within each neighborhood and the fact that the family income has a greater association with youth alcohol use compared to neighborhood-level median household income (Leventhal & Brooks-Gunn, 2000; Wodtke, Harding, & Elwert, 2011). For example, youth in high income families in disadvantaged communities may have heavier drinking patterns than youth in low income families (or vice versa), which attenuates the effect of family income on youth alcohol use patterns (Cambron et al., 2018). Another explanation for this finding could be that the small size of the class of heavy drinkers and close distribution of patterns across the two groups of schools make the effect of income statistically nonsignificant. Moreover, given the possibility that families may live in different socioeconomic neighborhoods over time, accounting for only the

current neighborhood income may lead to bias toward underestimation of the impact of neighborhood context (Cambron et al., 2018).

The number of off-premise alcohol outlets also had no significant association with youth drinking patterns, supporting past research in which the density of off-premise alcohol outlets around schools had no impact on student alcohol consumption (Larsen et al., 2017). Part of this nonsignificant effect can be attributed to the fact that there were no COMPASS schools without an alcohol outlet nearby, which indicates how available alcohol is to the youth population. Similar to research on tobacco that suggests density of tobacco outlets may not be important to the smoking behaviour of established/regular smokers (Adams, Jason, Pokorny, & Hunt, 2013; Marsh et al., 2016), this finding indicates that the presence or absence of alcohol-selling outlets is more relevant than the total number because the neighbourhood population could be served by a single outlet (Wagenaar, 1995). This result suggest that policy and programs need to reduce the current availability of alcohol to youth.

To the best of our knowledge, this research is among the few studies that have examined how patterns of youth alcohol consumption may vary across schools. The multilevel LCA used has the ability to adjust estimates of group-membership probabilities based on the hierarchy of students within schools. The method also allows researchers to investigate the association between distal and proximal factors in membership in both level 1 (individual) and level 2 (school) latent classes (Henry & Muthén, 2010; Vermunt, 2003). The data from 89 schools dispersed across Ontario and Alberta provided a heterogeneous sample of schools and students that enhanced the accuracy of identifying the alcohol use patterns. The large sample of secondary school students also ensured our ability to identify latent groups more precisely. Moreover, alcohol use indicators in the COMPASS questionnaire collect data on a multiple option response basis that enabled tracking of changes in consumption level rather than changes in less informative outcomes, such as use vs. no use, most commonly employed by previous studies (Jackson & Schulenberg, 2013; Malone, Van Eck, Flory, & Lamis, 2010).

This study is subject to some limitations. First, the research relied on self-reports of alcohol use, which may be subject to measurement errors and recall and social desirability biases that may lead to underreporting of alcohol use (Butt, Beirness, Gliksman, Paradis, & Stockwell, 2011). However, self-reported alcohol use measures have previously been demonstrated to be

reliable and valid and have been widely used in national surveys (Canadian Student Tobacco, Alcohol and Drug Survey, 2017). Moreover, the applied analytical method of LCA partially addressed the measurement errors by probabilistic assignment of individuals to latent classes (Collins & Lanza, 2013). Second, the binary boundary of 10 km for distances of schools from grocery stores may underestimate the correlation between the alcohol use patterns and proximity of alcohol outlets because 10 km in an urban region can be a long distance, whereas it might be a short distance in rural area. Third, in this study we relied on neighbourhood median household income to measure the association between household income and youth alcohol consumption which may underestimate the association compared to more the reliable measure of individual family income (Cambron et al., 2018; Wodtke et al., 2011). Finally, because that the students data were drawn from a non-random sample of schools, the results of this study are not representative of the general youth population in Ontario and Alberta. However, given the large sample size, the results will have important implications for current research and practice. Furthermore, the COMPASS study employs a passive-consent approach for enrolling students into the study, which results in a higher rate of participation and lower nonresponse bias in survey data than an active-consent approach would (Courser, Shamblen, Lavrakas, Collins, & Ditterline, 2009).

6.7 Conclusions

Our study identified four distinct latent alcohol use patterns among secondary school students; three of the patterns identified students who reported a level of drinking. This finding indicates that, in addition to prevention efforts that aim at delaying the onset of alcohol use as long as possible, we need intervention programs to encourage drinkers, especially regular and heavy drinkers, to quit drinking or lower their consumption. Significant differences in the size of alcohol use classes among schools suggest that global programs may not be effective for all schools. Schools need to select and/or alter external (national, provincial, or local) prevention programs according to the dominant patterns of alcohol use among their students.

Chapter 7
Manuscript 2

Identifying trajectories of alcohol use among a sample of secondary-school students in Ontario and Alberta: longitudinal evidence from the COMPASS study

Status: Accepted by Health Promotion and Chronic Disease Prevention journal

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7.1 Brief overview and purpose

The following chapter includes a copy of the manuscript accepted by the journal of Health Promotion and Chronic Disease Prevention. The manuscript answered the following research questions:

1. What are the dominant alcohol use patterns among a sample of Canadian youth in Ontario and Alberta participating in the COMPASS study? What is the prevalence of the patterns among the population?
2. What is the probability of youth transitioning among the patterns of alcohol use over time?
3. What individual characteristics are associated with engagement in different alcohol use patterns? What individual characteristics are associated with transitioning between alcohol use patterns over time?

7.2 Overview

Introduction: Despite evidence indicating a rapid progression in use of alcohol during adolescence, little is known about the ways patterns of drinking develop over time. This study investigated patterns of alcohol use within a cohort of youth in Ontario and Alberta and the probability of changes between patterns.

Methods: The sample consists of two-year linked longitudinal data (school year 2013/14-2014/15) from 19 492 students in grades 9 to 12 in 89 secondary schools across Ontario and Alberta, Canada, who participated in the COMPASS study. The latent class analysis used two self-reported items about the frequency of drinking (measured as none, monthly, weekly, and daily use) and the frequency of binge drinking (measured as none, once or less than a month, 2-4 times a month, more than once week) to characterize patterns of alcohol use. The effects of gender, ethnicity, cannabis and cigarette use on alcohol use patterns were examined.

Results: The study identified four drinking patterns: non-drinker, periodic drinker (reported monthly drinking and no binge drinking), lower risk drinker (reported monthly drinking and limited binge drinking), and high-risk regular drinker (reported drinking 1-3 times a week and binge drinking 2-4 times a month). Non-drinker was the most prevalent pattern in both baseline (55.7%) and follow-up (39.7%). Periodic drinker pattern indicated the highest likelihood of an increase in alcohol

consumption with 40% moving to a low-risk pattern. A notable proportion of participants who return to a lower severity pattern or transitioning out of drinking was observed.

Conclusion: There are four distinct youth alcohol use patterns. The high probability of transitioning to drinking during the secondary school years suggests the need for preventive interventions in earlier stages of use, before drinking becomes habitual.

Key words: Youth substance use, latent transition analysis, longitudinal study, Canada

7.3 Introduction

Alcohol use is common among Canadian youth and its excessive consumption is a major public health concern. By the time of secondary school graduation, 60% of Canadian students report alcohol consumption in the past year, 46% of whom have undertaken binge drinking (5 or more drinks on one occasion) (Public Health Agency of Canada, 2016). Youth who drink alcohol are more likely than others to experience health and social consequences, including motor vehicle accidents (Brubacher et al., 2016), unprotected sexual activity (Ellickson et al., 2003), suicide (Landberg, 2009), and mental health disorders (Brière et al., 2014). Furthermore, longitudinal studies indicate that alcohol-related consequences are not limited to adolescence and early drinkers tend to drink more as adults and therefore continue to be at higher risk of experiencing adverse outcomes (Oosterhoff, Kaplow, & Layne, 2016), and of using other substances such as cigarette and cannabis (Windle, 2016).

Existing empirical evidence indicates that youth alcohol-use behaviours are not static over time and consumption of alcohol typically increases throughout adolescence (McBride et al., 2014). Recent longitudinal studies have captured such developmental changes in alcohol use patterns and suggest this progression differs greatly between individuals in terms of timing and severity of escalation. For example, Peterson and colleagues (2018) identified five trajectories of non-drinkers, middle onset, late onset, moderate drinkers, and early high drinkers among students in grades 5 to 10. Shin and colleagues (2016) explored trajectories of drinking among students at 29 secondary schools in the USA and found four prominent alcohol patterns: non-drinker, potential drinker, experimenter, and regular drinker. Such alcohol patterns are distinguished by frequency and quantity of alcohol use (e.g., number of days the individual undertakes drinking or binge drinking) (Auerbach & Collins, 2006).

Although longitudinal research has characterized developmental patterns of alcohol use among youth over time, the number and types of identified patterns (or classes) are inconsistent. In addition, individuals may transition between classes over time, for example, a non-drinker may begin drinking, a drinker may cease, or individuals may move from high-risk drinking to a lower risk class. Youth-related substance use theories and models of development such as the gateway theory (Kandel, Yamaguchi, & Chen, 1992) and the common liability model (Vanyukov et al., 2003) emphasize understanding of how alcohol use classes among youth population and how distinct classes develop over time. This knowledge is critical for interventions that aim to help youth to maintain non-drinker class and promote transitions to lower or non-drinker class. Despite longitudinal studies documenting youth alcohol trajectories, only a few studies have investigated transitions between classes (Dauber et al., 2011; Jackson et al., 2014). Moreover, most of the relevant literature studied American or European youth populations while evidence among Canadian youth is lacking. In the latter category, Rawana and Ames (Jackson et al., 2014; Rawana & Ames, 2012) studied protective factors of the alcohol use trajectories among a sample of Aboriginal youth in Canada aged 12 to 23. They found a relatively stable frequency of heavy drinking over time with the peak at age 21 and the lowest rate at age 16. Since alcohol trajectories are extremely dependent on contextual factors, such as alcohol control and access policies and cultural norms, identifying changes in drinking patterns of Canadian youth is a key step to informing future intervention development.

This study adds to the literature by investigating whether there are distinct patterns of alcohol use within a cohort of youth in Ontario and Alberta, and, if so, what the likelihoods are of maintenance or change between drinking patterns over time. We used latent transition analysis (LTA) to characterize the profiles of drinking based on the frequency of alcohol use and binge drinking. LTA is a longitudinal extension of latent class modeling, in which unobserved heterogeneity in the population is allowed by identifying homogenous groups of individuals in a sample based on similar responses to a set of questions (Collins & Lanza, 2013). LTA, as a person-oriented modeling approach, can model changes in drinking behaviours over time and predict for whom, and in what direction, a change may occur (Roberts & Ward, 2011). This knowledge can be used by prevention programs to target the individuals at the highest risk of problematic drinking and to test the effectiveness of an intervention.

Considering previous research, we expected that a large proportion of the youth population would abstain during their secondary school years, but also that a considerable proportion would be engaged in drinking at different levels of consumption. We also hypothesized that a substantial proportion of youth would either reduce their levels of alcohol use or quit drinking. As some previous studies documented higher rates of alcohol use among upper-year students and male students (Brown et al., 2008; Mason & Spoth, 2012), we assessed the influence of these factors on subgroup membership and transitions between different latent classes. Furthermore, as it has been shown that changes in alcohol-use behaviour may be influenced by the use of other substances such as cigarettes and cannabis (Hix-Small et al., 2004; Scholes-Balog, Hemphill, Evans-Whipp, Toumbourou, & Patton, 2016), we evaluated the effect of other substance use on the likelihood of transitions between latent classes over the two years of follow-up.

7.4 Methods

Sample: The sample was drawn from year 2 (baseline; school year 2013-2014) and year 3 (follow-up, school year 2014-15) of the COMPASS study. COMPASS is a longitudinal study designed to annually collect hierarchical data from a cohort of Canadian students in grades 9 through 12. A full description of the COMPASS study and its methods are available in print (Leatherdale et al., 2014) or online (<https://uwaterloo.ca/compass-system/>).

The compass study purposefully recruited 89 secondary schools across Ontario (n=79) and Alberta (n=10) at the baseline. Participants from the schools were recruited using an active-information passive-consent procedure. The resulting baseline sample consisted of 34 839 students in grades 9 to 11 with an average participation rate of 79.2% across schools. The sample in the follow-up year consisted of 31,060 students in grades 10 to 12 with an average participation rate of 78.7%. The main reasons for non-participation were absenteeism, classroom spares, and a small number of parental or student refusals (1.2%). Data were linked between two consecutive years based on responses of participants to six questions that were used to create a unique code for each student (Qian, Battista, Bredin, Stephen, & Leatherdale, 2015). The linkage algorithm merged 19 492 students' data over two years, but could not match 11 568 (33.2%) individuals, and 554 (1.6%) individuals were excluded because they reported staying in the same grade as the previous year. As previously reported (Qian et al., 2015), students with non-linked

data were more likely to use alcohol, cigarette, or cannabis compared to the linked students (data not shown). The linked data were evenly distributed in terms of gender (53.1% female) and school years: 38.8% (n=7556) in Grade 9, 34.6% (n=6738) in Grade 10, and 26.6% (n=5165) in Grade 11.

Alcohol measures: The study used two self-reported items about the frequency of drinking and frequency of binge drinking that are currently used in Canadian surveillance of youth substance use (Canadian Student Tobacco, Alcohol and Drug Survey, 2017). The frequency of drinking alcohol was measured by responses to the question “In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?” The response options were in a 10-options scale. Considering the distribution of responses and in keeping with the WHO alcohol use identification test (AUDIT) system of recording the frequency of drinking (World Health Organization, 2001), the responses were classified into four outcomes of: no drink, up to 3 times a month (monthly use), 1 to 3 times a week (weekly use), and more than 3 times a week (nearly daily use). Binge drinking was assessed by the question “In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?” Responses in an original scale of 8-options were coded into four outcomes: no binge drinking, less than or once a month, 2 to 4 times a month, and more than once a week.

Students self-reported their demographic characteristics, including gender (female=1, male=2), school year (grades 9 to 12), and ethnicity (White, Black, Asian, Aboriginal people, Latin-American, Other). Ethnicity was classified as a binary variable (White=1, non-White=0) because of the low frequency of students that were Black (n=617, 3.2%), Asian (n=993, 5.1%), Aboriginal people (n=490, 2.5%), Latin- American (n=308, 1.6%), and other ethnicities (n=1965, 10.2%). Students’ cigarette use was assessed by asking students, “On how many of the last 30 days did you smoke one or more cigarettes?”. Responses were recorded for analysis into a binary variable (None=0, use in any day during the past 30 days=1). Cannabis use was assessed by asking students, “In the last 12 months, how often did you use marijuana or cannabis?”. Similar to cigarette use, responses were classified into a binary variable (None=0, use in any day during the last year=1).

Statistical analysis: We employed LTA on the two alcohol items of frequency of drinking and frequency of binge drinking in past year to a group of similar individuals based on their

levels of drinking and binge drinking. A two-stage analytical approach was used. In the first stage, two to six class solutions were tested and these models were compared using the Bayesian information criteria (BIC) as the goodness of fit statistic which includes a penalty for over-fitting; lower BIC values are therefore indicative of a better model for the data. To ensure that a global, rather than local, maxima is found for the likelihood function, we ran each model with 50 different starting values for the parameters (Nylund, Asparouhov, & Muthén, 2007). The quality of group separation was measured in terms of entropy statistics, which is a weighted average of group membership probabilities on a (0,1) scale (Ramaswamy, Desarbo, Reibstein, & Robinson, 1993). The closer the entropy statistic is to 1, the greater the distinction among latent classes. Once the most appropriate latent class model was selected, we examined the measurement invariance of latent classes over the two years of the study to see if the structure of latent classes remained stable over time.

In the second stage, we investigated the association between latent class membership and covariates of gender, ethnicity, and cigarette and cannabis use. We also explored the association between probability of transitions between different latent classes and gender and school years. To test the effect of covariates, individuals were assigned to latent classes based on the maximum posterior probability of class membership, then a set of multinomial logistic regressions were fitted. The outcome variable in the multinomial regression was membership in each class with the non-drinker class as the reference category. All models were fitted using PROC LTA in SAS 9.4.1 (PROC LCA & PROC LTA, 2015). Procedure LTA allows for missing values on the outcome variables, but excludes participants with missing covariate data. In the current study, LTA with covariates excluded 368 participants out of 19 492 linked data because of missing data on gender, school year, or other substance use (78 missing gender, 290 missing other substance use, and 31 missing both covariates). The structure of the latent classes did not change by this reduction.

Table 7-1. Frequency and percent of self-reported levels of alcohol and other substance use in baseline (school year 2013-14) and follow-up (school year 2014-15) of the COMPASS study (n=19 492)

Variable	Baseline (%)	Follow-up (%)	Relative change
Alcohol drinking			
None	10 327 (53.9)	7386 (38.4)	-28.5%
Up to 3 times a month	7534 (39.3)	9740 (50.6)	29.3%
1 to 3 times a week	1116 (5.8)	1804 (9.4)	61.6%
3+ times a week	186 (1.0)	302 (1.6)	62.4%
Binge drinking			
None	13 848 (71.3)	11 082 (57.0)	-20.0%
Less than or once a month	3855 (19.8)	5439 (28.0)	41.1%
2-4 times a month	1492 (7.7)	2512 (12.9)	68.4%
More than once a week	242 (1.2)	405 (2.1)	67.4%
Cigarette use	1115 (5.7)	1860 (9.5)	66.8%
Cannabis use	2999 (15.6)	5015 (26.1)	67.2%

7.5 Results

Table 1 presents the levels of alcohol and other substance use among participants in the study. The number of alcohol users and binge drinkers increased at the follow-up time. The rate of binge drinking increased from 28.7% in the baseline year to 43% in the follow-up year. At the baseline, 5.7% of participants reported use of cigarettes which increased to 9.5% at the follow-up. During the two years, the rate of cannabis use increased by 67.2% and rose from 15.6% at the baseline to 26.1% at the follow-up.

Table 2 reports changes in the levels of alcohol use and binge drinking between the two waves of the study according to school years. Of 5083 Grade 9 non-drinkers, 3374 (66.4%) individuals reported abstinence when they moved to Grade 10. The results in Table 2 indicate that the rate of abstinence between baseline and follow-up years was quite similar over the school years with rates of 66.4%, 62.2%, and 61.4% for Grades 9, 10, and 11, respectively. During the two years, rates of increase in the frequency of drinking changed similarly. For example, non-drinkers in Grades 9, 10, and 11 initiated monthly drinking at rates of 31.0%, 35.1%, and 35.6%.

Table 7-2. Changes in the frequency of youth alcohol drinking and binge drinking by school years in baseline (school year 2013-14) and follow-up (school year 2014-15) of the COMPASS study (n=19 492)^a

Baseline levels of drinking	Grade 9 to 10				Follow-up levels of drinking Grade 10 to 11				Grade 11 to 12			
	None	Monthly	Weekly	Daily	None	Monthly	Weekly	Daily	None	Monthly	Weekly	Daily
Drinking												
None	3374 (66.4)	1576 (31.0)	100 (2.0)	33 (0.6)	2021 (62.2)	1142 (35.1)	65 (2.0)	22 (0.7)	1122 (61.4)	651 (35.6)	46 (2.5)	8 (0.5)
Up to 3 times month (monthly)	232 (11.6)	1452 (72.4)	292 (14.5)	30 (1.5)	238 (8.5)	2149 (76.7)	366 (13.1)	48 (1.7)	183 (6.9)	2086 (79.1)	330 (12.5)	38 (1.5)
1 to 3 times a week (weekly)	15 (7.6)	85 (42.9)	83 (41.9)	15 (7.6)	15 (3.7)	167 (40.8)	202 (49.4)	25 (6.1)	13 (2.7)	202 (41.5)	238 (48.9)	34 (6.9)
3+ times a week (daily)	11 (29.0)	8 (21.0)	12 (31.6)	7 (18.4)	7 (10.6)	33 (50.0)	14 (21.2)	12 (18.2)	5 (6.6)	23 (30.3)	29 (38.1)	19 (25.0)
Binge drinking	None	Up to 3 times a month	1-3 times a week	3+ times a week	None	Up to 3 times a month	1-3 times a week	3+ times a week	None	Up to 3 times a month	1-3 times a week	3+ times a week
None	4889 (76.9)	1136 (17.9)	283 (4.4)	52 (0.8)	3300 (71.7)	1032 (22.4)	232 (5.0)	40 (0.9)	2021 (71.5)	651 (23.0)	127 (4.5)	27 (1.0)
Less than or once a month	184 (21.2)	405 (46.5)	260 (29.9)	21 (2.4)	232 (16.1)	813 (56.3)	365 (25.3)	34 (2.3)	233 (15.3)	897 (59.0)	362 (23.8)	29 (1.9)
2-4 times a month	34 (13.7)	77 (31.0)	115 (46.4)	22 (8.9)	57 (10.1)	170 (30.0)	290 (51.2)	49 (8.7)	57 (8.5)	189 (28.2)	367 (54.9)	56 (8.4)
More than once a week	13 (32.5)	5 (12.5)	12 (30.0)	10 (25.0)	12 (14.1)	16 (18.8)	35 (41.2)	22 (25.9)	14 (11.9)	18 (15.4)	45 (38.5)	40 (34.2)

^a Table shows changes in levels of alcohol consumption from baseline (rows) to follow-up (shaded columns).

Table 7-3. Fit statistics for latent class models of youth alcohol drinking and binge drinking participating in the COMPASS study (n=19 492)

Model	Log-Likelihood	<i>Df</i>	Adjusted BIC	BIC	Entropy	BLRT ^a <i>p</i> value
2-class	-56 561	240	8761.4	8809.1	0.95	<.001
3-class	-53 434	229	2582.9	2665.5	0.95	<.001
4-class	-52 778	216	1357.0	1480.9	0.93	<.001
5-class	-52 401	201	703.1	874.5	0.91	.302
6-class	-52 377	148	1011.7	1351.7	0.88	.950

^a Bootstrap likelihood ratio test on baseline data, a non-significant value suggests that the model with one fewer classes is accepted.

7.5.1 Identifying alcohol use patterns

LTAAs were conducted to identify distinct latent classes of drinking characterized by alcohol use patterns at the baseline. The model fitting procedure began with fitting latent transition models ranging from two to six latent classes to the data. Our decision on the number of latent classes was made according to goodness of fit statistics of BIC and also parsimony and interpretability of latent class structure (Table 3 represents fit statistics). BIC decreased substantially from 2- to 5-class solutions and then began to increase from the 6-class solution (BIC₂=8809, BIC₃=2665, BIC₄=1306, BIC₅=919, BIC₆=1012). Despite the lower BIC value, there was considerable overlap between two latent classes identified by the 5-class model. Comparing the degree to which the latent classes were distinguished by 4-class and 5-class models using average posterior probabilities indicated a slightly better recognition of classes by the 4-class model. The overall entropy estimates for the 4-class model were 0.91 and 0.89 at baseline and follow-up, respectively (ranged 0.45-0.99), compared to the 5-class estimates of 0.91 and 0.87, respectively (ranged 0.35-0.99). We also found that the classes identified by the 4-class model were more conceptually meaningful and interpretable relative to those of the 5-class model. We examined the local independence of latent variable items following Reboussin's (2008) approach. The results of a correlation analysis of latent variable items showed that despite the presence of structural zero in binge drinking responses for non-drinkers, standardized residuals decreased substantially from the 2-class model to the 4-class model (Figure B.1

Appendix B), indicating that local independence is not violated for the final model. Given these considerations,

Table 7-4. Structure and prevalence of latent classes of youth alcohol-use behaviours in baseline (school year 2013-14) and follow-up (school year 2014-15) of the COMPASS study (n=19 492)

Latent class characteristics	Non drinker	Periodic drinkers	Low risk drinker	High-risk regular drinker
Prevalence at baseline (%)	55.7	22.9	15.8	5.6
Prevalence at follow-up (%)	39.7	26.3	24.6	9.4
Drinking				
None	0.963	0.007	0.001	0.000
Up to 3 times a month	0.036	0.970	0.943	0.400
1 to 3 times a week	0.000	0.019	0.053	0.585
More than 3 times a week	0.000	0.004	0.002	0.015
Binge drinking				
None	0.999	0.701	0.000	0.031
Once or less than a month	0.001	0.287	0.864	0.127
2-4 times a month	0.000	0.011	0.136	0.827
More than once a week	0.000	0.003	0.000	0.014

we selected the 4-class model, which generates clearly distinct and interpretable classes of alcohol use with substantial class sizes.

According to the conditional probabilities of the final model, shown in Table 4, we assigned the following labels to the latent classes: non-drinkers (had never drunk or did not use alcohol in past year), periodic drinkers (reported drinking up to 3 times a month and no binge drinking), low risk drinkers (reported drinking up to 3 times a month and once or less than a month binge drinking), and high-risk regular drinkers (reported drinking 1 to 3 times a week and binge drinking 2 to 4 times a month). Non-drinkers were the largest subgroup in both waves (55.7% baseline to 39.7% follow-up), although the prevalence of this group decreased by 16% at follow-up. The number of periodic drinkers increased slightly from 22.9% at baseline to 26.3% at follow-up. The prevalence of the remaining of the two classes of low risk drinkers and high-risk regular drinkers increased close to 50% at follow-up.

To examine the stability of identified latent classes over time, we compared the fit of the 4-class model constraining item-response probabilities to be equivalent across two years with the unconstrained model. The BIC of the restricted model (1509.6) was lower than the BIC of the

unrestricted model (1640.1), indicating that the same classes across waves would represent the same characteristics.

7.5.2 Transition probabilities among alcohol use patterns

Table 5 shows latent transition probabilities based on the LTA model adjusted for the school year and cigarette and cannabis use. The probabilities on the diagonal reflect the probability of membership in the same latent class at both time points, which is high for all classes. Low risk drinkers and high-risk regular drinkers indicated a higher likelihood of maintaining the same class at follow-up relative to non-drinkers and periodic drinkers. In contrast, the periodic drinkers were most likely to transition to low-risk drinker class. In particular, 40% of the students in the periodic drinker class at baseline moved to the low-risk drinker class at follow-up. Non-drinkers demonstrated a 24% chance of transitioning to periodic drinking. The results also show that, despite 65% of high-risk regular drinkers maintaining their class at follow-up, a remarkable proportion of individuals in this group lowered their alcohol consumption. Specifically, 18% of high-risk regular drinkers moved to low-risk class, and 8% reported complete cessation of alcohol drinking (Table 5). Individuals within the low risk drinker and high-risk regular drinker classes had the same probability (8%) of becoming non-drinkers at follow-up. In total, 17% of drinkers at baseline quit drinking at follow-up.

7.5.3 Predictors of membership in latent class and transition probabilities

After determining latent classes, we examined the potential effects of gender and ethnicity in predicting the membership of individuals in the four latent classes at the baseline. Comparison fit of the model with gender and without gender showed that gender significantly related to latent class membership ($2(\log\text{likelihood}_{\text{without gender}} - \text{likelihood}_{\text{with gender}}) = 58.2$, $df=3$, $p<.001$). Odds ratios (OR) in Table 6 suggest that male students were more likely to be in the high-risk regular drinker class than females (OR=1.2, 95% CI: 1.04-1.36). Ethnicity was also found a significant predictor of class membership ($2(\text{likelihood}_{\text{without ethnicity}} - \text{likelihood}_{\text{with ethnicity}}) = 37.2$, $df=3$, $p<.001$), and White students were significantly at a higher risk of being engaged in a level of alcohol use compared to their peers from other ethnic groups.

Table 7-5. Transition probabilities for the four-latent class model of youth alcohol consumptions in baseline (school year 2013-14) and follow-up (school year 2014-15) of the COMPASS study (n=19 124) adjusted for the school year, cigarette and cannabis use

Baseline class	Follow-up class			
	Non-drinker	Periodic drinker	Low risk drinker	High-risk regular drinker
Non-drinker	0.64	0.24	0.09	0.03
Periodic drinker	0.01	0.54	0.40	0.05
Low risk drinker	0.08	0.02	0.69	0.20
High-risk regular drinker	0.08	0.09	0.18	0.65

Table 6 presents the odds ratios associated with transitions from each latent class relative to remaining in the same class. Male non-drinkers indicated 2.4 (95% CI: 1.76–3.27) times greater chance of being engaged in high-risk regular drinking. The back transition from the high-risk drinking to abstinence was also higher for male students (OR = 1.33, 95% CI: 0.78–2.28). Results of Table 6 indicate that Grade 9 students were more likely to move to higher risky drinking classes than Grade 11 students, while there were no significant differences between Grade 10 and Grade 11 students in transitioning to higher risk drinking classes.

7.6 Discussion

This study characterized patterns of alcohol use in a large sample of secondary school students, identifying four latent classes. These distinct classes align with previous research indicating the presence of an underlying grouping structure to alcohol use by youth (Jackson & Schulenberg, 2013; Tomczyk, Pedersen, Hanewinkel, Isensee, & Morgenstern, 2016). Consistent with other studies (Tomczyk et al., 2016), we found that the most prevalent class was non-drinkers. The size of this group decreased by 16 % at follow-up but remained the dominant group. Individuals in the two classes of the low risk drinker and high-risk regular drinker engaged in some levels of binge drinking, indicating that a considerable proportion of youth is at risk of immediate and long-term negative consequences of alcohol consumption. This finding is supported by the evidence that suggests when youth do drink alcohol, they are more likely to binge drink (Public Health Agency of Canada, 2016).

Latent transition analysis has allowed us to not only characterize the homogenous group of alcohol users but also to understand the developmental process of their alcohol use over time. In particular, the data showed that youth were highly likely to maintain their alcohol-use behaviour between baseline and follow-up. The low-risk drinker class was the most stable among the four identified. Furthermore, we found a high degree of transitioning between latent classes from baseline to the following year. Individuals mainly moved into the expected increasing use direction and consumed more at follow-up. Periodic drinkers demonstrated the highest likelihood of an increase in alcohol consumption by moving to the low-risk drinker class. This high transition probability suggests that many of those who drink a few times a month increase their frequency of drinking to a weekly frequency while also starting to engage in binge drinking. Estimated transition probabilities indicated that alcohol consumption increases incrementally and most of the transitions occurred into the next-higher level of consumption (Shin et al., 2016).

Although most youth moved to a higher alcohol use class, we saw a notable degree of returning to a lower severity class or transitioning out of drinking. Nearly one out of 10 low risk or high-risk regular drinkers was likely to stop drinking. Cessation among individuals in these two classes was more likely to occur relative to periodic drinkers, potentially because students using alcohol at such a high frequency are liable to be severely affected in their daily lives, experiencing effects such as poorer academic engagement and performance (Patte et al., 2017). In comparison, the likelihood of cessation among periodic drinkers was only one percent, suggesting that most students in the early stages of alcohol consumption continue to drink. Future research needs to determine the characteristics of these youth that reduce their consumption and to investigate the factors that influenced the decline of their consumption.

As in previous research (Jackson & Schulenberg, 2013), we found that school grade was associated with transitions among latent classes. The results of this study show that odds of transition from the non-drinker class to other classes are similar for students in different grades, indicating a stable chance of starting to drink alcohol between school years. On the other hand, periodic drinkers and low risk drinkers in Grade 9 relative to students in Grade 11 are more likely to escalate their alcohol use. This finding indicates that initiation and escalation of alcohol consumption among secondary school students are more likely to happen during the first two

years of secondary school and behaviours of students become more stable as they move to upper grades, suggesting the prevention programs are more efficient targeting Grade 9 and 10 students.

The results of this study confirmed previous research that male youth have higher odds than females of being engaged in, transitioning to, and remaining in problematic drinking. Also, male students indicated a higher probability of quitting drinking. Consistent with problem behaviour theory that posits an interrelation between use of different substances (Donovan & Jessor, 1985; Hix-Small et al., 2004; Scholes-Balog et al., 2016), results of the current study demonstrated the relevance of cigarette and cannabis use in relation to heightening the probability of membership in the higher risk drinking classes. The Odds ratio of membership in the periodic drinker class for cigarette smokers was more than four times that of non-smokers. Similar patterns were observed for cannabis users, in which odds of engaging in higher levels of drinking was greater for cannabis user relative to non-drinkers. This finding supports the existing literature, which shows that a high level of alcohol consumption co-occurs with cigarette or cannabis (Tomczyk, Hanewinkel, & Isensee, 2015). However, based on the current study it is unclear which of these substances serve as a gateway for the use of the others. Future research is needed to examine the sequencing of initiation between different substances. Theoretical models, such as gateway theory (Kandel et al., 1992) and common liability theory (Degenhardt et al., 2016; Vanyukov et al., 2003), and empirical evidence have documented that youth decisions on use of any of alcohol, cigarette, and cannabis is associated with a higher risk of the use of the others, regardless of use sequences. The findings of our study confirm the previous research and suggest that prevention interventions need to focus on all of the most common substances simultaneously.

Latent transition analysis that is used in the current research is a person-centred approach that can model individuals' changes based on their patterns of responses on an outcome of interest. Therefore, it can be used to understand the patterns in data and to explore whether individuals are different from one another with respect to the outcome. Moreover, LTA is able to account for the measurement errors typically associated with self-report surveys (Collins & Lanza, 2013). In this method, each individual with an empirical response has a probability of membership to every latent class and the model assigns individuals to a class for which their data

Table 7-6. Estimated Odds ratios (95% CI) reflecting the effects of covariates on membership and transitions between latent classes of youth alcohol drinking in baseline (school year 2013-14) and follow-up (school year 2014-15) of the COMPASS study (n=19 124)

Covariate	Non-drinker	Periodic drinker	Low risk drinker	High-risk regular drinker
Class membership covariate				
Males	Reference	0.85 (0.79,0.93)	0.86 (0.80, 0.93)	1.20 (1.04,1.36)
White ethnicity	Reference	1.51 (1.37,1.65)	1.72 (1.57, 1.89)	1.26 (1.08, 1.49)
Smoking	Reference	4.44 (3.50, 5.63)	12.63 (10.31,15.47)	22.85 (14.24, 33.62)
Cannabis	Reference	5.98 (5.17, 6.91)	10.88 (8.34, 13.75)	19.24 (9.81, 30.47)
Transition covariates				
Males				
Non-drinker	Reference	0.83 (0.76, 0.90)	1.15 (0.89, 1.49)	2.40 (1.76, 3.27)
Periodic drinker	1.64 (1.21, 2.22)	Reference	1.00 (0.87, 1.16)	1.90 (1.33, 2.71)
Low risk drinker	1.42 (0.80, 2.51)	0.00 ^a	Reference	1.77 (1.51, 2.08)
High-risk regular drinker	1.33 (0.78, 2.28)	0.75 (0.38, 1.48)	0.80 (0.57, 1.14)	Reference
Grade 9 (relative to Grade 11)				
Non-drinker	Reference	0.84 (0.77, 0.91)	0.95 (0.74, 1.22)	0.87 (0.65, 1.16)
Periodic drinker	1.11 (0.80, 1.55)	Reference	1.47 (1.26, 1.71)	1.91 (1.34, 2.74)
Low risk drinker	1.52 (0.80, 2.89)	0.00 ^a	Reference	1.37 (1.14, 1.65)
High-risk regular drinker	2.56 (1.42,4.61)	2.06 (0.94, 4.53)	1.14 (0.71, 1.83)	Reference
Grade 10 (relative to Grade 11)				
Non-drinker	Reference	1.11 (1.02, 1.22)	1.12 (0.83, 1.52)	1.01 (0.77, 1.33)
Periodic drinker	0.92 (0.67, 1.26)	Reference	0.98 (0.84, 1.13)	0.84 (0.58, 1.22)
Low risk drinker	0.82 (0.45, 1.49)	0.00 ^a	Reference	0.97 (0.83, 1.15)
High-risk regular drinker	0.91 (0.52, 1.58)	0.68 (0.32, 1.43)	1.21 (0.85, 1.72)	Reference

^aThere was no transitioning from the low risk to periodic class.

suggest the highest probability of membership. The results from the latent transition analysis need to be applied with consideration of its limitations. One of the main limitations of LTA is that detected subgroups in the study sample are not necessarily the same as real underlying subgroups in the population and the number of identified subgroups by LTA can be greater than the actual number (Twisk & Hoekstra, 2012). Another limitation of LTA is the local independence assumption that assumes the underlying latent variable describes any observed association between indicators of the latent variable. This assumption may be hard to meet in some real applications and may cause biases in parameter estimation, such as overestimation of the number of classes (Berzofsky, Biemer, & Kalsbeek, 2014; Lanza & Cooper, 2016).

The results of this study should be considered with its limitations. The main limitation of this study was reliance on self-report measures of alcohol use. Youth reports on alcohol and

other substance use are potentially associated with underreporting and measurement errors. Secondly, the linkage process could not link a portion of students' data over two years of follow-up. The non-linked data appears not to be a random collection, but data from students who are more likely to drink, smoke, and use cannabis. As a result, the linked data can underestimate the size of the latent groups, and the probability of transitioning from low to high-risk groups. Additionally, the developmental course of alcohol consumption was investigated with one year of follow-up. More comprehensive knowledge about change in drinking behaviour of youth would require a longer follow-up time. Finally, measurement time points were about one year apart, so students' alcohol behaviours could have changed several times over this period. Because of these types of potential missed transitions, the transitions probabilities should be interpreted with caution (Collins & Lanza, 2013).

Future research can evaluate to what extent transitioning between different identified patterns of alcohol use may be influenced by a change to any prevention programs or policies focused on alcohol control. For example, our research team is examining the impact of the new Liquor Control Board of Ontario (LCBO) policy authorizing up to 450 grocery stores across Ontario to sell alcohol on youth alcohol use patterns within the exposed jurisdictions using four years of data in a quasi-experimental design. Evaluating the effect of this natural experiment (or for researchers evaluating other forms of alcohol policy) would be better served by examining the impact on the more nuanced alcohol use transition patterns presented here rather than simply evaluating the impact on a less informative outcome such as use vs. no use. In addition, future research may implement and assess the impact of behavioural change interventions, such as Alcohol Brief Intervention (Bridgeman, 2012; World Health Organization, 2001) and Motivational Enhancement Therapy (Miller, 1995), to motivate problematic drinkers to quit alcohol or decrease their consumption. The transition modeling approach used here can also be applied to other risk behaviours or substance use domains, such as cannabis, cigarettes, and may serve as a template for guiding future evaluations of policies, such as the new cannabis regulations federally in Canada or changes to tobacco control efforts.

7.7 Conclusion

The study suggests that alcohol consumption tends to increase among those who start, but the volume of increase is not the same across all populations of youth. An observed large transition from periodic drinker class to higher levels of drinking indicates the need for preventive interventions in earlier stages of use before drinking becomes habitual. Additionally, there is more need for interventions that target current alcohol users to increase the likelihood of transitions from alcohol drinker classes to the non-drinker class. The study demonstrated that cigarette or cannabis use was associated with membership in classes with high levels of alcohol consumption, suggesting that efforts that address poly-substance use may be more efficient than single focus alcohol programs.

7.8 Acknowledgements

The COMPASS study was supported by a bridge grant from the Canadian Institutes of Health Research (CIHR) Institute of Nutrition, Metabolism and Diabetes (INMD) through the “Obesity – Interventions to Prevent or Treat” priority funding awards (OOP-110788; grant awarded to S. Leatherdale) and an operating grant from the Canadian Institutes of Health Research (CIHR) Institute of Population and Public Health (IPPH) (MOP-114875; grant awarded to S. Leatherdale), a CIHR Project Grant (PJT-148562; grant awarded to S. Leatherdale), a CIHR Project Grant (PJT-149092; grant awarded to K. Patte), and by a research funding arrangement with Health Canada (#1617-HQ-000012; contract awarded to S. Leatherdale).

7.9 Conflicts of interest

The authors have no conflicts of interest to disclose.

7.10 Authors’ contributions and statement

MG devised the project, performed the analyses, interpreted the results, and wrote the first draft of the manuscript. SL led the COMPASS host study. RC and JD provided methodological advice for data analyses. SL, RC, and JD contributed to interpretation of data and revised the manuscript. All authors read and gave the approval of the final version of the manuscript.

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Chapter 8

Manuscript 3

The impact of an alcohol policy change on developmental trajectories of youth alcohol use: examination of a natural experiment in Canada

Status: Submitted to Canadian Journal of Public Health

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8.1 Brief overview and purpose

The following chapter includes a copy of the manuscript submitted to the Canadian Journal of Public Health. The manuscript answered the following research questions:

1. Are there unobserved subgroups of the youth population that exhibit different alcohol use trajectories?
2. Does the new LCBO policy have an effect on the developmental trajectories of youth alcohol use in the exposed jurisdictions in the province of Ontario?

8.2 Overview

Objectives: In 2015, the *Liquor Control Board of Ontario* (LCBO) authorized sale of alcohol in some Ontario grocery stores. This research evaluates the impact of the new policy on alcohol use patterns of youth in a quasi-experimental design with two control groups.

Methods: The sample consists of 2,267 grade 9 students attending 60 secondary schools across Ontario (n=56) and Alberta (n=4), who provided four-year linked longitudinal data (2013-14 to 2016-17) in COMPASS study. The study used the frequency of drinking and the frequency of binge drinking to characterize alcohol-use behaviours.

Results: Latent transition analysis found four patterns (classes) of alcohol use: abstainer, periodic drinker, low risk drinker, and high-risk regular drinker. The class membership was not significantly different between the exposed and unexposed jurisdictions ($p=0.163$). The new policy had no negative impact among periodic and low risk drinkers, but the risk of transitioning from the abstainer to high-risk regular drinker class among the exposed cohort was 1.71 times greater post-policy than pre-policy, compared to those of Ontario-unexposed (0.50) and Alberta cohorts (1.00). Moreover, the probability of sustaining high-risk drinking among the exposed cohort increased by a factor 1.77, compared to the 1.13-fold and 0.89-fold among the Ontario-unexposed and Alberta cohorts, respectively.

Conclusions: Youth in the exposed jurisdictions to the latest change in LCBO policy authorizing grocery stores to sell alcohol are more likely to transition from abstinence to high-risk regular drinking and high-risk regular drinkers are more likely to maintain their behaviours.

Key words: Adolescents, substance use, latent transition analysis, policy evaluation, longitudinal study

8.3 Introduction

The latest change in the policy of the Liquor Control Board of Ontario (LCBO), enacted in December 2015, authorizes the sale of alcohol in 450 grocery stores that previously had not sold alcohol. This policy change increased the availability of alcohol to subpopulations of the province's population. Since alcohol consumption is highly prevalent among Canadian youth with an estimated 60% of secondary school students in Canada drinking alcohol by the time they graduate (Public Health Agency of Canada, 2016), this policy change may result in a change in youth alcohol use patterns.

The sale of alcohol in the grocery stores is an addition to existing off-premise primary channels for sale of alcoholic beverages (i.e., the network of LCBO and The Beer Stores). This migration of alcohol into grocery stores will increase the total number of off-premise alcohol outlets across the province by 34% (LCBO, 2018). Physical availability of alcohol in terms of density of alcohol outlets in forms of both on- and off-premise outlets has been established as a contributor to alcohol use and alcohol-related harms among youth (Campbell et al., 2009; Jackson et al., 2014; Thern et al., 2017). Rowland et al. (Rowland et al., 2016) suggested that a 10% increase in alcohol outlet density is related to 17% increase in youth alcohol consumption and a significant probability of initiating early age alcohol drinking. Previously, Stockwell and colleagues (2009) had found the number of alcohol stores to be positively associated with per capita sales across 89 regions of British Columbia. Further, following privatization of off-premise alcohol sales in British Columbia, the rate of alcohol-related deaths significantly increased by 3.25% for each 20% increase in private store density (Stockwell et al., 2011). This evidence on potential adverse effects on public health warrants the need for an evidence-based evaluation of the latest change in LCBO policy.

A growing body of research has indicated that developmental trajectories of alcohol use differ greatly between youth. Selected subgroups of the population characterized by distinct

alcohol use patterns, such as abstainers, experimenters, regular drinkers, and binge drinkers have been documented among the youth populations (Chan et al., 2013; Malone et al., 2012). As these subgroups differ in patterns of alcohol consumption, their responses to changes in public policies, such as alcohol-related policies, could likewise differ (Snowden, 2016). For example, we can expect that in response to an increase in the physical availability of alcohol, individuals who begin alcohol consumption in early adolescence will be more likely to be engaged in heavy drinking compared to individuals who begin drinking in late adolescence.

Given the impact of the density of off-premise alcohol outlets on alcohol use patterns of the population (Sherk et al., 2018), we used longitudinal data from a quasi-experimental study to evaluate the impact of the new LCBO policy on changes in alcohol use patterns of youth in the exposed jurisdictions before and after the policy change in comparison with two control cohorts of students in Ontario and Alberta during the same period. Alberta is a province in Canada with a privatized liquor retailing system that had no change in its alcohol policy during the study period. We use latent transition analysis (LTA) to identify distinct alcohol use patterns within the three cohorts and to estimate the transition probabilities between alcohol use patterns over time.

8.4 Methods

Design: The current study used four-year linked longitudinal data (2013-14 to 2016-17) from 2,267 grade 9 students recruited from 60 secondary schools across Ontario (n=56) and Alberta (n=4), Canada, at Year 2 of the COMPASS (Cannabis, Obesity, Mental health, Physical activity, Alcohol use, Smoking, and Sedentary behaviour) study (2013-14). The COMPASS study is a longitudinal study (2012-2021) designed to collect data annually from a cohort of Canadian students in grades 9 through 12 (Leatherdale et al., 2014). Data collection was conducted over two years (Wave 1 and 2) before and two years (Wave 3 and 4) following the LCBO policy change. The University of Waterloo Office of Research Ethics and participating school board review panels approved this study.

Measures: The study used two self-reported items about the frequency of drinking and binge drinking as previously used in national youth survey tools (Canadian Student Tobacco, Alcohol and Drug Survey, 2017). The frequency of drinking alcohol was measured by responses

to the question “In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?” Considering the distribution of responses and in accordance with the WHO AUDIT system of recording the frequency of drinking (World Health Organization, 2001), the frequency of drinking was coded 1= none, 2= up to 3 times a month (monthly use), 3= between 1 to 3 times a week (weekly use), and 4=more than 3 times a week (nearly daily use). The frequency of binge drinking was assessed by the question “In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?” Responses were coded 1= none, 2=less often than or once a month, 3= between 2 to 4 times a month, and 4=more than once a week.

Intervention: The policy change took place in December 2015 and the initial rollout included 58 participating grocery stores across Ontario. The list of all authorized stores was retrieved from the Ontario Ministry of Finance (The Ontario Ministry of Finance, 2018). Distances of the participating COMPASS schools from the grocery stores were obtained by entering the coordinates of the schools and stores manually into Google Maps. Exposure to the policy change was coded by a categorical variable indicating three cohorts of students. The exposed cohort consisted of 652 students within 13 schools with at least one alcohol-selling grocery store (intervention stores) within a 10 km buffer of the school. As students typically undertake drinking off-campus after school hours, the 10 km buffer represents a distance that individuals can drive within 10-15 minutes to purchase an alcoholic beverage. Second, the Ontario-unexposed cohort consisted of 1,527 students within 43 schools in Ontario with no grocery store selling alcohol closer than 10 km buffer zone. Third, the Alberta cohort consisted of 88 students within 4 schools in Alberta, not exposed to the intervention.

Analyses: We used a three-stage analytical approach. First, we used latent transition analysis (LTA) to find the most reasonable number of latent alcohol patterns by testing the fit of 2- to 6-class models across the four waves. Each model was fit with 50 different sets of random starting values of parameters to ensure that the best maximum likelihood estimates were obtained (Nylund et al., 2007). The relative fits of the models were compared using Bayesian information criteria (BIC) (Schwarz, 1978). BICs of models decreased substantially from 2- to 4-class models and then began to increase from the 5-class model ($BIC_2=4457.9$, $BIC_3=2779.7$, $BIC_4=2335.4$, $BIC_5=2484.7$, $BIC_6=2604.3$). Based on BIC and conceptual relevance of latent

classes, we selected the 4-class model as our final model which generated clearly distinct and interpretable latent classes of youth alcohol use patterns. The results of a correlation analysis of latent variable items showed that despite the presence of structural zero for binge drinking response among non- drinkers, standardized residuals decreased substantially from the 2-class model to the 4-class model, indicating that local independence is not violated for the final model (data not shown)(Reboussin et al., 2008).

Second, we examined the stability of latent structure across the four waves and also across the three cohorts. Stability of the latent class structure over four waves of study was tested by comparing the fit of a constrained LTA model, in which item-response probabilities (IRP) were constrained to be identical over the four waves, with an unconstrained LTA model, in which parameters were estimated freely. Results indicated that the latent class structure and interpretation were stable over the four waves of the study ($\Delta G^2 = 79.32$, $df = 72$, $p = 0.259$). After confirmation of classes' structure over time, we used a multiple-group LTA to examine the stability of latent classes across the exposed cohort and two unexposed cohorts before the policy change. Comparison of a model in which IRPs were identical across cohorts to a model in which IRPs were free to vary across cohorts confirmed that youths within the three cohorts represented similar drinking patterns before the policy change ($\Delta G^2 = 10.15$, $df = 48$, $p = 0.998$). Average posterior probabilities of class memberships for exposed, Ontario-unexposed, and Alberta cohorts were 0.93 (range 0.89-0.95), 0.92 (range 0.83-0.95), and 0.94 (range 0.84-0.95), respectively, indicating high classification quality of the model within the three cohorts.

Third, to evaluate the impact of the policy change, we estimated the probability of transitioning to latent classes with higher levels of alcohol use. The ratio of transition probabilities post-policy to that of pre-policy change were compared between the exposed and unexposed cohorts. We used PROC LTA in SAS (PROC LCA & PROC LTA, 2015) to identify latent classes and to estimate transition probabilities among latent classes. The LTA procedure accommodates missing data using a full maximum likelihood approach that allows incomplete outcome variables under a missing at random assumption (Little & Rubin, 2014). In the dataset, missing data on the frequency of drinking and frequency of binge drinking were 92 (4%) and 12 (0.5%), respectively.

Table 8-1. The frequency of different levels of alcohol consumption in four waves (school year 2013-14 to 2016-17) of the COMPASS study (n=2,267)

Variable	Wave 1 (%)	Wave 2 (%)	Wave 3 (%)	Wave 4 (%)
Alcohol drinking				
Non-drinker	1670 (74.8)	1248 (55.6)	895 (39.7)	704 (31.3)
Up to 3 times a month	517 (23.2)	869 (38.7)	1155 (51.3)	1230 (54.7)
1 to 3 times a week	38 (1.7)	110 (4.9)	175 (7.8)	267 (11.9)
3+ times a week	7 (0.3)	17 (0.8)	27 (1.2)	47 (2.1)
Binge drinking				
No binge drinking	2015 (88.9)	1677 (74.0)	1346 (59.5)	1114 (49.2)
Once a month or less	207 (9.1)	428 (18.9)	648 (28.7)	744 (32.9)
2-4 times a month	37 (1.6)	140 (6.2)	227 (10.0)	342 (15.1)
More than once a week	7 (0.3)	21 (0.9)	40 (1.8)	63 (2.8)

8.5 Results

Table 1 presents the frequency of different levels of alcohol use and binge drinking in the study sample. As expected, the prevalence of alcohol use and binge drinking tended to increase over time. In Wave 1, 25.2% of students reported some level of alcohol consumption that increased to 68.7% by Wave 4. The prevalence of binge drinking also increased from 11.1% at Wave 1 to 50.8% by Wave 4.

Table 2 presents the item response probabilities (Table 2) of the LTA that characterized four latent classes which we labeled as: non-drinker (or abstainer) (had never consumed alcohol or did not drink alcohol in past year, baseline prevalence 71%), periodic drinker (reported drinking up to 3 times a month and no binge drinking, baseline prevalence 17%), low-risk drinker (reported drinking up to 3 times a month and once or less than a month binge drinking, baseline prevalence 10%), and high-risk regular drinker (reported drinking 1 to 3 times a week and binge drinking 2 to 4 times month, baseline prevalence 1%). In grade 9 to 11 (wave 1 to 3) the most common alcohol use pattern was the abstainer class with a prevalence of 71%, 50%, and 34% for grades 9, 10, and 11, respectively. In comparison, the most common pattern in grade 12 was low-risk drinker (38%). The largest reduction in the abstinent pattern occurred between grade 9 and 10 with 21% reduction.

Table 8-2. Structure and prevalence of latent classes of youth alcohol-use behaviours in four waves (school year 2013-14 to 2016-17) of the COMPASS study (n=2,267)

	Abstainer	Periodic drinker	Low risk drinker	High-risk regular drinker
Prevalence at Wave 1 (%)	71	18	10	1
Prevalence at Wave 2(%)	50	24	21	5
Prevalence at Wave 3 (%)	34	24	33	9
Prevalence at Wave 4 (%)	26	21	38	15
Drinking				
None	0.984	0.268	0.000	0.000
Up to 3 times a month	0.015	0.712	0.959	0.213
1 to 3 times a week	0.001	0.016	0.039	0.658
More than 3 times a week	0.000	0.004	0.000	0.129
Binge drinking				
None	0.999	0.986	0.044	0.016
Once or less than a month	0.001	0.014	0.841	0.106
2-4 times a month	0.000	0.000	0.115	0.694
More than once a week	0.000	0.000	0.000	0.184

The results of LTA show substantial changes in alcohol-use behaviour of students over the years of high school. Consistent with expectations, as students aged, we observed a high degree of transitions toward classes in which individuals had higher rates of alcohol consumption. Table 3 compares three cohorts in terms of transition probabilities between the four latent classes during two years before the new policy and two years after. The results show that the periodic drinker and low-risk drinker classes among the three cohorts illustrated similar changes, particularly among exposed and Ontario-unexposed cohorts (Table 3). Despite this similarity, we see an exception that the probability of transitioning from the low-risk drinker to high-risk regular drinker class decreased among Ontario-unexposed students while remaining stable for students in the exposed jurisdictions.

To examine the potential influence of the new alcohol policy on the probability of transitioning between different alcohol use classes, we compared the fit of the model with and without a covariate defining the cohort in the 4-class model. The cohort variable was not significant in the model ($2(\text{likelihood}_{\text{without cohort}} - \text{likelihood}_{\text{with cohort}}) = 5.12$, $df=3$, $p>0.163$), indicating that, in general, the alcohol policy did not have a significant influence on the probability of transitioning between different classes of alcohol consumption. However, changes in transition probabilities in/out of the two extreme classes of abstainers and high-risk regular

drinkers indicated a difference between the three cohorts (Table 3). In the exposed jurisdictions, abstainers at Wave 1 had a 69.2% chance of remaining there at Wave 2; a chance similar to that of Ontario-unexposed students with 71.4% and higher than that of students in Alberta with 59.6%. Because of the small sample size of the Alberta cohort, only a single transition from a class to other classes makes a large ratio that might not reflect the actual changes. The probability of remaining in the abstainer class after the intervention among both exposed and Ontario-unexposed cohorts was slightly higher than previous years and increased to 71.9% and 74.4%, respectively. In contrast, the probability of maintaining abstinence among students in Alberta decreased by 2.2% and reached 57.4%.

Results of Table 3 indicate that the probability of transitioning from abstainer class to high-risk regular class for the exposed cohort was 0.007 during the two years before the policy change but doubled afterwards, reaching 0.011. This probability decreased from 0.02 to 0.01 among Ontario-unexposed students and remained stable at 0.001 among Alberta students. Despite these very low probabilities of a direct move from the abstainer class to a high-risk regular class for the three cohorts, transition probabilities suggest that after the policy change, risk of transitioning to high-risk regular class among abstainers in the exposed jurisdictions was 1.71 times that before the policy change, compared to 0.50 and 1.00 among Ontario-unexposed and Alberta cohorts, respectively.

Transition probabilities in Table 3 presents that before the policy change, students in the exposed jurisdictions had a 52.3% chance of maintaining high-risk regular drinking, lowest among the three cohorts (Ontario-unexposed students had 69.7% and Alberta students had 99.5%). After intervention, however, the chance of staying in the high-risk regular drinker class increased by 40.3% for the exposed cohort to reach 92.3%. In contrast, the probability increased by only 13.0% for the Ontario-unexposed cohort and decreased by 10.6% in the Alberta cohort. Among the exposed cohort, the risk of maintaining high-risk regular drinking after the policy change relative to before increased by a factor of 1.77 compared to the 1.13-fold and 0.89-fold change among Ontario-unexposed and Alberta cohorts.

8.6 Discussion

This study compared the dynamics of alcohol use patterns of three cohorts of secondary school students before and after the new LCBO policy within a context of natural experiment. We first identified four alcohol use patterns characterized as abstainer, periodic drinker, low-risk drinker, and high-risk regular drinker. These patterns were consistent with the findings of previous research that identified a youth population consisting of distinct drinking pattern subpopulations (Gohari, Dubin, Cook, & Leatherdale, 2019; McBride et al., 2014).

The results suggest that the new LCBO policy appears to have a negative impact only among the subgroups of youth considered the highest and lowest risk groups. After the policy change, youth in the intervention cohort were significantly more likely to transition from the abstainer (i.e. no risk) class to the high-risk class (highest risk), and high risk regular drinkers are more likely to maintain this behaviour over time compared to youth in two control cohorts. In comparison, changes in probabilities of transitioning into/out of the two middle drinking classes (i.e. periodic drinkers and low-risk drinkers) were similar among the three cohorts. One possible reason for the lack of change in alcohol-use behaviours of most of the youth may be the ubiquitous availability of alcohol outlets across the province. Our data show that all schools in the COMPASS host study had at least one off-premise alcohol outlet within a 10 km radius (range 1-19). As has been shown in earlier research (Wagenaar et al., 1996), a single store could be enough to serve the entire jurisdiction so that adding new alcohol outlets does not change the availability of alcohol and therefore does not influence alcohol use patterns among the population.

The intervention increased the probability of transitioning from abstainer to the highest risk drinking. After the policy change, abstainer students in the intervention cohort indicated greater chance of transitioning to the highest risk drinking pattern, while the chance decreased among Ontario-unexposed cohort. Abstainer students in the Alberta control group had the same chance of moving from abstainer class to high-risk regular class before and after the intervention start date. Participating students at time of the policy change were in grade 11 in which students indicate more stable alcohol behaviour than their younger age as we observed in both control

groups. Therefore, a continuing rate of increase in alcohol consumption in students of the intervention cohort is cause for concern.

A notable degree of returning to lower severity classes or transitioning out of drinking among all three cohorts was observed, but with different levels. Of note, the probability of high-risk regular drinkers lowering their consumption after the policy change in the exposed jurisdictions was reduced by 0.40, compared to a 0.09 reduction in the Ontario-unexposed and 0.11 in the Alberta cohort. High-risk regular drinkers in the exposed jurisdictions were less likely to reduce their drinking behaviour after the policy change compared to their peers in the unexposed jurisdictions. This meaningful decreased tendency to reduce alcohol consumption in the exposed jurisdictions may partly be explained by increased social acceptability of alcohol use and a concurrent change in attitude toward the negative impacts of alcohol. The presence of alcohol as a normal commodity in grocery stores can change youth attitudes toward alcohol consumption. This change in community, family, and individual norms due to effects of macrolevel factors (e.g., public policy and marketing of alcohol) and community factors (e.g., neighbourhood characteristics and available opportunities for purchasing alcohol) has been widely reported (Chung, Pedersen, Kim, Hipwell, & Stepp, 2014; Sudhinaraset, Wigglesworth, & Takeuchi, 2016). However, in order to examine the effect of the policy change on shifting attitudes more precisely, further research needs to be conducted.

Alcohol-use behaviour is influenced by a vast array of social and political factors (Sudhinaraset et al., 2016), however, previous studies have demonstrated the centrality of reduction in numbers of alcohol outlets and limiting the hours and days of sale to decrease the health consequences of alcohol consumption (Jackson et al., 2014; World Health Organization, 2015). This study indicated that the new LCBO policy could increase accessibility of alcohol to the youth population both directly, by providing more opportunities to purchase from commercial alcohol outlets, and indirectly, by increasing the informal availability of alcohol obtained by parents, peers or siblings.

Identifying patterns of alcohol consumption among subgroups of youth population using latent transition analysis enabled us to evaluate the impact of the policy change on specific population subgroups separately. Since the two subgroups of the population with periodic and

low risk drinking pattern included the bulk of the student population (57% in the year of the intervention), we could have missed the positive association between the intervention and high-risk regular drinking among the two subgroups of the population if we ignored the distinct patterns of alcohol use. Furthermore, the quasi-experimental pre-post design of the COMPASS host study used in this research provided a unique robust framework to evaluate the effects of the new LCBO policy at a population level in a real-world context (Leatherdale, 2019). In addition, this study fills a research gap in Canada and internationally on the impact of change to alcohol-related public policies on the youth population, for which little contemporary evidence exists. Previous research (Norström, 2004; Stockwell et al., 2009; Trollid, 2005) has typically studied alcohol policy effects on the whole population or adults only (i.e., those permitted to buy and consume alcohol) but not specifically on youth.

The study has some limitations. First, it was not aimed to be representative of Ontario's population since a convenience sample of schools and students was used. However, the diversity and large size of the sample are compelling reasons not to expect the results to substantially differ from representative studies. Second, we relied on self-reports of alcohol use that, despite their wide usage and general acceptance, are subject to possible biases and errors, such as a tendency to underreport alcohol use (Butt et al., 2011). However, it is likely that measurement errors across the three (exposed and unexposed) cohorts were similar and therefore will have had no significant impact on the results. Moreover, the applied analytical method of LTA partially addressed the measurement errors by probabilistic assignment of individuals to classes (Collins & Lanza, 2013). Third, the linked data set may be biased toward a conservative estimation of prevalence of high-risk latent classes, because students who report use of a substance are more likely to drop out of school and therefore are not likely to be included in the linked data set (Qian et al., 2015). Finally, this work used the measure of relative probability of transitioning between alcohol use patterns before and after the policy change for evaluation. Although the observed relative probabilities of transitions from abstinence to high-risk regular drinking and maintaining of the high-risk regular behaviour was high, the crude difference between before and after of the policy change was very low. However, even these small changes indicate different impacts of the

Table 8-3. Comparison of transitions probabilities between latent classes of youth alcohol consumption among three cohorts during two years before selling alcohol in Ontario grocery stores (W1: school year 2013-14 and W2: school year 2014-15) and two years after (W3: school year 2015-16 and W4: school year 2016-17). The sample consisted of participating students in COMPASS study (n=2,267).

Class membership	Class membership at subsequent year											
	Abstainer			Periodic			Low risk			High-risk regular		
	Before	After	Ratio of probabilities	Before	After	Ratio of probabilities	Before	After	Ratio of probabilities	Before	After	Ratio of probabilities
Abstainer												
Exposed cohort	0.714	0.744	1.04	0.187	0.174	0.93	0.092	0.071	0.77	0.007	0.011	1.71
Ontario-unexposed	0.692	0.719	1.04	0.195	0.185	0.95	0.093	0.091	0.98	0.020	0.010	0.50
Alberta	0.595	0.573	0.96	0.272	0.148	0.54	0.133	0.279	2.09	0.001	0.001	1.00
Periodic												
Exposed cohort	0.006	0.007	1.10	0.439	0.493	1.12	0.513	0.457	0.89	0.042	0.045	1.07
Ontario-unexposed	0.001	0.001	1.00	0.473	0.538	1.14	0.469	0.406	0.86	0.058	0.056	0.97
Alberta	0.015	0.115	7.67	0.363	0.001	0.01	0.621	0.883	1.42	0.001	0.001	1.00
Low risk												
Exposed cohort	0.001	0.002	2.00	0.237	0.099	0.42	0.591	0.732	1.24	0.171	0.167	0.98
Ontario-unexposed	0.017	0.051	3.00	0.141	0.068	0.48	0.535	0.716	1.34	0.306	0.165	0.54
Alberta	0.010	0.086	8.60	0.143	0.073	0.51	0.701	0.702	1.00	0.146	0.139	0.95
High risk-regular												
Exposed cohort	0.292	0.027	0.09	0.184	0.048	0.26	0.001	0.002	2.00	0.523	0.923	1.76
Ontario-unexposed	0.220	0.011	0.05	0.001	0.001	1.00	0.082	0.201	2.45	0.697	0.788	1.13
Alberta	0.001	0.011	11.00	0.001	0.001	1.00	0.003	0.001	0.33	0.995	0.887	0.89

policy change on subgroups of the population and may indicate to policy makers the potential negative impacts of the policy change on vulnerable subgroups of the population that must not be overlooked. The current study only evaluated the immediate impact of the policy change, future research is required to evaluate long term effects of the policy change on alcohol use patterns, community and family norms, and attitudes of youth toward alcohol.

The results of this study demonstrated that, following the increase in physical availability of alcohol, the probability of high-risk regular drinking among youth has been increased. Abstainers in the exposed jurisdictions had a higher risk of being engaged in high-risk drinking regularly compared to youth in unexposed jurisdictions. Further, high risk regular drinkers are

more likely to maintain their behaviours following the policy change. This study suggests that, when formulating policy interventions, youth access to alcohol should be considered to reduce their harmful alcohol consumption.

Chapter 9

General Discussion

The frequent consumption of alcohol among Canadian youth (Public Health Agency of Canada, 2016) represents an important public health concern, given the numerous immediate and long-term health consequences. There is a lack of evidence on the impact of changes in alcohol policies on alcohol consumption among youth. Within a natural experiment context, this dissertation research has

- (1) identified patterns of alcohol consumption among the youth population;
- (2) investigated differences in alcohol use patterns across secondary schools;
- (3) estimated probabilities of transitioning between drinking patterns over time;
- (4) examined how individual- and school-level covariates predict patterns of alcohol use and transitioning between the patterns; and,
- (5) evaluated the impact of the new LCBO policy on the alcohol use patterns of youth in the exposed jurisdictions through pre and post-policy comparisons.

The following sections present key findings of this dissertation, their public health and policy implications, the study's limitations and strengths, and possible directions for future research.

9.1 Summary of key findings

Chapter 6 examined the presence of a latent structure to describe the heterogeneity in the youth population in terms of alcohol use patterns. Similar to previous research that established that the population consists of a finite number of subpopulations (Auerbach & Collins, 2006; Peterson et al., 2018; Romelsjö, 2010), Chapter 6 identified four distinct patterns of alcohol consumption, each representing a unique subpopulation: non-drinkers, light drinkers, regular drinkers, and heavy drinkers. The largest proportion of youth consisted of non-drinkers (44.2%), followed closely by light drinkers (41.8%) who indicated consuming alcohol up to 3 times a month and binge drinking once a month. Consistent with other studies (Dauber et al., 2011; Huh & Leventhal, 2016), the heavy-drinker group was the smallest of the four groups. However, a heavy-drinker group was identified at all schools, ranging from 2.2% to 9.3% of a school's

population. This finding indicates that the problems associated with heavy drinking are present in all schools but to different degrees, supporting the importance of community environment on alcohol use among youth (Foster et al., 2017; Paschall, Mallie, Lipperman-Kreda, & Grube, 2014; Sudhinaraset et al., 2016). The positive correlation between frequency of alcohol use occasions and frequency of binge drinking for the regular drinker and heavy drinker groups indicates that a large proportion of drinking occasions consist of binge drinking. This finding is consistent with past research suggesting that when youth drink alcohol they are more likely to undertake binge drinking (Public Health Agency of Canada, 2016). Given the many negative health consequences associated with binge drinking (Cservenka & Brumback, 2017; Gmel, Kuntsche, & Rehm, 2011; Kuntsche, Emmanuel, Kuntsche, Thrul, & Gmel, 2017), the finding emphasizes the need for reducing the number of alcohol consumption occasions overall.

A novel aspect of this chapter was using the multilevel LCA approach to cluster schools according to the alcohol-use behaviours of their students. The model identified two groups of schools: low-use [schools with a relatively large number of non-drinkers (n=40, 44.9% of schools)] and high-use [schools with higher rates of regular and heavy drinkers (n=49, 55.1%)]. The proportions of regular and heavy drinkers in high-use schools were nearly double the proportions in low-use schools. Membership in groups with higher levels of alcohol consumption was more likely in high-use schools, indicating that youth alcohol behaviours differ among schools. To explain this variation, we examined the effects of two environmental factors (i.e., the number of off-premise alcohol outlets and the average household income) on school level latent class membership. Average household income was not a significant factor in group membership across schools. This result is consistent with other studies that found null associations between family income and youth alcohol use (Cambron et al., 2018). This finding supports past research that indicated a null association between the amount of alcohol consumption among youth and socioeconomic status of families (Åslund & Nilsson, 2013; Brenner et al., 2011; Cambron et al., 2018). This nonsignificant association may be explained by the high variability of family income within each neighborhood and the fact that the family income has a greater association with youth alcohol use compared to neighborhood-level median household income (Leventhal & Brooks-Gunn, 2000; Wodtke et al., 2011). For example, youth in high income families in

disadvantaged communities may have heavier drinking patterns than youth in low income families (or vice versa), which attenuate the effect of family income on youth alcohol use patterns (Cambron et al., 2018). Another explanation for this finding could be that the small size of the class of heavy drinkers and close distribution of patterns across the two groups of schools make the effect of income statistically non-significant. Moreover, given the possibility that families may live in different socioeconomic neighborhoods over time, accounting for only the current neighborhood income may lead to bias toward underestimation of the neighborhood context (Cambron et al., 2018).

The number of off-premise alcohol outlets also had no significant association with youth drinking patterns, supporting past research findings that the density of off-premise alcohol outlets around schools has no impact on youth alcohol consumption (Larsen et al., 2017). Part of this insignificant effect can be attributed to the fact that there were no COMPASS schools without an alcohol outlet nearby, which indicates how available alcohol is to the youth population. Similar to research on tobacco that suggests the density of tobacco outlets may not be important in the smoking behaviour of established/regular smokers (Adams et al., 2013; Marsh et al., 2016), this chapter indicates that the presence or absence of alcohol-selling outlets is more relevant than the total number because a neighbourhood's population may be served by a single outlet (Wagenaar, 1995).

In addition to the school-level covariates, Chapter 6 examined the effects of individual factors of gender and grade on individual-level class membership. Like similar studies that have shown the predictive role of gender and grade on alcohol-use behaviours of students (Freeman et al., 2016; Jackson & Schulenberg, 2013; Leatherdale & Rynard, 2013), the findings of this dissertation suggest that male students and upper grade students were more likely to be engaged in higher levels of alcohol consumption. Inquiry into the initiation age of drinkers showed that the majority of heavy drinkers had initiated alcohol consumption before age 14. This finding is consistent with other research indicating that youth with early initiation into alcohol use are more likely to undertake risky drinking later in life (Oosterhoff, Kaplow, & Layne, 2016). This increased risk could be because early drinkers have more time to increase their consumption, or because early drinkers are more likely to become involved in the use of other substances (e.g.,

tobacco and cannabis) which is often associated greater alcohol consumption (Gruber et al., 1996; Peleg-Oren et al., 2009). This result underscores the need for screening for alcohol consumption in early adolescence, even before youth start secondary school, to reduce alcohol-related harm (Peleg-Oren et al., 2009). Although the majority of regular drinkers began drinking before secondary school, the high proportion of regular drinkers who started drinking at age 14 or after suggests that even those at later ages of onset are at risk of heavy drinking.

Building on the previous chapter, to understand the developmental process of the four alcohol use patterns over time, Chapter 7 investigated the likelihood of maintenance or change between drinking patterns during the two years before the policy change authorizing alcohol sale in grocery stores. The results of this chapter suggest that alcohol consumption tends to increase among those who start, but the volume of increase is not the same across all populations of youth (Hix-Small et al., 2004; McBride et al., 2014). While 64% of abstainers remained non-drinkers, 24% of them demonstrated risk of transitioning to periodic drinking. Consistent with past research (Tomczyk, Isensee, & Hanewinkel, 2015), the greatest risk of increasing consumption was observed among the periodic drinker group: 40% of periodic drinkers demonstrated not only an increase in their consumption but also reported occasions of binge drinking at the follow-up year when previously they had not engaged in binge drinking at all. These new groups of binge drinkers were in addition to individuals who maintained their low risk and high-risk regular drinking, that is those who had reported prior binge drinking. The transition probabilities showed that among those who reported binge drinking, the probability of maintaining this behaviour is quite high [the low-risk drinking class estimated 0.69, and the high-risk regular drinking class estimated 0.65]. As a result, the proportion of individuals engaged in some level of binge drinking rose from 21.2% at baseline to 33.9% at follow-up, confirming past research showing that binge drinking tends to increase over the secondary school years (Freeman et al., 2016; Larsen et al., 2017).

The results of Chapter 7 suggest that some youth do quit drinking or reduce their level of consumption over time. Estimated transition probabilities indicate that despite the high likelihood of movement to higher levels of alcohol use or maintenance of the current status of

consumption, a meaningful proportion of individuals lowered their consumption or quit drinking. As expected, the rate of quitting alcohol depends on the individual's patterns of consumption. Nearly 10% of low risk or high-risk regular drinkers were likely to have stopped stop drinking one year later at the follow-up. In comparison, the likelihood of quitting among periodic drinkers was only 1%, confirming past research indicating that individuals in the early stages of drinking are more likely to continue to drink (Jackson & Schulenberg, 2013). This finding shows that in addition to work on preventing alcohol initiation as the primary prevention approach, interventions might also target drinker subpopulations and promote the transition from drinking to quitting. This result raises the possibility of implementing and evaluating the impact of behavioural change approaches, such as Alcohol Brief Interventions (Babor & Higgins-Biddle, 2000) and Motivational Enhancement Therapy (Miller, 1995), to motivate low risk and high-risk regular drinkers to quit alcohol or decrease their consumption.

The results of Chapter 7 demonstrate an association between use of other substances (i.e., cigarettes and cannabis) and membership in drinking classes. The heavy use of either cigarettes or cannabis was found to be strongly associated with greater risk of membership in higher risk drinking classes. The Odds ratio of membership in periodic, low risk, and high-risk regular classes for cigarette and cannabis users was greater than that for non-drinkers. From this research it is unclear which of these substances serves as a gateway; however, the results confirm past research showing that youth decisions to use any of alcohol, cigarettes, or cannabis is associated with a higher risk of using the others, regardless of the sequence of substance use (Green et al., 2016; Hix-Small et al., 2004; Mistry et al., 2015; Orlando et al., 2005). This finding supports past research that suggests efforts addressing poly-substance use may be more efficient than alcohol only programs (Kelly, 2015; Merrin & Leadbeater, 2018).

In Chapters 6 and 7, the thesis explored heterogeneity in the alcohol-use behaviours of the youth population and investigated developmental processes among the population's subgroups. In Chapter 8, I examined changes in the alcohol use trajectories of identified subpopulations in the exposed jurisdictions compared with a control cohort in Ontario and one in Alberta before and after the new LCBO policy. The new LCBO policy increased the availability of alcohol in terms of the number of off-premise alcohol stores and sale hours and days. As shown in Chapter

6, before the policy change no COMPASS school was without an alcohol off-premise store around. Despite this existing availability, the policy change brought another source of alcohol to the youth population both directly, through grocery store purchase, and indirectly, through increased availability from home, older peers or siblings (Wagenaar et al., 1996). The probabilities estimated by latent transition analysis suggest that the new LCBO policy has had no negative impact on the periodic and low risk drinkers who comprised 57% of the population. In contrast, there is a negative impact among non-drinker and high-risk regular drinker groups as the lowest and highest risk groups, respectively. In communities with alcohol in grocery stores, the lowest risk group (non-drinkers) were more likely to transition to the highest risk group (high-risk regular drinkers), and individuals in the highest risk group indicated higher likelihood of maintaining their behaviour. Comparison of the prevalence of high-risk regular drinking among the three cohorts indicated that youth in the exposed jurisdictions had the highest rate of increase during the follow up years. These findings are consistent with previous research that indicates neighbourhood characteristics such as the density of alcohol outlets influence substance use behaviours of youth according to their levels of use (Adams et al., 2013; Marsh et al., 2016). Using a novel approach, this dissertation research has determined the impact of the new LCBO policy on subgroups of the youth population. This impact would have been missed if the research had focused on the whole sample as a homogenous population and used typical approaches for policy evaluation.

Similar to the results of Chapter 7, the results of Chapter 8 show that a notable degree of returning to lower-severity classes or quitting drinking was observable among all three cohorts, but at different levels. Of note, in the exposed jurisdictions the probability of high-risk regular drinkers lowering their consumption was 0.48 before the policy change and decreased to 0.08 afterwards, indicating a 0.40 decrease in the probability of reducing alcohol consumption. In comparison, the change in the probability among the Ontario-unexposed cohort was a 0.09 decrease (from 0.70 before to 0.79 after) and 0.11 increase in the Alberta cohort. The lower tendency to reduced alcohol consumption in the exposed compared to unexposed jurisdictions may partly result from the increased social acceptability of alcohol and changed attitudes about the negative impacts of alcohol. The presence of alcohol in grocery stores as a normal

commodity may have promoted perceived alcohol availability and reinforced normalization of alcohol consumption among youth even in the short period since the policy change (Campbell et al., 2009; Kuntsche, Emanuel, Kuendig, & Gmel, 2008; Stanley, Henry, & Swaim, 2011). Indeed, this change in community, family, and individual norms due to the effects of macrolevel factors (e.g., public policy and marketing of alcohol) and community factors (e.g., neighbourhood characteristics and available opportunities for purchasing alcohol) has been widely reported (Chung et al., 2014; Paschall et al., 2014; Sudhinaraset et al., 2016). However, further research is needed in order to examine this effect of the policy change on shifting attitudes more precisely.

Consistent with existing literature reporting that the largest proportion of youth in Grade 9 consists of abstainers (Dauber, Sarah E. et al., 2011; Huh & Leventhal, 2016), our findings showed that rates of drinking alcohol start off low but increased through high school. While the size of the periodic drinker class remained stable over the four years of follow-up, the size of the two classes engaged in some levels of binge drinking (i.e., low risk drinkers and high-risk regular drinkers) steadily increased over the school years. The data showed that more than half of grade 12 students reported past-year binge drinking, supporting previous research (Public Health Agency of Canada, 2016) that a large proportion of youth is at risk of immediate and long-term consequences of binge drinking.

9.2 Overall strengths of the dissertation

This dissertation has several strengths. First, its most powerful and unique major contribution is to provide a new approach to evaluating policy change that does not overlook the subgroups of a given population. Specifically, latent transition analysis (LTA) has provided insight into trajectories of alcohol consumption among youth and allowed the researcher to evaluate separately the impact of the policy change on specific population subgroups. Techniques that are used for policy evaluation typically model the aggregate data and infer the effect of a policy on the overall population (Stockwell et al., 2009; Stockwell et al., 2011; Trollid, 2005; Zalcman & Mann, 2007). Traditional approaches would have ignored the distinct

alcohol use trajectories that LTA identified. As a result, we could have not discovered the positive association between the intervention and problematic transitioning from abstinent to high-risk regular drinker because the bulk of the student population included in the two subgroups had not been influenced by the policy change. Latent transition analysis is a person-centred approach that models actual alcohol use at the individual level, in contrast to the commonly used variable-centred approach that models the association between variables (Collins & Lanza, 2013; Laursen, 2006). Modelling the individuals' substance use behaviours enables person-centred models to identify patterns of use and to cluster individuals corresponding to the patterns. Moreover, the analytic approach used in the dissertation offers a template for future evaluations of the impacts of change in public policy, including substance use policies. For example, the LTA approach used here could be employed to explore the impact of the new federal cannabis regulation in Canada by identifying and comparing cannabis use trajectories before and after the legalization, examining the potential predictive factors that impact transitions between distinct patterns of cannabis use. The ability of the model to incorporate covariates into the model would enable researchers to explore trajectories of cannabis use among specific subgroups of the population, such as ethnic, socio-economic, and age groups.

Second, this dissertation provides a robust evaluation of the government policy that can improve government accountability (Leatherdale, 2019). The COMPASS host study provided a unique opportunity to evaluate a provincial policy by providing data from two years pre-policy change and six years post-policy change. The data used in this study to inform government decision making already existed, and it required little additional time and few resources to design and conduct a new study and, consequently, a new data collection protocol. The data was available from the COMPASS host data collection, and the researcher has been involved in the data collection. The COMPASS survey collects longitudinal data on a variety of youth behaviours across four provinces and one territory (University of Waterloo School of Public Health and Health Systems, 2017), and government and researchers can use it for further investigation of the impact of the new LCBO policy. Further, the COMPASS study offers a natural experiment setting for evaluating the impact of other federal, provincial, or local policy and programs, such as cannabis legalization, on a wide range of youth behaviours.

Third, this study is among the first studies that evaluates the impact of the new LCBO policy, and among the few natural experiments in Canada that evaluate the impact of a policy change on substance use behaviour of the population. This dissertation can inform provincial policy makers on ways to improve the implementation of the policy. In addition, the results of this research can inform policy makers on the development and implementation of similar policies in other jurisdictions for which there are no local available data and policy. Such decisions are often made based on evidence from other jurisdictions (O'Donoghue Jenkins, Kelly, Cherbuin, & Anstey, 2016). The longitudinal quasi-experimental pre-post design of the COMPASS host study used in this dissertation, as an analogy for clinical trials in the clinical context (Craig et al., 2012), has provided a unique robust framework for evaluating the effects of the policy change at the population level in a real-world context (Leatherdale, 2019). This practice-based evidence provides high-quality scientific evidence that takes account of various confounders existing in public health practice, thus supporting evidence-based decisions around interventions (Leatherdale, 2019). This research is strengthened by using data prior to the implementation of the 2015 LCBO policy changes, allowing true pre/post comparison of the impact of youth alcohol behaviours (Craig et al., 2012). In addition, the use of two distinct control cohorts within unexposed jurisdictions (in Ontario and Alberta) have decreased the biases that might have emerged if only the pre/post-policy alcohol behaviours of youth only in the exposed jurisdictions had been compared (Petticrew et al., 2005). Moreover, the large sample of COMPASS schools spread out across the two provinces enabled the evaluation of how dynamics of alcohol patterns and responses to the policy change may differ across schools.

Additionally, this research has filled a research gap in Canada and internationally on the impact of change to alcohol-related public policies on the youth population, for which little contemporary evidence exists. Previous research (Norström, 2004; Stockwell et al., 2009; Trollidal, 2005; Wagenaar, 1995) has typically studied alcohol policy effects on the general population or adults (i.e., those permitted to buy and consume alcohol) but not specifically on the youth population. Alcohol behaviour established during adolescence is known to have long-term impacts on different aspects of an individual's life, including an elevated risk of numerous social and health consequences in adulthood (Alfonso-Loeches & Guerri, 2011; Peterson et al., 2018).

Therefore, identifying the impact of policy changes that shift alcohol-use behaviours of youth is a public health priority.

Finally, this dissertation has used multiple indicators (i.e., the frequency of drinking, the frequency of binge drinking, and the time of initiating alcohol use) to measure the multidimensional behaviour of alcohol consumption to provide an improved picture of the behaviour compared to past research that has measured alcohol consumption using only a single alcohol use indicator (Chan et al., 2017; Hix-Small et al., 2004; Mistry et al., 2015; Modecki et al., 2014). Using multiple indicators has allowed investigation of alcohol use patterns, alcohol use trajectories, and changes in consumption levels before and after the policy change. Moreover, alcohol use indicators in the COMPASS questionnaire have collected data on a multiple option response basis that enables the tracking of changes in consumption level rather than on less informative outcomes, such as the use vs. no use most commonly employed by previous studies (Jackson & Schulenberg, 2013; Malone, Van Eck, Flory, & Lamis, 2010).

9.3 Overall limitations of the dissertation

Although this research project has many strengths, there are also some limitations. The largest limitation is in the generalizability of the results to all youth in Ontario or Canada. The COMPASS study was not designed to be a representative sample since it uses a convenience sample of schools (and therefore students) to evaluate the impact of school-based policies and programs on a variety of student health behaviours (Leatherdale et al., 2014). Therefore, the results may be different from a representative sample. However, given the longitudinal nature of the study and the large school and student sample size, the results will have important implications for current research and practice. Moreover, the COMPASS survey employs a passive-consent approach for enrolling the students into the study. The passive-consent approach results in a high rate of participation and much lower nonresponse bias in survey data compared to the active-consent approach (Courser et al., 2009; Hollmann & McNamara, 1999). Hence, the COMPASS design potentially yields more-valid data compared to similar studies that typically use an active-consent method. Also, collection of data longitudinally over the school years more

precisely details the individuals' behaviour compared to cross-sectional studies (Cook & Ware, 1983).

Second, the research study relied on self-reports of alcohol use, which may be subject to measurement errors and recall and social desirability biases which may lead to underreporting alcohol use (Butt et al., 2011). However, self-reported alcohol use measures have previously been demonstrated to be reliable and valid and have been widely used in national surveys (Canadian Student Tobacco, Alcohol and Drug Survey, 2017). Moreover, for the evaluation part of this research, it is likely that measurement errors across the exposed cohort and the two control cohorts were similar; therefore, the potential biases of under-reporting alcohol consumption will have had no significant impact on the evaluation of the new LCBO policy. In addition, the applied analytical method of LTA partially addressed the measurement errors by probabilistically assigning of individuals to latent classes (Collins & Lanza, 2013).

Third, this dissertation is limited by losing a proportion of students' data over the linkage process. The non-linked data appears not to be a random collection, but data from students who were more likely to drink, smoke and use cannabis. Consequently, the linked data are biased toward a conservative estimation of the prevalence of high-risk groups. However, the main reason for inability to link data over time was because of the anonymity of participants. This is a common challenge with anonymous surveys in comparison to their advantage of promoting participation and enhancing the disclosure of sensitive information on self-administered questionnaires (Hollmann & McNamara, 1999; Thompson-Haile, Bredin, & Leatherdale, 2013). In addition, a large proportion of the non-linked data was attributed to students who were not at the school on the day of data collection in any two consecutive years.

Further, this dissertation used the relative probability of transitioning between alcohol use patterns before and after the policy change to evaluate the impact of the new alcohol policy. Although the observed relative probabilities of transitions from abstinence to high-risk regular drinking and maintaining of the high-risk regular behaviour was high, the crude difference between before and after the policy change was very low. In addition, the probability of transitions between these two patterns after the policy change in the exposed jurisdictions was still quite low. For example, while the relative probability of abstainers transitioning to the high-

risk regular class was 1.71 times higher than before the policy change in the exposed jurisdictions, the crude difference between before and after was 0.004. This probability of abstainers transitioning to the high-risk regular class after the policy change was 0.011, indicating a very small risk that an abstainer would become a high-risk regular drinker in the exposed jurisdictions. However, even these small changes indicate different impacts of the policy change on subgroups of the population and alarm policy makers about the potential negative impacts of the policy change on vulnerable subgroups of the population.

Finally, there are limitations to latent class analysis and latent transition analysis. One of the main limitations of LTA is that detected subgroups in the study sample are not necessarily the same as real underlying subgroups in the population (Berzofsky et al., 2014; Twisk & Hoekstra, 2012). Also, the number of subgroups identified by LTA can be greater than the actual number (Twisk & Hoekstra, 2012). However, the 4 latent classes identified throughout the three study of this dissertation using cross-sectional (study 1), 2-year linked data (study 2), and 4-year linked data (study 3) provide a sense of confidence that the youth population consists of four subgroups in terms of alcohol use. Another limitation of LTA is the local independence assumption that assumes the underlying latent variable describes any observed association between indicators of the latent variable (Lanza & Cooper, 2016). This assumption may be hard to meet in some real applications and may cause biases in parameter estimation, such as overestimation of the number of classes (Twisk & Hoekstra, 2012). In this dissertation, however, the results of a correlation analysis of latent variable items showed that despite the presence of structural zero in binge drinking responses for non-drinkers, standardized residuals decreased substantially from the 2-class model to the 4-class model, indicating that the local independence assumption had been met.

9.4 Implication for policy

First, this dissertation provides an evidence-based evaluation of the new LCBO policy on youth alcohol-use patterns, to provide knowledge for any action required to address prevalent alcohol use among Canadian youth. The results of this dissertation research indicate that the

probability of transitioning to higher risk patterns of alcohol use and maintaining these risky behaviours rose among youth in jurisdictions exposed to the new policy. While the change to the LCBO policy aligns with the nationwide trend toward liberalization of alcohol regulations, potential associated health consequences underscore the need for improved public health contribution to the design, development, and implementing of population-level alcohol policy. The results of this research indicated that two subgroups in tails of the sample, the lowest and highest risk groups, indicated negative change post policy. Specifically, increased likelihood of the abstainer class moving to the high-risk regular class and decreased likelihood of the high-risk regular class reducing consumption. This finding shows that while the overall impact of a policy can be seen as null, certain groups of populations can be affected negatively (or positively). As such, when formulating public policy, the impact of the policy on subpopulations vulnerable to the change must not be overlooked.

Second, this dissertation supports past research indicating that alcohol is part of Canadian youth culture (Canadian Centre on Substance Use and Addiction, 2007). A large proportion of the youth population drink alcohol regularly, and the level of consumption increases throughout the secondary school years. The popularity of alcohol among this dissertation's sample, signals that the "Don't drink" approach used to discourage underage drinking may be ineffective and many youth are engaged in alcohol consumption. This dissertation estimated a notable degree of consumption reduction among drinkers, which supports the need for a national youth-specific alcohol strategy that not only targets the ideal goal of abstinence but also provides guidelines for low-risk drinking among those individuals who choose to drink. This strategy could provide recommendations for actions in different areas such as:

- a. prevention programs for non-drinkers to raise awareness of immediate and long-term risks involved in drinking with the goal of delaying initiation of drinking as long as possible (primary prevention),
- b. limitation of availability of alcohol to youth population, and
- c. reduction of consumption programs for drinkers, with the goal of encouraging less-harmful alcohol use to reduce the harm of consumption (secondary prevention).

Third, this dissertation indicated that the presence of alcohol in grocery stores influences alcohol-use behaviours of youth, not only through increasing the availability of alcohol but also through influencing norms and the attitudes of communities, families, and ultimately individuals toward alcohol. These findings are consistent with a social-ecological model that posits that various macrolevel factors, such as economic and marketing policies, and community characteristics affect alcohol use in populations, in addition to microlevel factors, such as family, peers, and individual characteristics (Soloski et al., 2016; Studer et al., 2014; Sudhinaraset et al., 2016). Given the centrality of families' behaviour and norms on alcohol use by youth (Soloski et al., 2016), interventions need to incorporate and engage families in their efforts to prevent or reduce youth alcohol use. Community environments, such as neighbourhood characteristics (Bernstein, Galea, Ahern, Tracy, & Vlahov, 2007), density of alcohol outlets (both on and off-premise retailers) (Foster et al., 2017), and community norms and attitudes about alcohol (Brooks-Russell et al., 2014) also have an established influence on alcohol use patterns of youth, and so should be addressed in interventions. Further, peers play an important role in substance use behaviours of youth, in the form of peer alcohol norms (Brooks-Russell et al., 2014) and peer pressure (Studer et al., 2014). Overall, this dissertation suggests that multilevel interventions that incorporate proximal factors (i.e., families and peers) and distal factors (i.e., communities) would likely increase the likelihood of interventions' success (Chapman, Buckley, Sheehan, & Shochet, 2013; Perry et al., 2002; Toumbourou, Gregg, Shortt, Hutchinson, & Slaviero, 2013).

Fourth, this dissertation has identified two groups of schools according to the prevalence of alcohol patterns in the school. Knowledge of the different patterns of use helps schools to address the alcohol consumption at the school level by adopting interventions according to the dominant alcohol use patterns of their students. For example, high-use schools may focus on interventions that aim to decrease the risky drinking to lower risk levels, initiate family programs to restrict the access of youth to alcohol through the home (Jongenelis, 2018; Soloski et al., 2016), and communicate to all stakeholders to enforce restriction of alcohol sale to underage individuals.

Additionally, this dissertation provides evidence of the need for multi-substance use interventions throughout adolescence. The results lend support for theoretical models such as

gateway theory (Kandel et al., 1992) and common liability theory (Vanyukov et al., 2003), as well as empirical evidence (Green et al., 2016; Merrin & Leadbeater, 2018; Mistry et al., 2015; Orlando et al., 2005), that suggest substance misuse tends to cluster and that the use of one substance is associated to a great extent with the use of other substances. The results of this research indicate that tobacco and cannabis use increase the risk of membership in high-risk drinking patterns. Accordingly, development and implementation of policy on a single substance have a broader impact on the use of other substances through potential switching between substances or co-use of multiple substances (Kelly, 2015; Merrin & Leadbeater, 2018).

Finally, a considerable opportunity exists within the COMPASS host survey to evaluate the influence of school policies and programs on alcohol use patterns of students. The COMPASS study collects data on various school-based programs aimed to promote student health. The programs include substance use prevention programs run solely by schools or in collaboration with other stakeholders, such as local health units, police departments, and community-based groups. Evaluation of preventive programs run by schools would be valuable for modification of the programs and, also, for new school-based preventive initiatives.

9.5 Implications for future research

Future research is required to build upon the findings of this dissertation. Recommended actions from the results of this dissertation are outlined below.

1. *Investigate the long-term impact of the policy change on youth alcohol knowledge, attitudes, and consumption.* This dissertation has estimated the immediate impact of the new LCBO policy on youth alcohol-use behaviours one year post-policy change. The COMPASS host study allows unique opportunities to extend this dissertation research to further years in order to evaluate longer term impacts of the policy change. For example, by the end of the second phase of the COMPAS study, there will be five years of post-policy data available to capture comprehensive knowledge about post-policy changes in drinking behaviour of youth. In addition, future research should evaluate the change in youth attitudes towards alcohol following

the presence of alcohol in grocery stores. Continuous exposure to alcoholic beverages beside other ordinary commodities of daily life, such as food and soft drinks, may alter youth's alcohol knowledge, attitudes, and norms. Past research (Paschall, 2012) has shown that such changes in youth attitudes and norms may facilitate the development of pro-drinking attitudes, likely increasing the likelihood of transitioning to and maintaining high-risk patterns of alcohol consumption. The availability of alcohol in grocery stores may also contribute to overestimations of peer alcohol consumption, in turn leading to higher alcohol consumption among youth (Stock et al., 2014).

2. *Explore the sources of alcohol available to youth.* The COMPASS questionnaire does not collect any information about the source of alcohol for students, where drinking is typically occurring, or the number of peers who drink. Although studies have explored the source of alcohol for youth (Harrison, 2000; Jongenelis, 2018; Wagenaar et al., 1996), there is a lack of longitudinal study on how alcohol sources may change over time because of changes in alcohol marketing, social norms, and knowledge and attitudes toward alcohol. Moreover, there is a specific need to explore available sources of alcohol for Canadian youth since the literature is mainly focused on the US context. Knowing where alcohol is obtained (e.g., sources: family, friends, retailers) could help researchers determine whether adding grocery stores as an alcohol outlet (source) brings on a shift in where alcohol is obtained. Moreover, these data could inform future policy development. For example, there is likely more alcohol available at home because parents can bring alcohol there easily. Also, the grocery stores would be a new source for direct purchase by youth.

3. *Examine the effect of alcohol online shopping on trajectories of alcohol use among youth.* Since a main objective of the new LCBO policy was introducing competition into the beverage alcohol sector in Ontario (the Ontario Premier's Advisory Council on Government Assets, 2016), the governmental LCBOs and The Beer Stores adapted their business models. Following the LCBO policy, these stores developed new plans and services to be able to compete with the private sector. For example, they developed a new online e-commerce platform and

delivery system (LCBO, 2018) that may result in improved accessibility of alcohol to youth. Future research should focus on estimating separately the weight of physical sources compared to online sources for serving alcohol to youth, so as to understand how policy changes to either could influence youth alcohol use trajectories over time. Given the market shift to online shopping, especially among the young population, and the influence of online platforms on youth behaviours (Cook, Bauermeister, Gordon-Messer, & Zimmerman, 2013), evaluation of the long term impact of the policy change through developing online platforms for alcohol purchase is crucial.

4. *Explore the effect of the new LCBO policy on home alcohol supplies and parents' alcohol habits.* From January 2019, selected LCBO stores in some cities of Ontario extended their operating hours, and are now open Fridays and Saturdays until 11pm (LCBO News, 2019). The extended hours could offer more alcohol supply at home. Given a direct association between parental supply and youth drinking behaviour (Chan et al., 2017; Jongenelis, 2018), future research needs to assess how the convenience of purchasing alcohol from grocery stores when grocery shopping may affect home alcohol supplies. Moreover, research has illustrated the importance of parents' drinking habits on shaping youth drinking behaviour through modelling the behaviour themselves and also facilitating access to alcohol (Kuntsche et al., 2017). Future research should assess to what extent trajectories of parents' behaviour have been influenced by the new alcohol policy, which would in turn influence youth drinking trajectories. Building on this could aid the development of interventions that focus on youth alcohol consumption in the home. Also, given the importance of peer alcohol use patterns (Schwinn & Schinke, 2014; Soloski et al., 2016; Tomczyk et al., 2015), knowledge about changes in trajectories of older siblings and peers after the policy change would be valuable to prevention efforts.

5. *Examine trajectories of co-substance use after the policy change.* Evidence from this dissertation, as well as past research (Jones, 2019; Tomczyk et al., 2015), indicates a direct association between the probability of high-risk drinking and cigarette and cannabis use. This finding underscores the potential of the new LCBO policy to impact other substances among youth. Future research should monitor changes in cigarette and cannabis use behaviours of youth

post-policy in the exposed jurisdictions. Since the COMPASS questionnaire collects data on the levels and the frequency of use of cigarettes, cannabis, e-cigarettes, and a few other substances, COMPASS is well situated to evaluate change in co-substance use due to the new LCBO policy.

6. *Investigate the impact of the policy change on health outcomes of the population.* This dissertation only evaluated the effect of the new LCBO policy on trajectories of youth alcohol consumption, while there might be broader immediate and long-term issues in public health (Public Health Agency of Canada, 2016), the economy (Canadian Centre on Substance Use and Addiction, 2018), and society (Canadian Centre on Substance Use and Addiction, 2005). In each context, the increased risk of transitioning to and maintaining high risk drinking evident from this dissertation may have impacts on individuals, families, communities, and society. Future research must evaluate the effects of the new policy within various contexts. For example, issues of alcohol misuse can be measured in the exposed jurisdictions pre- and post-policy using the number of alcohol-attributed deaths or injuries, alcohol-attributed suicides, and prevalence of mental health disorders among drinkers. Social issues of alcohol use can be measured using student's sick days, academic grades, and academic aspiration.

9.6 Conclusion

Alcohol consumption is popular among Canadian youth. This dissertation research found that although a notable proportion of Canadian youth abstains from alcohol use up to graduation from secondary school, a large proportion consume alcohol regularly, and the overall level of consumption increases throughout the school years. Four distinct, dominant trajectories of alcohol use were identified, each with a specific transition probability to other trajectories. Schools can be classified in two distinct groups based on the prevalence of the identified patterns of alcohol use. This knowledge can help decision makers to adopt and modify global interventions according to the patterns of alcohol consumption in individual schools.

This dissertation concludes that the 2015 change in LCBO policy to allow alcohol sale in some grocery stores across Ontario has had mixed results on youth alcohol use patterns. While the new policy appears to have had no negative impact on the alcohol-use behaviours of most

youth, it has had a negative effect, although small in size, among two subgroups of the youth population. The subgroup of high-risk regular drinkers in the exposed jurisdictions was more apt to maintain heavy drinking rather than reduce it compared to their peers in non-exposed jurisdictions. Furthermore, the subgroup of non-drinkers in the exposed jurisdictions was more apt to become high-risk drinkers. More alcohol outlets around schools may encourage curiosity and raise the temptation to alcohol use among non-drinkers and provide opportunities for drinkers to buy alcohol. The increase likelihood of transitioning into and maintaining high-risk drinking is a public health alarm considering that alcohol not only harms risky drinkers but also broader society. Additionally, given the direct association between risky drinking and cigarette and cannabis use, the higher probability of high-risk drinking among youth in the exposed jurisdictions may undermine the previous success in reducing the use of other substances, such as tobacco. These dissertation findings highlight the need for long-term evaluation of the new LCBO policy and its possible effects on trajectories of youth alcohol consumption and on other health indicators.

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Appendix A

Supplementary material for Study 1

A.1. Multilevel latent class model

Let Y_{ijk} denote the response of individual i , $1, 2, \dots, n$, within a cluster k , $1, 2, \dots, K$, on the j th question, and let each question j , $1, 2, \dots, M$, have a possible discrete response r_j , $1, 2, \dots, R_j$. The latent class model can be written as follows:

$$\begin{aligned} & p(Y_{ik1} = r_1, Y_{ik2} = r_2, \dots, Y_{ikM} = r_M | X_{ik}) \\ &= \sum_{c=1}^L p(C_{ik} = c | X_{ik}) \prod_{j=1}^M \prod_{r_j=1}^{R_j} p(Y_{ikj} = r_j | C_{ik} = c)^{I(y_{ikj}=r_j)} \end{aligned}$$

where C_{ij} is the latent class membership, c is used to refer to a particular latent class, $C_{ik} = 1, 2, \dots, L$, $I(y_{ikj} = r_j)$ is an indicator function that equals 1 if the response to question $j = r_j$ and equals zero otherwise, and X_{ik} is a vector of individual covariates. The parameters of the model are estimated using the expectation-maximization (EM) algorithm. Traditional LCA assumes that observations are independent of one another. In the current research, however, students are classified into schools and the independent assumption is violated. As such, a multilevel LCA was used.

Multilevel LCA (MLCA) considers the two-level structure of data and allows latent class memberships to vary across schools (Finch & French, 2014; Henry & Muthén, 2010). For the nonparametric approach of MLCA used in this dissertation, between-cluster variations are expressed through assuming an additional latent structure for level 2 units. That is, similar to the level 1 latent structure that is defined using observed indicator variables, the between-cluster structure is created using the prevalence of level 1 class memberships. Thus, clusters belong to one of T cluster-level mixture components, and each class of level 2 consists of clusters with similar prevalence of within-cluster level 1 classes. The MLCA can now be expressed as

$$\begin{aligned}
& p(Y_{ik1} = r_1, Y_{ik2} = r_2, \dots, Y_{ikM} = r_M | W_k, X_{ik}, Z_k) \\
&= \sum_{c=1}^L p(C_{ik} = c | W_k = w, X_{ik}, Z_k) \prod_{j=1}^M \prod_{r_j=1}^{R_j} p(Y_{ikj} = r_j | C_{ik} = c)
\end{aligned}$$

where Z_j denotes the vector of level 2 covariates, W_k represents the level 2 class membership for cluster k , and $w, 1, 2, \dots, T$ is a particular level 2 class. In this representation, the probability of class membership can be defined as follows:

$$p(C_{ik} = c | W_k = w, X_{ik}, Z_k) = \frac{\exp(\gamma_c + \beta_c x_{ik} + \alpha_c z_k + \alpha_{cw})}{1 + \sum_{r=2}^L \exp(\gamma_r + \beta_r x_{ik} + \alpha_r z_k + \alpha_{rw})}$$

where $c = 2, 3, \dots, L$, and α_{cw} , is a random latent variable associated with clusters in class w .

Appendix B

Supplementary materials for study 2

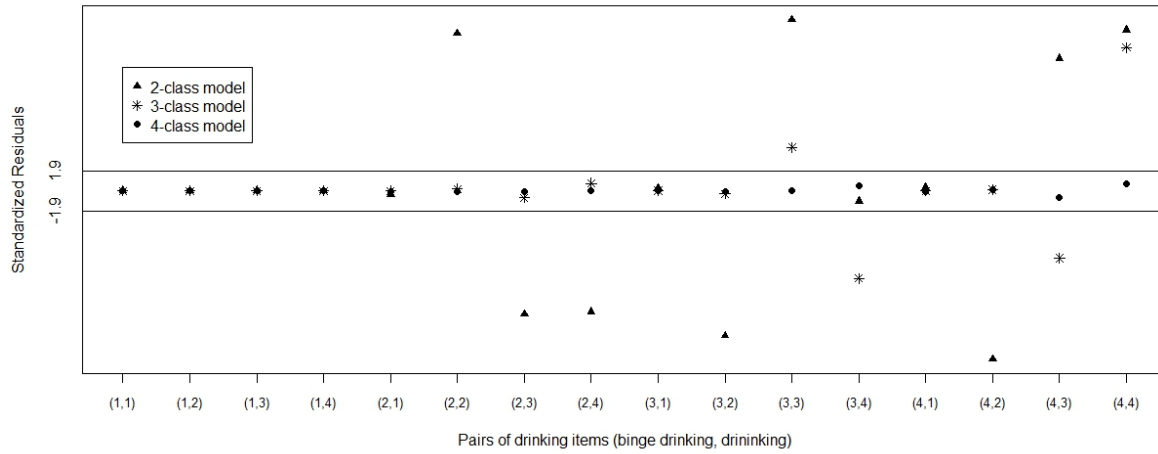


Figure B.1. Standardized residuals of bivariate correlations among frequency of drinking and binge drinking levels used for creating latent classes

Appendix C

Supplementary materials for study 3

Table C-1. The number of off-premise alcohol outlets around the 10 km buffer of the COMPASS study according to exposure to the new LCBO policy

Exposed jurisdictions		Unexposed jurisdictions in Ontario								Alberta	
school	# ^a	school	#	school	#	school	#	school	#	school	#
1	20	1	28	13	2	25	8	37	22	1	5
2	25	2	31	14	3	26	17	38	26	2	2
3	15	3	4	15	5	27	3	39	4	3	1
4	8	4	3	16	26	28	3	40	14	4	6
5	15	5	1	17	3	29	1	41	5		
6	13	6	2	18	2	30	3	42	4		
7	48	7	2	19	24	31	7	43	15		
8	26	8	2	20	3	32	5				
9	27	9	3	21	3	33	27				
10	28	10	3	22	3	34	2				
11	15	11	3	23	2	35	4				
12	18	12	3	24	4	36	9				

^a The number of off-premise alcohol outlets

Table C-2. The effects of individual covariates on membership in latent classes of youth alcohol consumption among exposed and unexposed jurisdictions in Ontario over four years of follow-up (school year 2013-14 to 2016-17). The sample consisted of participating students in COMPASS study (n=2,267).

Covariate	Abstainer	Periodic	Low risk	High-risk
Gender (male)				
Exposed	Reference	0.85	0.90	0.84
Unexposed	Reference	1.11	0.75	1.01
Ethnicity (white)				
Exposed	Reference	3.48	1.96	2.68
Unexposed	Reference	2.94	1.66	0.52
Cigarette use				
Exposed	Reference	2.41	10.98	17.94
Unexposed	Reference	9.42	16.93	17.59
Cannabis use				
Exposed	Reference	4.03	13.73	23.58
Unexposed	Reference	2.92	13.03	17.92

Transition probabilities according individual characteristics

The effects of individual characteristics of gender, ethnicity, and use of smoking and cannabis on changes in alcohol use trajectories were investigated using multinomial logistic regression in latent class analysis. Because of the size of high-risk regular class was small, particularly in Alberta, these investigations have been done using data from the two cohorts in Ontario. The new alcohol policy on the probability of transitioning between different alcohol use classes, we compared the fit of the model with and without a covariate defining the cohort in the 4-class model. The gender of youth was not significant in the LTA model ($2(\text{likelihood}_{\text{without gender}} - \text{likelihood}_{\text{with gender}}) = 3.64$, $df=3$, $p>0.725$). Table C-2. The effects of individual covariates on membership in latent classes of youth alcohol consumption among exposed and unexposed jurisdictions in Ontario over four years of follow-up (school year 2013-14 to 2016-17). The sample consisted of participating students in COMPASS study (n=2,267). Table C-2 presents the estimated ORs by LTA. Race ($2(\text{likelihood}_{\text{without race}} - \text{likelihood}_{\text{with race}}) = 40.19$, $df=6$, $p<0.001$), cigarette use ($2(\text{likelihood}_{\text{without cigarette}} - \text{likelihood}_{\text{with cigarette}}) = 40.19$, $df=6$, $p<0.001$),

cigarette=116.33, $df=6$, $p<0.001$), and cannabis use 2($likelihood_{without\ cannabis}-likelihood_{with\ cannabis}=247.72$, $df=6$, $p<0.001$) were significant factors on the latent class memberships.

Table C-3. Comparison of transitions probabilities between latent classes of youth alcohol consumption among exposed and unexposed jurisdictions in Ontario during two years before selling alcohol in Ontario grocery stores (W1: school year 2013-14 and W2: school year 204-15) and two years after (W3: school year 2015-16 and W4: school year 206-17) according to gender. The sample consisted of participating students in COMPASS study (n=2,267).

Class membership at baseline	Class membership at subsequent year															
	Abstainer				Periodic				Low risk				High-risk regular			
	Female		Male		Female		Male		Female		Male		Female		Male	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
Abstainer																
Exposed cohort	0.668	0.811	0.766	0.665	0.229	0.097	0.135	0.248	0.099	0.082	0.085	0.073	0.003	0.009	0.014	0.013
Ontario-unexposed	0.665	0.676	0.719	0.750	0.222	0.252	0.163	0.126	0.094	0.058	0.098	0.121	0.019	0.014	0.020	0.003
Periodic																
Exposed cohort	0.032	0.022	0.001	0.107	0.338	0.529	0.561	0.486	0.587	0.449	0.399	0.309	0.043	0.001	0.039	0.098
Ontario-unexposed	0.001	0.001	0.001	0.015	0.388	0.586	0.554	0.475	0.588	0.411	0.373	0.415	0.001	0.001	0.073	0.095
Low risk																
Exposed cohort	0.026	0.001	0.001	0.079	0.171	0.043	0.241	0.089	0.583	0.830	0.641	0.614	0.025	0.001	0.118	0.218
Ontario-unexposed	0.001	0.043	0.043	0.072	0.099	0.065	0.172	0.027	0.649	0.758	0.449	0.694	0.001	0.043	0.336	0.207
High risk-regular																
Exposed cohort	0.272	0.033	0.001	0.024	0.001	0.049	0.92	0.057	0.001	0.001	0.001	0.011	0.728	0.917	0.005	0.907
Ontario-unexposed	0.168	0.001	0.001	0.014 1	0.001	0.001	0.320	0.001	0.160	0.367	0.001	0.110	0.672	0.633	0.680	0.876

Table C-4. Comparison of transitions probabilities between latent classes of youth alcohol consumption among exposed and unexposed jurisdictions in Ontario during two years before selling alcohol in Ontario grocery stores (W1: school year 2013-14 and W2: school year 204-15) and two years after (W3: school year 2015-16 and W4: school year 206-17) according to ethnicity. The sample consisted of participating students in COMPASS study (n=2,267).

Class membership at baseline	Class membership at subsequent year															
	Abstainer				Periodic				Low risk				High-risk regular			
	Non-white		White		Non-white		White		Non-white		White		Non-white		White	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
Abstainer																
Exposed cohort	0808	0763	0.659	0.723	0.131	0.184	0.216	0.166	0.061	0.053	0.111	0.086	0.001	0.001	0.014	0.025
Ontario-unexposed	0.787	0.762	0.665	0.690	0.113	0.109	0.217	0.216	0.084	0.127	0.096	0.081	0.015	0.001	0.021	0.012
Periodic																
Exposed cohort	0.135	0.033	0.001	0.092	0.506	0.667	0.415	0.411	0.304	0.257	0.552	0.465	0.054	0.042	0.033	0.031
Ontario-unexposed	0.196	0.118	0.001	0.001	0.439	0.499	0.446	0.518	0.366	0.313	0.491	0.438	0.001	0.069	0.063	0.044
Low risk																
Exposed cohort	0.041	0.028	0.001	0.002	0.398	0.124	0.180	0.093	0.438	0.738	0.638	0.719	0.121	0.110	0.182	0.186
Ontario-unexposed	0.065	0.130	0.007	0.040	0.130	0.080	0.142	0.066	0.657	0.688	0.531	0.720	0.147	0.102	0.320	0.175
High risk-regular																
Exposed cohort	0.001	0.001	0.404	0.045	0.995	0.088	0.001	0.027	0.001	0.058	0.001	0.001	0.002	0.854	0.596	0.928
Ontario-unexposed	0.193	0.001	0.150	0.014	0.305	0.071	0.001	0.001	0.001	0.577	0.126	0.173	0.502	0.352	0.723	0.813