Understanding youth tobacco and nicotine product use: Exploring susceptibility to, use of, and trajectories for six tobacco and nicotine products

by

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Author's Declaration

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 four manuscripts that have been submitted for publication. Exceptions to sole authorship:

Chapter 5: Cole AG, Kennedy RD, Chaurasia A, Leatherdale ST. (2017). Exploring the predictive validity of the susceptibility to smoking construct for tobacco cigarettes, alternative tobacco products, and e-cigarettes. *Nicotine & Tobacco Research*, 1-8. doi: 10.1093/ntr/ntx265.

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Chapter 8: Cole AG, Chaurasia A, Kennedy RD, Leatherdale ST. (submitted). Identifying latent trajectory groups describing the use of five tobacco products and e-cigarettes. *Journal of Adolescent Health*

As lead author of these four chapters, I was responsible for developing the research questions, conducting background research, leading the study designs, conducting the statistical analyses, interpreting the results, and writing the initial drafts of the 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. Leatherdale's supervision, I also prepared the remaining chapters in this thesis, which were not written for publication.

Abstract

One of the greatest accomplishments of public health has been the significant reductions in harms due to smoking. Although tobacco cigarettes have typically been the product with the highest prevalence of use, there remains a significant number of youth that use other products such as e-cigarettes, cigarillos or little cigars (CLCs), cigars, smokeless tobacco (SLT), and hookah. Past research has focused on tobacco cigarette smoking behaviours and has neglected investigating the use of other tobacco and nicotine products. The objectives of this dissertation were (1) to examine the ability of current susceptibility measures to predict the use of other tobacco and nicotine products, (2) to identify latent classes of tobacco and nicotine product use, and (3) to identify latent trajectory groups for the use of each product. Four manuscripts addressed these objectives for six tobacco products (i.e., tobacco cigarettes, e-cigarettes, CLCs, cigars, SLT, and hookah) using longitudinal data from students in Ontario that participated in the COMPASS study from 2013-2016.

The first manuscript calculated the sensitivity, specificity, positive and negative predictive values of the susceptibility to smoking construct for the use of each tobacco and nicotine product. Results indicated that the sensitivity of the construct was moderate while the specificity was high. The positive predictive value was variable, depending on the prevalence of the product, while the negative predictive value was very high. Similar values were calculated for each measure of the susceptibility construct.

The second manuscript identified student-level sociodemographic and behavioural characteristics of non-smoking youth at baseline that used each tobacco and nicotine product one- and two-years later. Given that the first manuscript provided evidence for the predictive validity of the susceptibility construct, this manuscript included susceptibility to future smoking as a predictor in the models. Baseline susceptibility to future smoking was strongly associated with the use of each tobacco product and e-cigarette at one- and two-year follow-up. Additionally, students that had friends that smoked cigarettes or who reported binge drinking at baseline had higher odds of reporting the use of each product at follow-up.

The third manuscript identified tobacco and nicotine product use clusters for three consecutive years using latent class analysis. At baseline, a three-class model was identified as best [(1) *non-current users*; (2) *current tobacco cigarette, CLC, and e-cigarette users*; (3) *current polyproduct users*], while a four-class model was identified one-year [(1) *non-current users*; (2) *current e-cigarette users*; (3) *current dual tobacco cigarette and CLC users*; (4) cu*rrent polyproduct*

users] and two-years later [(1) *non-current users*; (2) *current dual tobacco cigarette and e-cigarette users*; (3) *current tobacco cigarette, CLC, cigar, and e-cigarette users*; (4) *current polyproduct users*]. Results of the multinomial regression models indicate that students that reported having friends that smoked cigarettes, binge drinking, and using marijuana were more likely to be classified into a current use class relative to a non-current use class.

The final manuscript identified latent trajectory groups for the use of each tobacco and nicotine product using latent trajectory analysis. Given the results of the first two manuscripts, measures of susceptibility to future smoking were included when identifying trajectory groups. Consistent across all products, five groups of users were identified: (1) *non-susceptible non-users*, (2) *non-susceptible puffers*, (3) *stable low intenders*, (4) *escalating experimenters*, and (5) *consistent current users*. Across all tobacco and nicotine products, students had the highest probability of remaining in the same group over time, although some transitions in group membership were evident. Results of the multinomial logistic regression models indicate that across all products, students that reported having friends that smoked cigarettes, binge drinking, and using marijuana were more likely to be classified into any other trajectory group relative to the *non-susceptible non-users* group. Additionally, students that reported a higher school connectedness score and eating breakfast every day in a usual school week were less likely to be classified into any other trajectory group relative to the *non-susceptible non-users* group.

This dissertation fills an important gap with respect to our knowledge of other tobacco and nicotine product use among youth in Canada. The findings of this dissertation have implications for research and practice and highlight the need for inclusive tobacco control programming, particularly with respect to school-level prevention and cessation programs. Given than many youth reported using more than one tobacco or nicotine product and commonly reported binge drinking and using marijuana, multi-substance use programs are needed. In addition, given that students transition into and out of tobacco and nicotine product use throughout secondary school, consistent programming may be needed to discourage the initiation and escalation of tobacco and nicotine product use throughout adolescence.

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To my parents, Geoff and Daphne, thank you for your unconditional love and support over the years. I learned the value of hard work, the significance of education, and the importance of perseverance from your example. I never imagined this would be my career path after my undergraduate degree. Thank you for challenging my thinking and encouraging me to pursue a research career. Thank you for the sacrifices you made to ensure I had the best education possible and for the countless prayers you have made over my life. I know I have been given a unique gift and I will continue to work to use it well.

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Alternative tobacco and nicotine products (ATNPs): a range of tobacco and nicotine products that are used in place of, or in addition to tobacco cigarettes, including cigars, cigarillos or little cigars, electronic cigarettes, smokeless tobacco, and hookah.

Cigar: looks like a tobacco cigarette but is typically larger and has a higher tobacco content; consists of filler (the inner part of the cigar), a binder, and a wrapper, all of which are made with air-cured and fermented tobacco.

Cigarillo or little cigar (CLC): cigarillos look like tobacco cigarettes but are typically longer and slimmer with a variable tobacco content; little cigars are smaller cigars that have a lower tobacco content relative to cigarillos.

Electronic cigarette (or e-cigarette): an electronic device that has a cartridge with a heater that vaporizes liquid (with or without nicotine) instead of burning tobacco; many are designed to look like a tobacco cigarette.

Hookah: other names include waterpipe, narghile, sheesha, and goza; consists of a glass or plastic bottle filled with water, a tray for tobacco (or herbal shisha), and a tube for inhaling tobacco smoke after it has been cooled by passing through water.

Smokeless tobacco (SLT): a group of non-combustible tobacco products (e.g., chewing tobacco, pinch, snuff, snus, etc.) that are placed in the mouth or nasal passage rather than smoked; three main types (chewing tobacco, moist snuff, and dry snuff); snus is a type of moist snuff that is popular in Sweden, is flavoured, and is spitless.

Tobacco cigarette: factory manufactured roll of finely cut tobacco cured for smoking; usually wrapped in thin white paper and smoked with a filter.

List of Abbreviations

95% CI	95% Confidence Interval
ATNP	Alternative tobacco and nicotine product
ATP	Alternative tobacco product
BIC	Bayesian Information Criterion
adj-BIC	model-adjusted Bayesian Information Criterion
Cq	COMPASS student questionnaire
CLC	Cigarillo or little cigar
LCA	Latent Class Analysis
LTA	Latent Transition Analysis
NPV	Negative Predictive Value
PBT	Problem Behavior Theory
PPV	Positive Predictive Value
SE	Standard Error
SLT	Smokeless tobacco

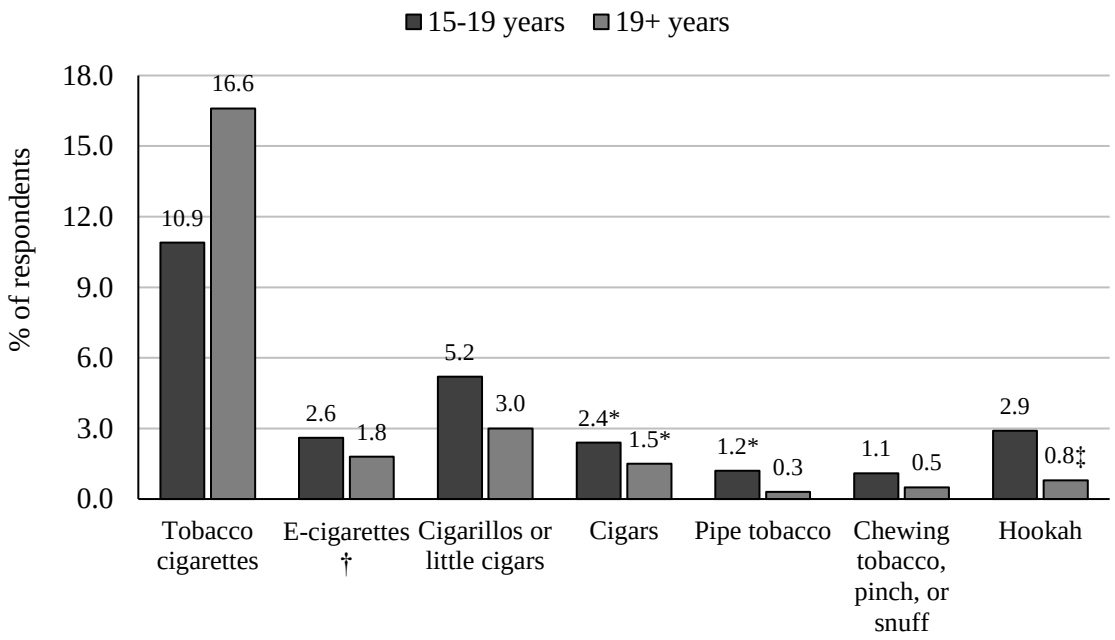
Chapter 1
Background

Since the early 2000s, the prevalence of ever and current tobacco cigarette smoking decreased substantially among secondary-school aged youth (between the ages of 15 and 19) and young adults (between the ages of 20 and 24) in Canada (Reid, Hammond, Rynard, Madill, & Burkhalter, 2017). Canadian data show that the prevalence of ever tobacco cigarette smoking among youth dropped from approximately 50% in 2000 to less than 20% in 2013; similarly the prevalence of current daily and non-daily tobacco cigarette smoking among youth dropped from approximately 25% in 2000 to 10% in 2013 (Reid et al., 2017). Although tobacco cigarettes have typically been the product with the highest prevalence of use (Reid et al., 2017), there remains a significant number of youth that use alternative tobacco products in Canada (see Figure 1), including cigars, cigarillos or little cigars (CLCs), pipe tobacco, roll-your own (RYO) cigarettes, smokeless tobacco (SLT) products (including smokeless tobacco, snuff, and snus), and hookah (waterpipe to smoke tobacco). Although there are differences between products, tobacco cigarettes and alternative tobacco products deliver nicotine to the user through tobacco.

Some alternative tobacco products have a similar design to tobacco cigarettes and are smoked in the same way (e.g., cigars, CLCs, RYO cigarettes). Differences between these products tend to be in the cost (RYO cigarettes tend to be less expensive; Wilson et al., 2009; Young, Wilson, Borland, Edwards, & Weerasekera, 2010) and tobacco content (cigars tend to have a lower tobacco content than cigarillos; Blank, Nasim, Hart, & Eissenberg, 2011). On the other hand, using a hookah to smoke tobacco is noticeably different from smoking tobacco cigarettes because of the design of the device and because a hookah is usually shared with a group of people (Akl et al., 2010). In contrast, SLT products are not smoked but rather are placed in the mouth or nasal passage where the nicotine is then absorbed through the lining of the mouth (Kennedy, Leatherdale, Burkhalter, & Ahmed, 2011).

In recent years, electronic nicotine delivery systems such as electronic cigarettes (e-cigarettes) have emerged and quickly gained popularity in the Canadian market (Czoli, Reid, Rynard, & Hammond, 2015). E-cigarettes are different from tobacco cigarettes and alternative tobacco products in that they deliver nicotine to the user in the absence of tobacco and combustion (Czoli, Reid, et al., 2015). The prevalence of use of e-cigarettes has dramatically increased over the last few years such that the prevalence of ever and current use of e-cigarettes is similar to that of tobacco

cigarettes in many countries (Alcalá, Albert, & Ortega, 2016; Babineau, Taylor, & Clancy, 2015; Cooper, Case, & Loukas, 2015; Goniewicz, Gawron, Nadolska, Balwicki, & Sobczak, 2014; Krishnan-Sarin, Morean, Camenga, Cavallo, & Kong, 2015; Porter et al., 2015; White, Li, Newcombe, & Walton, 2015), including Canada (Czoli, Hammond, Reid, Cole, & Leatherdale, 2015). Within this dissertation, the collection of alternative tobacco products (CLCs, cigars, SLT products, and hookah) and e-cigarettes will be referred to as alternative tobacco and nicotine products (ATNPs).



Prevalence data from the Canadian Tobacco Use Monitoring Survey, 2012 unless otherwise indicated.
* Interpret with caution: subject to moderate sampling variability.
† Prevalence data from the Canadian Tobacco, Alcohol and Drug Use Survey, 2013
‡ Prevalence of use among Canadians aged 15+
Data retrieved July 19, 2016 from the Tobacco Informatics Monitoring System: http://tims.otru.org

Figure 1. Prevalence of use in the past 30 days for various tobacco and nicotine products, by age group, 2012

While past research has typically focused on the use of tobacco cigarettes, Canadian studies have begun to examine the prevalence and correlates of use of ATNPs (Chan, Leatherdale, Burkhalter, & Ahmed, 2011; Cole, Leatherdale, & Rynard, 2014; Czoli, Hammond, et al., 2015; Czoli, Leatherdale, & Rynard, 2013; Kennedy et al., 2011; Leatherdale, Rios, Elton-Marshall, &

Burkhalter, 2011). Although the prevalence of current use of these products among Canadian youth populations is lower than that of tobacco cigarettes (Czoli, Reid, et al., 2015), Figure 1 illustrates that ATNP use is higher among youth (15-19 years) than adults (19 years and older). Furthermore, evidence indicates that youth are likely to concurrently use both tobacco cigarettes and CLCs (Leatherdale et al., 2011), tobacco cigarettes and RYO cigarettes (Cole et al., 2014), tobacco cigarettes and SLT products (Kennedy et al., 2011), tobacco cigarettes and hookah (Chan et al., 2011; Czoli et al., 2013), and tobacco cigarettes and e-cigarettes (Czoli, Hammond, et al., 2015). Given that the vast majority of adults that currently smoke tobacco cigarettes began using them during adolescence (U.S. Department of Health and Human Services, 2014), and that the limited trend data in Canada indicate that the prevalence of use of many alternative tobacco products has remained stable (Reid et al., 2017), additional knowledge of factors that influence the use of these products among youth is needed for prevention and cessation strategies.

This dissertation research provides important information to address a knowledge gap in Canada with respect to patterns of ATNP use among youth over time. Specifically, using a longitudinal cohort of Ontario youth, this research (1) investigated susceptibility to use each tobacco and nicotine product, (2) identified latent classes for the use of tobacco and nicotine products, and (3) identified latent trajectory groups for the use of each tobacco and nicotine product.

This dissertation begins with a summary of relevant background information (Chapter 1 Background) and then provides a review of literature pertaining to susceptibility to, use of, and trajectories for use of ATNPs (Chapter 2). The research rationale and questions are presented (Chapter 3), followed by a brief overview of the methods (Chapter 4). The results of each study are presented as they were submitted for peer-review publication in Chapter 5, Chapter 6, Chapter 7, and Chapter 8. A general discussion follows (Chapter 9), presenting a summary of key findings, overall strengths and limitations, and implications for practice and directions for future research.

1.1 Alternative tobacco and nicotine product use in Canada

The prevalence of ever and current use of tobacco cigarettes decreased substantially among youth over the last 14 years (Reid et al., 2017); however, the same reductions have not been evident for the use of ATNPs. The early 2000s saw a large increase in the prevalence of use of CLCs among youth in Canada; by 2008 over 12% of youth between the ages of 15 and 19 years reported using CLCs in the last 30 days (Reid et al., 2017). Even though use has since decreased, CLCs remain the

most prevalent alternative tobacco product, used by 4.3% of Canadian youth in the last 30 days (Czoli, Reid, et al., 2015; Reid et al., 2017). In contrast, the prevalence of use of other products, including pipe tobacco and SLT, has remained relatively stable over time (Reid et al., 2017). Canadian data indicate that approximately 1.2% of youth reported using pipe tobacco and 1.2% of youth reported using smokeless tobacco in the last 30 days (Czoli, Reid, et al., 2015). More recently, e-cigarettes and hookah have gained popularity among both smokers and non-smokers; in 2013, 2.6% of Canadian youth reported using e-cigarettes in the last 30 days (Czoli, Reid, et al., 2015), while more recent provincial data indicate that 7.2% of Ontario youth reported using e-cigarettes in the last 30 days (Czoli, Hammond, et al., 2015). This represents an almost 250% increase in the prevalence of use over a couple of years. Similarly, 3% of Canadian youth reported using a hookah to smoke tobacco in the last 30 days (Reid et al., 2017), and over 4% of Ontario youth reported using a hookah in the last 30 days (Czoli, Hammond, et al., 2015).

A variety of factors make ATNPs appealing to youth. Some novel products, such as e-cigarettes, have become more accessible and can be used in locations where tobacco cigarette smoking is not permitted (Choi, Fabian, Mottey, Corbett, & Forster, 2012; Czoli, Hammond, & White, 2014; Wray, Jupka, Berman, Zellin, & Vijaykumar, 2012). Other products, such as cigars and CLCs, are perceived as stronger or longer lasting than tobacco cigarettes and can be purchased in smaller quantities that are more affordable to youth with a lower disposable income (Choi et al., 2012; Richter, Caraballo, Gupta, & Pederson, 2008; Soldz & Dorsey, 2005; Wray et al., 2012). The flavouring in ATNPs also encourages their use; of the adolescents that reported using an alternative tobacco product, the vast majority reported using a flavoured tobacco product in the last 30 days (Reid et al., 2017). The desire to try something new (Hammal et al., 2016) and certain social situations may also encourage experimentation with ATNPs. For example, research indicates that many young adults may try ATNPs as part of a peer group, when tobacco cigarettes are not available, or at a party with alcohol or marijuana (Hammal et al., 2016; Richter et al., 2008; Wray et al., 2012).

1.2 Concerns with alternative tobacco and nicotine product use among youth

Although rates of current use of some ATNPs among Canadian youth are low, this use is particularly concerning for a variety of reasons. Firstly, some youth may only use ATNPs and not tobacco cigarettes. Secondly, the use of ATNPs can lead to the initiation and escalation of smoking, and youth are highly likely to concurrently use multiple tobacco and nicotine products. Finally, the use of ATNPs is associated with negative health effects and increased nicotine addiction.

Some youth only report using ATNPs and do not use tobacco cigarettes. As a result, these youth are not included in surveillance measures that typically only report the prevalence of traditional cigarette smoking, meaning that within Canada, the tobacco burden may be underestimated (Leatherdale et al., 2011). Results from one study of youth in the United States identified that more youth reported currently using alternative tobacco products and e-cigarettes than only using tobacco cigarettes (Lee, Hebert, Nonnemaker, & Kim, 2015). Similarly, recent data from Ontario, Canada indicated that one in five youth reported using any tobacco product or e-cigarette in the last 30 days (Czoli, Hammond, et al., 2015). This estimate is higher than tobacco cigarette smoking rates typically reported in provincial and national surveillance studies due to the inclusion of other tobacco and nicotine products. Nationally representative Canadian data show that there is a population of youth that use cigars, cigarillos, or little cigars that do not use or have never used tobacco cigarettes (Leatherdale et al., 2011). Other evidence from the United States supports these findings, showing that approximately 40% of students that reported currently using cigars or SLT did not report currently using tobacco cigarettes (Soldz, Huyser, & Dorsey, 2003) and over one third of current tobacco users did not smoke tobacco cigarettes (Arrazola, Kuiper, & Dube, 2014). Similar findings have also been found for hookah and e-cigarette use among youth: many students in the United States and Canada that reported using a hookah did not report currently using tobacco cigarettes (Gilreath et al., 2016; Hamilton et al., 2015; Primack et al., 2015), and a high number of youth that used e-cigarettes reported never using tobacco cigarettes (Chapman & Wu, 2014; Czoli, Reid, et al., 2015; Gilreath et al., 2016). All of this might suggest that youth using only ATNPs would not be impacted by conventional prevention programs that specifically target tobacco cigarette smokers.

Although there are data to show that at least half of youth smokers begin with tobacco cigarettes (Soldz et al., 2003), up to 20% of youth report first using an ATNP, such as SLT, hookah, or cigars or cigarillos, and then progress to using tobacco cigarettes (Soldz et al., 2003; Soneji, Sargent, & Tanski, 2014). Longitudinal studies have only recently begun to examine the positive relationship between the use of ATNPs and the initiation and escalation of tobacco cigarette smoking. Two longitudinal school-based studies examined the relationship between hookah smoking and tobacco cigarette smoking (Jaber et al., 2015; Jensen, Cortes, Engholm, Kremers, & Gislum, 2010). One study of students in Jordan found that those who reported using a hookah were twice as likely to start using tobacco cigarettes at 3-year follow-up compared to those who had never used a hookah (Jaber et al., 2015). The other study of smoking students in Denmark reported that those who reported using a hookah were more likely to increase their smoking of tobacco cigarettes at 9-month follow-up

compared to those who had never used a hookah (Jensen et al., 2010). Similarly, a longitudinal study of youth and young adults from the United States found increased odds of initiating tobacco cigarette smoking when participants used a hookah or snus at baseline (Soneji, Sargent, Tanski, & Primack, 2015). A similar relationship has also been found between the use of e-cigarettes and the initiation of other combustible tobacco products, including tobacco cigarettes, cigars, or a hookah (Leventhal et al., 2015), and between the use of SLT and the initiation of tobacco cigarettes (Tomar, 2003). It also appears that a dose-response relationship exists, such that youth that report greater frequency of alternative tobacco product use are more likely to initiate or escalate tobacco cigarette use relative to those with a lower frequency of alternative tobacco product use (Jaber et al., 2015; Jensen et al., 2010). It is apparent that the use of ATNPs may increase the risk of tobacco cigarette smoking among some youth.

In addition to using various ATNPs individually, youth are also more likely to use multiple tobacco products and e-cigarettes concurrently. There is evidence to suggest that youth that use one tobacco or nicotine product are more likely to use additional tobacco and nicotine products (Brooks, Gaier Larkin, Kishore, & Frank, 2008; Saunders & Geletko, 2012) and this behaviour of dual product use may persist into young adulthood rather than stop (Kaufman, Land, Parascandola, Augustson, & Backinger, 2015). For example, recent data from Ontario, Canada indicate that three quarters of e-cigarette users reported using a tobacco product in the last 30 days (Czoli, Hammond, et al., 2015). Other data illustrate that in the United States, greater than 90% of students that reported currently using e-cigarettes also reported ever using SLT or a hookah (Cooper et al., 2015), and many secondary school-aged youth reported using both e-cigarettes and tobacco cigarettes (Dutra & Glantz, 2014). Concurrent use of tobacco cigarettes and CLCs (Schuster, Hertel, & Mermelstein, 2013), hookah (Smith et al., 2011; Sterling & Mermelstein, 2011), or SLT (Galanti, Wickholm, & Gilljam, 2001; Grotvedt, Stigum, Hovengen, & Graff-Iversen, 2008; Horn, Gao, Dino, & Kamal-Bahl, 2000; Tomar, Alpert, & Connolly, 2010) have also been reported among a high percentage of youth. Studies of youth in the United States illustrate that between 10% and 50% of youth report using at least two tobacco or nicotine products (Arrazola et al., 2014; Bombard, Rock, Pederson, & Asman, 2008; Everett, Malarcher, Sharp, Husten, & Giovino, 2000; Soneji et al., 2014; Tercyak & Audrain, 2002; Yu, 2011); similarly, between 40% and 50% of youth tobacco cigarette smokers reported also using an ATNP (Gilpin & Pierce, 2003; Nasim, Blank, Cobb, & Eissenberg, 2012). This is a significantly higher percentage of concurrent users than is reported by adults (Backinger et al., 2008; Bombard,

Pederson, Nelson, & Malarcher, 2007). It is evident that multiple, concurrent tobacco and nicotine product use is an issue, especially among youth populations (Fix et al., 2014).

Some people believe that ATNPs are less harmful than tobacco cigarettes even though many of these products have similar negative health effects as tobacco cigarettes (Chapman & Wu, 2014; Choi et al., 2012; Smith et al., 2011; Wray et al., 2012). For example, many people mistakenly believe that tobacco smoked in a hookah is safer than smoking tobacco cigarettes because they believe that the water filters out any harmful chemicals (Smith et al., 2011; Wray et al., 2012). In fact, there is evidence to suggest that the use of a hookah to smoke tobacco is associated with lung cancer, respiratory illness, and the development of Chronic Obstructive Pulmonary Disease (COPD; Akl et al., 2010; Raad et al., 2011). Furthermore, a single hookah session exposes users to higher levels of carbon monoxide and nicotine than a typical tobacco cigarette smoking session (Eissenberg & Shihadeh, 2009; Jacob et al., 2011), and those who use multiple tobacco products, such as tobacco cigarettes and a hookah to smoke tobacco, may be exposed to even higher levels of toxins (Jacob et al., 2011). There are also health risks associated with other tobacco and nicotine products. The use of cigars is associated with an increased risk of various cancers (Baker et al., 2000; Iribarren, Tekawa, Sidney, & Friedman, 1999; Shapiro, Jacobs, & Thun, 2000; Wyss et al., 2013), coronary heart disease, and COPD (Iribarren et al., 1999). Finally, the use of SLT is associated with oropharyngeal and oesophageal cancers (Lee & Hamling, 2009), oral cancer (Rodu & Jansson, 2004), and cardiovascular disease (Bolinder, Alfredsson, Englund, & de Faire, 1994). There are few studies that have examined the health risks associated with e-cigarettes. A review comparing the potential disease burden of e-cigarettes with tobacco cigarettes found e-cigarettes to have a much lower potential burden than tobacco cigarettes (Oh & Kacker, 2014), suggesting that smoking e-cigarettes could be marketed as a safer alternative to smoking tobacco cigarettes. However, another review noted that e-cigarette users may still be exposed to propylene glycol and various heavy metals (Zulkifli et al., 2016); additionally, given the lack of regulation of e-liquid in Canada, users may be exposed to higher doses of nicotine than stated on the packaging (Czoli, Goniewicz, Palumbo, White, & Hammond, 2018). Evidence suggests that nicotine can alter the developing adolescent brain (U.S. Department of Health and Human Services, 2014). Longitudinal studies are needed to evaluate the long-term health impact of e-cigarettes compared to tobacco cigarettes (Oh & Kacker, 2014).

There is also evidence that youth who report using more than one tobacco or nicotine product report more symptoms of nicotine dependence (Apelberg et al., 2014; Lee et al., 2015) and report

smoking tobacco cigarettes on more days in a week and more tobacco cigarettes per day (Goniewicz et al., 2015) than those who use tobacco cigarettes or another tobacco or nicotine product alone. Tobacco cigarette smokers move through a series of stages of smoking development and nicotine addiction (as described in section 1.3), and using ATNPs may advance users through the stages more rapidly. Cross-sectional data suggest that those who use both tobacco cigarettes and another ATNP reported smoking cigarettes on more days in the past month or smoking more cigarettes per day relative to those that only used tobacco cigarettes (Brooks et al., 2008; Frazier, Fisher, Camargo, Tomeo, & Colditz, 2000; Goniewicz et al., 2015). For example, one study of youth in the United States found that the majority of dual users of tobacco cigarettes and another ATNP reported smoking cigarettes on 20 or more days in the previous month, compared to only about one-third of tobacco cigarette-only users (Brooks et al., 2008). Another study using a representative sample of youth in the United States identified that those who reported using tobacco cigarettes and another ATNP were more likely to report a shorter time between cigarettes compared to those that only used tobacco cigarettes (Nasim, Blank, et al., 2012). Other international evidence indicates that individuals that use both e-cigarettes and tobacco cigarettes are more likely to smoke within the first 30 minutes of waking up compared to exclusive e-cigarette or exclusive tobacco cigarette smokers (Goniewicz et al., 2015). There is evidence that people can become dependent on alternative tobacco and nicotine products, such as tobacco smoked in a hookah (Maziak, 2011). It is clear that there is a risk of nicotine dependence with using many ATNPs. However, because some ATNPs are not readily available in all retail locations or through school friendship networks, youth may resort to using tobacco cigarettes to satisfy their nicotine craving (Jaber et al., 2015). Due to the health risks, nicotine dependence risks, and the lack of cessation programming targeted to the use of ATNPs (Maziak, 2011), it is important to prevent youth from initiating and escalating their use of tobacco and nicotine products.

1.3 Describing the stages of smoking development

Beginning in the 1980s, researchers began to describe the stages of smoking development starting from initiation, to regular use, and finally cessation, to help plan and develop prevention and cessation programs. Although various researchers have identified a different number of stages, it is generally agreed that five stages adequately describe the progression of smoking behaviour: (1) preparation, (2) initiation, (3) experimentation, (4) maintenance, and (5) cessation (Flay, d'Avernas, Best, Kersell, & Ryan, 1983; Leventhal & Cleary, 1980). Although these stages are not unique to

youth smokers, the examples that follow will focus on youth smokers. Since the identification of these stages, researchers have developed numerous measures to identify youth that use tobacco cigarettes in each stage of smoking behaviour.

(1) Preparation Stage

During the preparation stage, youth develop attitudes and perceptions about what is involved with smoking behaviour and the potential uses of smoking when interacting with their parents and peers (Flay et al., 1983; Leventhal & Cleary, 1980). Perceptions of smoking behaviour influence youth differently towards experimentation with cigarettes. For example, some youth may experiment with cigarettes in order to be perceived as rebellious, while others may experiment with cigarettes because they believe it will gain them social acceptance in a group (Leventhal & Cleary, 1980). Youth in this stage are at risk of experimenting with cigarettes, and Pierce and colleagues (1996, 1995) developed a series of measures that help to identify students that are at higher risk of advancing to the next stage of smoking (described more fully in section 2.1).

(2) Initiation Stage

The initiation stage is marked by the first cigarette smoked (Flay et al., 1983; Leventhal & Cleary, 1980). Peer influences and individual characteristics and values most strongly influence whether and when an individual first tries a cigarette (Flay et al., 1983; Pallonen, Prochaska, Velicer, Prokhorov, & Smith, 1998). For example, some youth that feel anxious or inadequate may try a cigarette to be accepted by a social group, while others may try smoking as part of experimenting with a variety of risk behaviours with friends (Flay et al., 1983). A long period of time may elapse before a youth moves from the preparation to the initiation stage, and not all youth that are at high risk of initiating cigarette use actually try a cigarette.

(3) Experimentation and (4) Maintenance Stages

During the experimentation stage, positive and negative reinforcers and parent or peer influences encourage smoking progression by teaching a youth how to smoke, when to smoke, and who to smoke with (Flay et al., 1983; Pallonen et al., 1998). While some youth will progress to a consistent smoking habit, others will experiment with cigarettes for a short time and stop smoking before it becomes an addiction (Leventhal & Cleary, 1980). The maintenance stage is marked by smoking at greater frequency and in more situations than when youth first began (Flay et al., 1983; Leventhal & Cleary, 1980). Although it is highly individual, some evidence suggests that it takes

approximately two years for a youth to transition from the experimentation stage to the maintenance stage (Flay et al., 1983).

(5) Cessation Stage

The final stage, cessation, is not typically experienced during adolescence despite many youth attempting to quit smoking. Many youth typically progress to higher stages of smoking and nicotine dependence and do not try to quit smoking until later in adulthood. Of note, smoking development does not necessarily follow a linear developmental process (Pallonen et al., 1998). Individuals advance and revert to stages at different times, and some may pass through the same stage multiple times or remain in a stage for a long period of time before advancing to a new stage of smoking behaviour (Pallonen et al., 1998).

These distinct smoking stages provide justification for tailoring intervention strategies to reduce smoking based on the attitudes and beliefs that youth in a particular stage hold about smoking (Leventhal & Cleary, 1980). For example, youth that are in the preparation stage require a message focused on preventing smoking initiation, while those in the maintenance stage require a message focused on reducing or quitting smoking. Similarly, youth that are experimenting with smoking in order to gain social acceptance require prevention messaging that counters peer influence, while those who wish to deal with stress and emotions require prevention messaging that encourages alternative, healthy ways to deal with pressure.

Although there has considerable attention on the various stages in tobacco cigarette smoking progression and development, there is a lack of evidence for similar stages in the use of ATNPs. In light of this lack of evidence, preventing youth from initiating multiple tobacco and nicotine product use and progressing rapidly through stages of smoking development and nicotine addiction should be a focus of tobacco control programs and policies. These changes necessitate identifying youth that are at higher risk to begin using various ATNPs, and identifying the patterns of use and characteristics of youth that use various ATNPs.

Chapter 2
Literature review

The following chapter presents a review of the literature for relevant studies of adolescents examining susceptibility to the use of tobacco and nicotine products, use of tobacco and nicotine products, and developmental trajectories for the use of tobacco and nicotine products.

2.1 Susceptibility to the use of alternative tobacco and nicotine products

It would be useful to identify students at risk of smoking using simple methods that do not require biochemical validation. Given that intentions are a strong predictor of performing a behaviour, methods that assess a never-smoking student's intentions to begin smoking may help to identify those who are at risk to begin smoking. Almost two decades ago, Pierce and colleagues (1996, 1995) identified a series of questions that have been used to identify students that have never smoked tobacco cigarettes who are less committed to remaining smoke-free. Identified as susceptible to future smoking, these individuals respond positively to questions about their intentions to start smoking cigarettes in the future and to smoke cigarettes if offered by friends (Pierce, Choi, Gilpin, Farkas, & Merritt, 1996; Pierce, Farkas, Evans, & Gilpin, 1995). Pierce and colleagues (1995, 1996) initially identified three questions that have been used to identify students susceptible to smoking:

1. "Do you think that you will try a cigarette soon?" (response option: yes, no)
2. "If one of your best friends were to offer you a cigarette, would you smoke it?" (response option: definitely not, probably not, probably yes, definitely yes)
3. "Do you think you will be smoking cigarettes 1 year from now?" (response option: definitely not, probably not, probably yes, definitely yes)

The algorithm to identify susceptibility to smoking, as proposed by Pierce and colleagues, incorporates the responses from each of these questions (1996, 1995). Never-smoking students who respond "no" to the first question and "definitely not" to the next two questions are classified as 'not susceptible to smoking,' while all other response groupings are classified as 'susceptible to smoking' (Pierce et al., 1996, 1995). Based on their validation study, almost half of never-smoking students were classified as susceptible to smoking and 19% of these students became smokers (Strong et al., 2015). The sensitivity of the measure was 62.2% and the specificity was 49.6% (Strong et al., 2015).

Throughout the years, variations on these questions have been used in longitudinal and cross-sectional studies around the world. Many measures of susceptibility include one question to assess intention to smoke in the future, one question to assess intention to smoke if a best friend offered a cigarette, and one question to assess intention to smoke within the next year. Longitudinal studies have used one (Forrester, Biglan, Severson, & Smolkowski, 2007; Guo, Unger, Azen, MacKinnon, & Johnson, 2012; Nguyen, Gildengorin, Gregorich, McPhee, & Kaplan, 2008; Nuño, Zhang, Harris, Wilkinson-Lee, & Wilhelm, 2011; Wakefield et al., 2004), two (Bold, Kong, Cavallo, Camenga, & Krishnan-Sarin, 2017; Gritz et al., 2003; McNeill et al., 1989; Prokhorov et al., 2002), or three questions (Choi, Gilpin, Farkas, & Pierce, 2001; Huang, Hollis, Polen, Lapidus, & Austin, 2005; Nodora et al., 2014; Pierce, Choi, Gilpin, Farkas, & Berry, 1998; Pierce et al., 1996; Spelman et al., 2009; Strong et al., 2015; Unger, Johnson, Stoddard, Nezami, & Chih-Ping, 1997) to measure susceptibility to smoking. There have also been attempts to improve the predictive ability of this measure through the addition of questions to measure curiosity to smoking (Nodora et al., 2014; Pierce, Distefan, Kaplan, & Gilpin, 2005; Strong et al., 2015). Although adding curiosity improved the sensitivity of the measure, the specificity of the measure decreased and the positive predictive value remained essentially unchanged (Nodora et al., 2014; Pierce et al., 2005; Strong et al., 2015).

Only two longitudinal studies of youth in the United States have examined risk factors for becoming susceptible to tobacco cigarette smoking among high-school-aged youth (Forrester et al., 2007; Nguyen et al., 2008). The study by Forrester and colleagues (2007) identified that male students were more likely to become susceptible to smoking tobacco cigarettes relative to female students at two year follow-up; additionally, students who reported exposure to anti-tobacco messaging were less likely to become susceptible to smoking tobacco cigarettes at two year follow-up, while students who reported deviant behaviour, low parental monitoring, lower grades, and easy access to tobacco were more likely to become susceptible to smoking tobacco cigarettes at follow-up. The study by Nguyen and colleagues (2008) identified that female students compared to male students were less likely to become susceptible to smoking tobacco cigarettes at two year follow-up, while those who reported having friends who smoked were more likely to become susceptible to smoking tobacco cigarettes at follow-up. More research has examined the progression from never-smoker to experimental smoker among high-school-aged youth. These studies from the United States have found that susceptibility measures are typically the strongest predictors of tobacco cigarette smoking experimentation at follow-up (Choi et al., 2001; Forrester et al., 2007; Huang et al., 2005; Pierce et al., 1996, 2005; Prokhorov et al., 2002; Strong et al., 2015; Wakefield et al., 2004). Other

predictors include curiosity of smoking (Guo et al., 2012; Pierce et al., 2005; Strong et al., 2015), having friends that smoke cigarettes (Huang et al., 2005; Nguyen et al., 2008; Pierce et al., 1996, 2005), and having family members that smoke (Huang et al., 2005; Pierce et al., 1996).

It is clear that the susceptibility measures proposed by Pierce and colleagues have been extensively studied and evaluated with respect to initiating tobacco cigarette smoking. In contrast, there have been few studies that have modified these susceptibility questions to identify students susceptible to the use of other tobacco and nicotine products. The susceptibility measures proposed by Pierce and colleagues provide a framework for understanding how we can measure susceptibility to ATNPs. However, with the exception of one study (Bold et al., 2017), all other studies of susceptibility measures of other tobacco and nicotine products to date have used a cross-sectional design, barring the examination of their predictive ability (Krishnan-Sarin et al., 2015; Mathur et al., 2014; Portnoy, Wu, Tworek, Chen, & Borek, 2014; Saddleson et al., 2015). With the exception of one study (Mathur et al., 2014), all others used populations from the United States. In each of these studies, authors modified the original questions proposed by Pierce and colleagues to identify students susceptible to e-cigarettes (Bold et al., 2017; Krishnan-Sarin et al., 2015; Saddleson et al., 2015); cigars, cigarillos, or little cigars (Portnoy et al., 2014); and SLT (Mathur et al., 2014; Portnoy et al., 2014). The cross-sectional evidence for e-cigarettes suggests that students that were male (Krishnan-Sarin et al., 2015), younger age (Saddleson et al., 2015), reported tobacco cigarette smoking (Krishnan-Sarin et al., 2015; Saddleson et al., 2015), and binge drinking (Saddleson et al., 2015) were more likely to be susceptible to using e-cigarettes. Similarly, students that were female and older were less likely to be susceptible to using SLT, while older students were more likely to be susceptible to using cigars, cigarillos, or little cigars (Portnoy et al., 2014). Results of the only longitudinal study indicate that e-cigarette susceptibility measures are the strongest predictors of e-cigarette smoking experimentation at follow-up, and other predictors include female gender and other tobacco product use (Bold et al., 2017).

Summary and knowledge gaps

Since their development, measures to identify never-smoking students that are susceptible to future tobacco cigarette smoking have been extensively studied in the United States (Choi et al., 2001; Huang et al., 2005; Nodora et al., 2014; Pierce et al., 1998, 1996; Spelman et al., 2009; Strong et al., 2015; Unger et al., 1997). Some researchers have also modified these measures to identify students susceptible to using alternative tobacco and nicotine products (Bold et al., 2017; Krishnan-

Sarin et al., 2015; Mathur et al., 2014; Portnoy et al., 2014; Saddleson et al., 2015). However, in the absence of validation studies that use longitudinal data it is not known whether these modified measures are actually able to predict students that will use each product in the future; given the lack of longitudinal data from Canada, it is also not known whether the original susceptibility measures are valid for use in the Canadian context. Additionally, it is not known whether there are measures that can identify students at risk for tobacco and nicotine use more generally. It would be useful to know if the original questions identified by Pierce and colleagues could also be used to identify students susceptible to the use of other tobacco or nicotine products or whether specific measures need to be developed for each product. Knowledge of such a measure could significantly reduce the burden on survey participants by eliminating the necessity to complete susceptibility questions specific to various tobacco and nicotine products.

2.2 Use of alternative tobacco and nicotine products

There are a variety of tobacco and nicotine products available for youth to use. Past Canadian research has identified sociodemographic and behavioural factors associated with the use of various ATNPs among youth populations (e.g., Cole et al., 2014; Czoli et al., 2013; Kennedy et al., 2011; Leatherdale et al., 2011); however, very few studies have used a longitudinal design. As a result, much of the evidence presented in this section is limited to cross-sectional evidence for sociodemographic and behavioural characteristics associated with the use of each ATNP, and not specifically to the onset of use of each product. Furthermore, most of the research has been conducted in the United States, leaving a lack of Canadian data identifying sociodemographic and behavioural characteristics associated with the use of ATNPs.

Only one cross-sectional study examined factors associated with the use of CLCs (Leatherdale et al., 2011). This study used a representative sample of high school-aged youth in Canada and found that male students, older students, those that reported having more spending money, and those that reported using traditional cigarettes or flavoured tobacco were more likely to report currently using CLCs (Leatherdale et al., 2011). There is more evidence for factors associated with the use of cigars, however none of the studies used a longitudinal design, and with the exception of one study from Canada (Leatherdale et al., 2011) all other evidence is from youth in the United States (Brooks et al., 2008; Frazier et al., 2000; Nasim, Khader, Blank, Cobb, & Eissenberg, 2012; Saunders & Geletko, 2012; Soldz et al., 2003). The evidence consistently shows that high school-aged youth that were male (Brooks et al., 2008; Leatherdale et al., 2011; Nasim, Khader, et al., 2012;

Saunders & Geletko, 2012; Soldz et al., 2003), older (Brooks et al., 2008; Soldz et al., 2003), and reported using other tobacco products including tobacco cigarettes (Brooks et al., 2008; Frazier et al., 2000; Leatherdale et al., 2011; Nasim, Khader, et al., 2012), pipe tobacco (Saunders & Geletko, 2012), or SLT (Brooks et al., 2008; Frazier et al., 2000; Saunders & Geletko, 2012) were more likely to report currently using cigars. There is also some evidence for an association between current cigar use and other health behaviours including increased alcohol use, increased binge drinking, and decreased physical activity (Frazier et al., 2000). Of importance to school stakeholders, youth that reported currently using cigars were more likely to skip school, have lower grades, and lower school attachment (Soldz et al., 2003).

More research has explored factors associated with the use of SLT products among high school-aged youth; these studies were conducted using youth populations from Canada (Kennedy et al., 2011), Norway (Grotvedt et al., 2008; Martinsen & Sundgot-Borgen, 2014), Sweden (Galanti et al., 2001; Wickholm, Galanti, Soder, & Gilljam, 2003), and the United States (Agaku, Ayo-Yusuf, Vardavas, Alpert, & Connolly, 2013; Boyle, Claxton, & Forster, 1997; Horn et al., 2000; Nasim, Khader, et al., 2012; Saunders & Geletko, 2012; Simon, Sussman, Dent, Burton, & Flay, 1993). The evidence consistently shows that male youth (Grotvedt et al., 2008; Kennedy et al., 2011; Martinsen & Sundgot-Borgen, 2014; Nasim, Khader, et al., 2012; Saunders & Geletko, 2012) and those that reported currently using tobacco cigarettes were more likely to currently use SLT products (Boyle et al., 1997; Kennedy et al., 2011; Martinsen & Sundgot-Borgen, 2014; Nasim, Khader, et al., 2012). Social influences are also important; most evidence illustrates that youth that have friends that use SLT products are more likely to report currently using SLT products themselves (Agaku et al., 2013; Boyle et al., 1997), and having family members that use SLT also increases the likelihood that a youth reported currently using SLT (Agaku et al., 2013; Horn et al., 2000; Saunders & Geletko, 2012). Similar to cigar use, there is also some evidence for a positive association between current SLT product use and other risk behaviours including increased cigar, pipe tobacco (Saunders & Geletko, 2012), e-cigarette (Agaku et al., 2013), and alcohol use (Galanti et al., 2001; Martinsen & Sundgot-Borgen, 2014; Simon et al., 1993; Wickholm et al., 2003). There is no longitudinal evidence for sociodemographic and behavioural factors associated with the onset of SLT products among youth populations.

A number of cross-sectional studies have examined factors associated with the use of a hookah to smoke tobacco among youth; these studies were conducted using youth populations from

Canada (Chan et al., 2011; Czoli et al., 2013; Hamilton et al., 2015), Lebanon (Afifi, Yeretzian, Rouhana, Nehlawi, & Mack, 2010), multiple Arab countries (Veeranki et al., 2015), and the United States (Barnett, Curbow, Weitz, Johnson, & Smith-Simone, 2009; Bover Manderski, Hrywna, & Delnevo, 2012; Jordan & Delnevo, 2010; Primack et al., 2015; Primack, Walsh, Bryce, & Eissenberg, 2009; Smith et al., 2011; Sterling & Mermelstein, 2011). Similar to other tobacco and nicotine products, these studies indicate that youth who are male (Afifi et al., 2010; Barnett et al., 2009; Chan et al., 2011; Czoli et al., 2013; Primack et al., 2015, 2009; Sterling & Mermelstein, 2011), older (Barnett et al., 2009; Hamilton et al., 2015; Primack et al., 2009), and report using tobacco cigarettes (Afifi et al., 2010; Barnett et al., 2009; Bover Manderski et al., 2012; Chan et al., 2011; Czoli et al., 2013; Hamilton et al., 2015; Jordan & Delnevo, 2010; J. R. Smith et al., 2011; Sterling & Mermelstein, 2011) or other tobacco and nicotine products (Bover Manderski et al., 2012; Hamilton et al., 2015; Jordan & Delnevo, 2010; Sterling & Mermelstein, 2011) are more likely to report currently using a hookah to smoke shisha. Youth that report using a hookah are also more likely to report using alcohol (Czoli et al., 2013; Hamilton et al., 2015; Sterling & Mermelstein, 2011) or marijuana (Chan et al., 2011; Czoli et al., 2013). Few studies have explored social influences on use; one study identified that youth were more likely to report using a hookah to smoke tobacco when their friends used a hookah (Afifi et al., 2010) and another identified that youth were more likely to report using a hookah to smoke tobacco when their parents used a hookah (Veeranki et al., 2015). While one study found that youth that reported higher academic achievement were more likely to report using a hookah (Hamilton et al., 2015), others have found that youth that reported lower academic achievement (Primack et al., 2015) or lower educational aspirations (Primack et al., 2009) were more likely to report using a hookah.

With the recent increase in e-cigarette use among youth in many countries (Czoli, Hammond, et al., 2015; Czoli, Reid, et al., 2015; Dutra & Glantz, 2014; Eastwood et al., 2015; Goniewicz et al., 2014; Lippert, 2016; Porter et al., 2015; White et al., 2015), many studies have begun to examine sociodemographic and behavioural characteristics associated with their use. These studies have used youth populations from Canada (Czoli et al., 2014), Great Britain and Wales (Eastwood et al., 2015; Moore et al., 2015), Ireland (Babineau et al., 2015), Switzerland (Surís, Berchtold, & Akre, 2015), Korea (Lee, Grana, & Glantz, 2014), and the United States (Barnett, Soule, Forrest, Porter, & Tomar, 2015; Barrington-Trimis et al., 2015; Bostean, Trinidad, & McCarthy, 2015; Camenga et al., 2014; Dutra & Glantz, 2014; Krishnan-Sarin et al., 2015; Leventhal et al., 2015; Lippert, 2016). Cross-sectional studies illustrate that youth that are male (Babineau et al., 2015; Barnett et al., 2015;

Barrington-Trimis et al., 2015; Chapman & Wu, 2014; Czoli, Hammond, et al., 2015; Dutra & Glantz, 2014; Eastwood et al., 2015; Krishnan-Sarin et al., 2015; Lee et al., 2014; Lippert, 2016; Surís et al., 2015) and report currently using traditional cigarettes (Barnett et al., 2015; Barrington-Trimis et al., 2015; Chapman & Wu, 2014; Czoli, Hammond, et al., 2015; Dutra & Glantz, 2014; Eastwood et al., 2015; Krishnan-Sarin et al., 2015; Lee et al., 2014; Lippert, 2016; Moore et al., 2015; Surís et al., 2015) are more likely to report currently using e-cigarettes. While some evidence suggests that older youth are also more likely to report currently using e-cigarettes (Krishnan-Sarin et al., 2015), others have found conflicting results depending on whether respondents use other tobacco products (Bostean et al., 2015). Social factors have also been found to influence e-cigarette use: those with friends or family members that use e-cigarettes are more likely to report currently using e-cigarettes (Barrington-Trimis et al., 2015). Other evidence indicates that youth with more disposable income are more likely to report currently using e-cigarettes (Lee et al., 2014). Current use of e-cigarettes is also positively associated with the use of alternative tobacco products including a hookah (Barnett et al., 2015; Camenga et al., 2014), cigars, and SLT (Camenga et al., 2014). Consistent with the use of alternative tobacco products, other evidence indicates that those that report currently using e-cigarettes are more likely to report using alcohol (Surís et al., 2015) and marijuana (Moore et al., 2015; Surís et al., 2015). A single longitudinal study found that youth that reported using e-cigarettes at baseline were more likely to report using traditional cigarettes, cigars, and hookah at follow-up (Leventhal et al., 2015).

Summary and knowledge gaps

It is apparent from this review that there are some common risk factors for use across ATNPs. Students that are male, older, use other tobacco and nicotine products, use alcohol, and use marijuana are more likely to report currently using each ATNP. However, there is a clear absence of longitudinal studies to support the cross-sectional findings.

2.2.1 Concurrent tobacco and nicotine product use

Although many youth report using a single tobacco or nicotine product, there is a high-risk group that uses more than one tobacco or nicotine product concurrently. For example, evidence from one study in the United States identified that although 11.4% of grade 9 students reported currently using only one tobacco or nicotine product, 4.1% reported currently using two products and 4.0% reported currently using three or more products, and the prevalence of multiple product use increased over time (Huh & Leventhal, 2016). Although tobacco and nicotine products can be used in many

different combinations, tobacco cigarettes are typically one of the tobacco products that are used among concurrent tobacco and nicotine product users (Soneji et al., 2014). Multiple studies have found that the dual use of tobacco cigarettes and cigars, cigarillos, or little cigars is most common (Bombard et al., 2008; Everett et al., 2000; Fix et al., 2014; Lee et al., 2015; Soneji et al., 2014), while other popular combinations of tobacco and nicotine products include tobacco cigarettes and SLT (Bombard et al., 2008), tobacco cigarettes and a hookah (Soneji et al., 2014), and tobacco cigarettes and e-cigarettes (Soneji et al., 2014).

Some studies have identified sociodemographic and behavioural factors associated with concurrent use of tobacco and nicotine products. With the exception of one study using youth populations in South Africa (Rantao & Ayo-Yusuf, 2012), one study using youth populations from multiple Arab countries (Veeranki et al., 2015), and one study using youth populations in Poland (Goniewicz et al., 2015), these studies have been primarily based on youth populations in the United States (Brooks et al., 2008; Horn et al., 2000; Mushtaq, Williams, & Beebe, 2012; Schuster et al., 2013; Simon et al., 1993). However, variations in the number and types of tobacco and nicotine products included in the analyses and contextual differences in the popularity of different tobacco and nicotine products make it difficult to identify common themes across the research. Some studies have focused on identifying sociodemographic and behavioural characteristics associated with particular combinations of tobacco and nicotine product use among youth populations. For example, evidence suggests that those that are male (Brooks et al., 2008; Schuster et al., 2013), display antisocial behaviour (Schuster et al., 2013), have lower school grades (Brooks et al., 2008), and have more friends that smoke tobacco cigarettes (Brooks et al., 2008) are more likely to report concurrent use of tobacco cigarettes and cigars, cigarillos, or little cigars. Similarly, those that are male (Horn et al., 2000), have family members or friends that use SLT products (Horn et al., 2000), use alcohol (Mushtaq et al., 2012; Rantao & Ayo-Yusuf, 2012; Simon et al., 1993), and display permissive attitudes toward tobacco cigarettes (Horn et al., 2000; Rantao & Ayo-Yusuf, 2012; Simon et al., 1993) are more likely to report concurrent use of tobacco cigarettes and SLT products. Other evidence shows that youth that have parents that smoke tobacco cigarettes or a hookah are more likely to report concurrent use of tobacco cigarettes and hookah (Veeranki et al., 2015). Female youth are less likely to report concurrent use of tobacco cigarettes and e-cigarettes (Goniewicz et al., 2015). Finally, younger youth are more likely to report concurrent use of tobacco cigarettes and e-cigarettes relative to exclusive tobacco cigarette smokers, while they are less likely to report concurrent use of tobacco cigarettes and e-cigarettes relative to exclusive e-cigarette smokers (Goniewicz et al., 2015).

Other studies that used youth populations from the United States (Bombard et al., 2008; Everett et al., 2000; Fix et al., 2014; Gilpin & Pierce, 2003; Lee et al., 2015; Leventhal et al., 2015; Soneji et al., 2014; Yu, 2011) have focused on identifying sociodemographic and behavioural characteristics associated with concurrent use of multiple tobacco or nicotine products (polytobacco use) without specifying particular combinations of products. These studies included various ATNPs in addition to tobacco cigarettes to define polytobacco use as shown in Table 1 below. These data indicate that the most consistent predictor of polytobacco use is male gender (Bombard et al., 2008; Fix et al., 2014; Lee et al., 2015; Soneji et al., 2014). While some studies have found that youth with family members or friends that smoke are more likely to report concurrent use of multiple tobacco or nicotine products (Bombard et al., 2008; Gilpin & Pierce, 2003; Leventhal et al., 2015; Yu, 2011), other studies have failed to find this association (Lee et al., 2015; Soneji et al., 2014). Consistent with previous evidence, other risk behaviours have been shown to be positively associated with polytobacco use, including skipping class (Gilpin & Pierce, 2003; Yu, 2011), using alcohol (Everett et al., 2000; Fix et al., 2014), and using marijuana (Everett et al., 2000; Fix et al., 2014).

Table 1. Summary of alternative tobacco and nicotine products included in studies of polytobacco use

Study	**Bidis**	**Blunts**	**Cigars**	**Cigarillos/ little cigars**	**Dissolvables**	**E-cigarettes**	**Kreteks**	**Pipes**	**Roll-your-own cigarettes**	**Smokeless tobacco products**	**Waterpipes**
Bombard et al., 2008	X		X				X	X		X	
Everett et al., 2000			X						X		
Fix et al., 2014			X							X	
Gilpin & Pierce, 2003	X		X							X	
Leventhal et al., 2015		X	X	X		X					X
Lee et al., 2015	X		X		X	X	X	X	X	X	X
Soneji et al., 2014			X	X	X	X				X	X

Study	Bidis	Blunts	Cigars	Cigarillos/ little cigars	Dissolvables	E-cigarettes	Kreteks	Pipes	Roll-your-own cigarettes	Smokeless tobacco products	Waterpipes
Yu, 2011			X	X				X		X	

Latent class analysis is a relatively new technique that identifies mutually exclusive groups of individuals that respond in similar ways to given variables within a large population (Lanza, Collins, Lemmon, & Schafer, 2007; Quek et al., 2013). Multiple studies have begun to use this technique to identify common groups of tobacco and nicotine product users (Gilreath et al., 2016; Harrell, Naqvi, Plunk, Ji, & Martins, 2017; Huh & Leventhal, 2016; Morean et al., 2016; Nasim, Blank, et al., 2012; Simon et al., 2017). One study identified four groups of tobacco and nicotine product use among youth: 1) nonusers that had a low probability of trying any of the tobacco or nicotine products; 2) polytobacco experimenters that had tried multiple products in their lives but were not current users; 3) current e-cigarette/hookah users that had a high probability of reporting only current e-cigarette or hookah use; and 4) current polytobacco users that had a high probability of reporting current use of all the tobacco or nicotine products (Gilreath et al., 2016). However, this study of grade 11 and 12 youth from the United States only asked about the use of tobacco cigarettes, cigars (including CLCs), e-cigarettes, hookah, and SLT products (Gilreath et al., 2016). A similar study of grade 9 students from the United States identified three groups of tobacco and nicotine product use among youth: 1) nonusers that had a low probability of using any of the tobacco or nicotine products in the last 6 months; 2) e-cigarette/hookah users that had a high probability of reporting only e-cigarette and hookah use in the last 6 months; and 3) polytobacco users that had a high probability of reporting past 6 month use of all the tobacco or nicotine products (Huh & Leventhal, 2016). This study included five tobacco and nicotine products: tobacco cigarettes, e-cigarettes, hookah, blunts, and cigars (including CLCs; Huh & Leventhal, 2016). A nationally representative study of students from the United States that included nine tobacco and nicotine products [cigarettes, cigars (including CLCs), SLT, pipe (non-hookah), bidis, kreteks, hookah, snus, and e-cigarettes] identified nine classes of use: 1) cigarette smokers; 2) cigar smokers; 3) smokeless tobacco users; 4) hookah smokers; 5) tobacco smoke/chewers that had a high probability of using cigarettes, cigars, pipes, and SLT; 6) tobacco/hookah smokers that had a high probability of using cigarettes, cigars, and hookah; 7) tobacco/snus/e-cigarette users that had a high probability of using cigarettes, cigars, SLT, and e-

cigarettes; 8) e-cigarette users; and 9) polytobacco users that had a high probability of using all products (Harrell et al., 2017). Another study that included alcohol and marijuana in the analysis identified four groups of substance users: 1) nonusers that had a low probability of currently using any of the tobacco or nicotine products; 2) current e-cigarette/alcohol users that had a high probability of reporting current e-cigarette and alcohol use; 3) current marijuana/blunt/alcohol users that had a high probability of reporting current marijuana, blunt, and alcohol use; and 4) current polytobacco users that had a high probability of reporting current use of all the substances (Morean et al., 2016). This study included grade 9 to 12 students from three schools in the United States and included a more comprehensive list of tobacco and nicotine products, including tobacco cigarettes, cigars, blunts, e-cigarettes, hookah, and SLT; however it only investigated the association of a small list of demographic characteristics to each latent class (Morean et al., 2016). Another study identified six groups of tobacco and nicotine product use among youth smokers in the United States that reflected different patterns of tobacco cigarette consumption, frequency, and history and different patterns and preferences for alternative tobacco products: 1) nondaily, light smokers that reported the lowest use of ATNPs; 2) light smokers that reported concurrent cigar and SLT use; 3) light smokers that reported concurrent cigar, SLT, bidi, and clove cigarette use; 4) intermittent smokers that reported concurrent cigar, SLT, bidi, and clove cigarette use; 5) daily smokers; and 6) daily smokers that reported concurrent cigar, SLT, bidi, and clove cigarette use (Nasim, Blank, et al., 2012). However, this study focused on a sample of smokers and only asked about the use of SLT, cigars, bidis, and clove cigarettes (Nasim, Blank, et al., 2012). Similar to the findings for using individual tobacco or nicotine products, males were twice as likely as females to be polytobacco users relative to non-users (Gilreath et al., 2016). A final study of high school students from one state in the United States included ever and current use of seven tobacco and nicotine products (e-cigarettes, blunts, cigarettes, cigarillos, cigars, hookah, and SLT) and identified five groups of tobacco and nicotine product use: 1) current polytobacco users that had a high probability of current use of all products; 2) ever polytobacco users that had a high probability of ever use of all products; 3) current e-cigarette, blunt, and cigarette users; 4) ever e-cigarette and blunt users; and 5) never users that had a low probability of ever or current use for all products (Simon et al., 2017).

Summary and knowledge gaps

Many youth may report currently using more than one tobacco or nicotine product. The studies conducted to date that examined concurrent tobacco and nicotine product use have included a

variety of ATNPs in addition to tobacco cigarettes. Students that report polytobacco use share many characteristics in common with those that report using a single ATNP, including being male, having friends or family members that smoke, and reporting using alcohol or marijuana. However, because of the range of products included in definitions of polytobacco use, it is evident that more research is needed to identify groups of tobacco and nicotine product use among youth. Additionally, Canadian data of polytobacco use are lacking.

2.3 Trajectories for the use of tobacco and nicotine products

As stated in section 1.3, youth progress through a series of stages of smoking before becoming established smokers (Flay et al., 1983; Leventhal & Cleary, 1980). Movement through these stages can be identified through latent trajectory modeling, which identifies groups of individuals that have similar behaviours and follow similar behavioural outcomes over time (Jones & Nagin, 2007). While past research focused on identifying the stages of tobacco cigarette use (Flay et al., 1983; Leventhal & Cleary, 1980), more recent studies have used trajectory modeling to identify patterns of tobacco cigarette use (Audrain-McGovern et al., 2004; Bernat, Erickson, Widome, Perry, & Forster, 2008; Colder et al., 2001; Karp, O'Loughlin, Paradis, Hanley, & DiFranza, 2005; Orpinas, Lacy, Nahapetyan, Dube, & Song, 2015; Pollard, Tucker, Green, Kennedy, & Go, 2010; Rosendahl, Galanti, & Gilljam, 2008; Soldz & Cui, 2002; Stanton, Flay, Colder, & Mehta, 2004). These studies used populations from Canada (Karp et al., 2005), Sweden (Rosendahl et al., 2008), New Zealand (Stanton et al., 2004), and the United States (Audrain-McGovern et al., 2004; Bernat et al., 2008; Colder et al., 2001; Orpinas et al., 2015; Pollard et al., 2010; Soldz & Cui, 2002). By identifying various trajectories for the use of tobacco and nicotine products and when they occur, the content and delivery timing of tobacco prevention programs could be improved and could be matched to particular stages of tobacco uptake and experimentation.

Studies of latent trajectories of tobacco cigarette use have used longitudinal data to track the smoking behaviours of individuals over time. Using specific statistical techniques, studies have been able to identify common paths that groups of individuals take during the initiation, experimentation, and cessation of smoking. Previous studies have identified between three (e.g., White, Johnson, & Buyske, 2000; White, Pandina, & Chen, 2002) and six (e.g., Bernat et al., 2008; Pollard et al., 2010; Soldz & Cui, 2002) trajectories of tobacco cigarette smoking, where most trajectories include a never smoking group, an experimental smoking group, a late-onset smoking group, and a continuous smoking group. The range in trajectories identified has typically been a result of the analysis sample

size and the age range of individuals included in the studies. Studies with larger sample sizes that followed individuals into young adulthood (e.g., Nelson, Van Ryzin, & Dishion, 2015; Orlando, Tucker, Ellickson, & Klein, 2004; White et al., 2002) have typically identified more smoking trajectories as some groups of individuals start smoking after high school or reduce their smoking during young adulthood. Only nine studies have focused on the high school years to identify trajectories of tobacco use and relevant risk factors for use (Audrain-McGovern et al., 2004; Bernat et al., 2008; Colder et al., 2001; Karp et al., 2005; Orpinas et al., 2015; Pollard et al., 2010; Rosendahl et al., 2008; Soldz & Cui, 2002; Stanton et al., 2004) and only one of these used Canadian data (Karp et al., 2005).

These studies have identified a number of sociodemographic and behavioural characteristics that can be used to differentiate between trajectory groups. Sociodemographic characteristics include gender (Karp et al., 2005; Rosendahl et al., 2008), ethnicity (Bernat et al., 2008), parental education level (Rosendahl et al., 2008), attitudes to tobacco use (Bernat et al., 2008; Soldz & Cui, 2002), and depressive symptoms (Audrain-McGovern et al., 2004), while behavioural characteristics include parental smoking (Bernat et al., 2008; Rosendahl et al., 2008; Stanton et al., 2004), friend's smoking (Audrain-McGovern et al., 2004; Bernat et al., 2008; Karp et al., 2005; Pollard et al., 2010; Rosendahl et al., 2008; Stanton et al., 2004), alcohol use (Audrain-McGovern et al., 2004; Orpinas et al., 2015; Soldz & Cui, 2002), marijuana use (Audrain-McGovern et al., 2004; Soldz & Cui, 2002; Stanton et al., 2004), and reported academic achievement (Audrain-McGovern et al., 2004; Karp et al., 2005; Soldz & Cui, 2002). No study has examined the influence of ATNPs on the smoking trajectories of those who use tobacco cigarettes. Knowledge of the influence of ATNPs on the smoking trajectories of those who use tobacco cigarettes would be useful for planning prevention programs and identifying students who are most at risk of continued tobacco use.

A single study of Swedish youth examined trajectories for a tobacco and nicotine product other than tobacco cigarettes (Rosendahl et al., 2008). This study identified three trajectory groups for snus use among a sample of Swedish students using a comprehensive measure of snus use: 1) sustained trial use (tried using snus but did not escalate use); 2) late escalation use (experimented with snus until the end of grade 9, then escalated to daily snus use); and 3) early escalation use (quickly escalated snus use to become daily user by grade 9; Rosendahl et al., 2008). The study also identified a variety of sociodemographic and behavioural characteristics that differentiated between trajectory groups. Female students were less likely to be in trajectories of high snus consumption, while

students with at least one parent that used tobacco were more likely to be in trajectories of high snus consumption (Rosendahl et al., 2008). No other studies have identified trajectories for other tobacco and nicotine products.

2.4 Overall summary and knowledge gaps

The use of ATNPs among Canadian youth is concerning because of the altering effect of nicotine on the developing adolescent brain (U.S. Department of Health and Human Services, 2014), the risk of long-term nicotine addiction, and the negative long-term health effects given that the use of many ATNPs carry similar health risks as tobacco cigarettes. Some youth only use ATNPs and do not use tobacco cigarettes; however, these youth are at risk of initiating tobacco cigarette use or escalating their use of tobacco and nicotine products through concurrent use of multiple products. Additional tobacco control programs and policies may be necessary to prevent the initiation, reduce the escalation, and promote cessation of ATNP use. However, in order to design effective programs and policies, we must first increase our understanding of the youth that use these products.

Identifying youth most at risk of initiating ATNP use represents an important first step in preventing the uptake of these products. However, there is an absence of validated measures which can be used to identify students at risk for experimenting with various tobacco and nicotine products. Since evidence indicates that many youth concurrently use more than one tobacco or nicotine product, it is important to identify whether there are certain groups of youth that prefer certain combinations of tobacco and nicotine products, who could then be targeted for tobacco control programming. Additionally, identifying how youth progress through the use of ATNPs would be useful for planning cessation programs and identifying students who are most at risk of continued tobacco use. However, there is a lack of longitudinal Canadian data to identify and describe these populations of youth.

Chapter 3
Study rationale & research questions

This research project furthered our understanding of ATNP use among youth populations through three studies and four manuscripts. The research questions and implications for each study are described below.

3.1 Study 1: Identifying students susceptible to using alternative tobacco and nicotine products

As described in section 2.1, simple measures have been developed to measure youth susceptibility to tobacco use (e.g., Pierce et al., 1996); however, the predictive validity of these measures has not been tested since they were initially developed almost 20 years ago. Furthermore, it is unknown how well these measures can be used to predict the onset of ATNPs, specifically e-cigarettes, CLCs, cigars, SLT, hookah, or tobacco and nicotine use in general (including the six forms of tobacco and nicotine products examined throughout this research).

Implications

Within Canada, the number of youth who are susceptible to tobacco use may be underestimated. If these same measures could be used to predict other tobacco and nicotine product use, prevention programs could identify and target students who are at risk for using particular tobacco products. If these measures have low predictive ability, then additional measures of susceptibility specific to each tobacco and nicotine product may need to be created and assessed. Additional knowledge about the predictive validity of these measures of susceptibility to smoking to a variety of tobacco and nicotine products and the relation to individual-level sociodemographic and modifiable characteristics will further our understanding of youth susceptibility to using tobacco, aid in the identification of youth who are most susceptible to tobacco and nicotine use, and promote the development of additional prevention activities targeted to other tobacco and nicotine products.

3.1.1 Study 1 research questions

The objective of Study 1 was to examine the ability of current susceptibility measures to predict the use of ATNPs among a sample of Ontario secondary school youth. The first study answered the following research questions:

1. What is the sensitivity, specificity, positive predictive value, and negative predictive value of each measure of smoking susceptibility (i.e., S1-Try: *Do you think in the future you might try smoking cigarettes?*; S2-Offer: *If one of your best friends was to offer you a cigarette, would you smoke it?*; and S3-Smoke: *At any time during the next year do you think you will smoke a cigarette?*) for the use of (i) tobacco cigarettes, (ii) e-cigarettes, (iii) CLCs, (iv) cigars, (v) SLT, (vi) hookah, and (vii) any tobacco or nicotine product use?
2. What is the sensitivity, specificity, positive predictive value, and negative predictive value of the combined measure of smoking susceptibility (using questions S1-S3) for each of the aforementioned tobacco and nicotine products?
3. What individual-level sociodemographic and modifiable characteristics place youth at risk for experimenting with (i.e., use within the last 30 days) each of the aforementioned tobacco and nicotine products?

3.1.2 Study 1 hypotheses

I expected the following results for each research question:

1. I expected that for most tobacco and nicotine products, question S3-Smoke would consistently perform the highest (i.e., high sensitivity, specificity, positive predictive value, and negative predictive value) followed by S2-Offer and S1-Try.
2. I expected that the combined susceptibility measure would perform the highest (i.e., high sensitivity, specificity, positive predictive value, and negative predictive value) for tobacco cigarettes and e-cigarettes, followed by CLCs, cigars, hookah, and SLT.
3. Consistent with previous research, I expected that male students, those with a higher disposable income, those with friends that smoke, those that reported using alcohol or marijuana, and those who were susceptible to future smoking would have higher odds of experimenting with tobacco and nicotine products.

3.2 Study 2: Identifying latent classes of tobacco and nicotine product use

A variety of tobacco and nicotine products are currently available in Ontario for youth to use, including tobacco cigarettes, e-cigarettes, CLCs, cigars, SLT, and hookah. However, there is a lack of evidence for the combinations of tobacco and nicotine products commonly used by youth in Ontario,

whether these clusters differ each year, and whether youth from different tobacco usage classes share similar sociodemographic and behavioural characteristics.

Implications

Knowledge of the combinations of tobacco and nicotine products that are commonly used by youth in Ontario could promote the development of additional prevention activities targeted to specific groups of youth.

3.2.1 Study 2 research questions

The objective of Study 2 was to identify the latent classes of tobacco and nicotine product use among a sample of Ontario secondary school youth. Specifically, this study answered the following research questions:

1. How does the use of various tobacco and nicotine products cluster for each data collection year?
2. How do the behavioural clusters identified in question 1 differ by sociodemographic and modifiable characteristics for each data collection year?

3.2.2 Study 2 hypotheses

I expected the following results for each research question:

1. Overall, I expected to identify six clusters of tobacco and nicotine product use, that center around (1) tobacco cigarettes only, (2) tobacco cigarettes and CLCs, (3) tobacco cigarettes and SLT, (4) tobacco cigarettes and hookah, (5) tobacco cigarettes and e-cigarettes, and (6) tobacco cigarettes and more than one ATNP. I predicted there would be fewer clusters identified in Year 2 relative to Year 4.
2. I expected that the clusters would share many sociodemographic and modifiable characteristics in common. I expected that male gender, more disposable income, alcohol use, and marijuana use would be common predictors of membership in each cluster. I expected that ethnicity, the amount of disposable income, and physical activity level would vary between clusters. I expected that many sociodemographic and modifiable characteristics would be the same across clusters for each data collection year.

3.3 Study 3: Identifying latent trajectory groups of tobacco and nicotine product use

Following the initiation of tobacco and nicotine products, youth progress through a series of stages (Flay et al., 1983; Leventhal & Cleary, 1980) that result in different smoking trajectories. Although there is some evidence for the various patterns of use of tobacco cigarettes, there is a lack of evidence for use trajectories of ATNPs.

Implications

Identifying the various stages of tobacco and nicotine product use and when they occur could improve the content and delivery timing of tobacco prevention programs to match particular stages of tobacco initiation and experimentation. Additional knowledge of the similarities and differences between the trajectories of various tobacco and nicotine products and the sociodemographic and modifiable factors associated with each trajectory would be informative to current tobacco prevention and cessation programs, such as those employed at the school level.

3.3.1 Study 3 research questions

The objective of Study 3 was to identify the latent trajectory groups for the use of each tobacco and nicotine product among a sample of Ontario secondary school youth. The final study answered the following research questions:

1. For each tobacco and nicotine product, namely (i) tobacco cigarettes, (ii) e-cigarettes, (iii) CLCs, (iv) cigars, (v) SLT, and (vi) hookah, how many distinct latent trajectory groups described the patterns of use among youth?
2. What individual-level sociodemographic and modifiable characteristics predicted membership to each trajectory group?

3.3.2 Study 3 hypotheses

I expected the following results for each research question:

1. I expected to identify between three and four developmental trajectories to describe the use of each tobacco and nicotine product. Similar to previous research, I expected to identify (1) a no tobacco and nicotine product use group, (2) an experimental use group that tried using a product but did not sustain use, (3) a late-onset use group that began using a product later in secondary school (Grade 11), and (4) a continuous use group that began using a product early in secondary school (Grade 9) and continued using the product throughout secondary school.

2. I expected that each trajectory pattern would share many sociodemographic and modifiable characteristics in common. I expected that male gender, more disposable income, alcohol use, and marijuana use would be common predictors of membership in each trajectory pattern. However, I also expected that some characteristics would be unique to certain trajectory patterns: ethnicity, social sources of tobacco, and physical activity level would vary between clusters.

Chapter 4
Methodology

The following chapter presents an overview of the methods that were used to answer the described research questions, including the theoretical framework that guided the project, the data source, and the measures.

4.1 Theoretical framework

Adolescence is an important time of growth and identity creation in the life stage. It is during this time that adolescents learn and identify different social roles as they begin to move away from the influence of parents and family members (Jessor & Jessor, 1977). Adolescents learn various skills and interests, including job skills, educational skills, and interpersonal skills, that will be required throughout the rest of their life (Jessor & Jessor, 1977). It is during this stage of development that adolescents come to know their identity (Jessor & Jessor, 1977).

A variety of behaviours can place a youth's health at risk. Risk behaviours can be categorized as problem behaviours and as health-compromising behaviours (Turbin, Jessor, & Costa, 2000). Problem behaviours include behaviours such as tobacco use, alcohol abuse, delinquency, and illicit drug use, while health-compromising behaviours include behaviours such as unhealthy eating and physical inactivity (Turbin et al., 2000). While both classes of behaviours can negatively impact health, problem behaviours are different from health-compromising behaviours because they usually involve defying a social or legal norm that is typically dependent on age or stage of development (Turbin et al., 2000). For example, in Canada, smoking is considered a risk behaviour for adolescents because it is restricted to those over the age of 18 years in most provinces and territories; social and legal consequences can occur when those below this age smoke (Turbin et al., 2000). Although problem behaviours can serve a range of positive purposes, including gaining acceptance from peers, gaining independence from parents, coping with emotions, and transitioning from childhood to adulthood, problem behaviours can also endanger the normal development of social roles, skills, and self (Jessor, 1991).

Theory can help to focus and direct research on problem behaviours by indicating factors that may be important to consider in analyses. Problem Behavior Theory (PBT) is a psychosocial theory that is used to understand and predict youth engagement in various problem behaviours. As shown in

Figure 2 and similar to the Theory of Triadic Influence (Flay, 1999; Flay & Petraitis, 1994; Flay, Snyder, & Petraitis, 2009), PBT contains three systems of influence: personality, environment, and behaviour (Jessor & Jessor, 1977). Within the personality system, sources of motivation (i.e., value and expectation for academic achievement, independence, and peer affection), personal beliefs (i.e., social criticism, alienation, and self-esteem), and personal control (i.e., tolerance of deviance, religiosity, and positive and negative functions of the behaviour) each positively or negatively affect the choice to engage in problem behaviours (Jessor & Jessor, 1977). Knowing a youth with a given set of factors within the personality system, we can predict their likelihood of engaging in a problem behaviour. For example, a youth that places more value on independence than academic achievement, has lower expectations for academic achievement, has greater social criticism and alienation and lower self-esteem, has lower religiosity, has higher tolerance of deviance, and identifies more positive functions of the behaviour relative to negative functions would be more likely to engage in a problem behaviour (Jessor & Jessor, 1977).

The environment system focuses on the perceived environment for the individual rather than the external environment (Jessor & Jessor, 1977). Variables within this system can be classified as proximal (directly influence a behaviour) or distal (indirectly or theoretically influence a behaviour) depending on the behaviour they are being linked to (Jessor & Jessor, 1977). For example, the perceived prevalence of a given problem behaviour among a youth's friends would be classified as a proximal variable within the environment system, while the perceived general support and control from a youth's friends would be classified as a distal variable within the environment system (Jessor & Jessor, 1977). Again, knowing a youth with a given set of factors within the environment system, we can predict their likelihood of engaging in a problem behaviour. For example, a youth that has low parental support and controls, low peer controls, low parent versus peer influence, low parental disapproval of the behaviour, and many friends that model and approve of engaging in the behaviour would be more likely to engage in a problem behaviour (Jessor & Jessor, 1977).

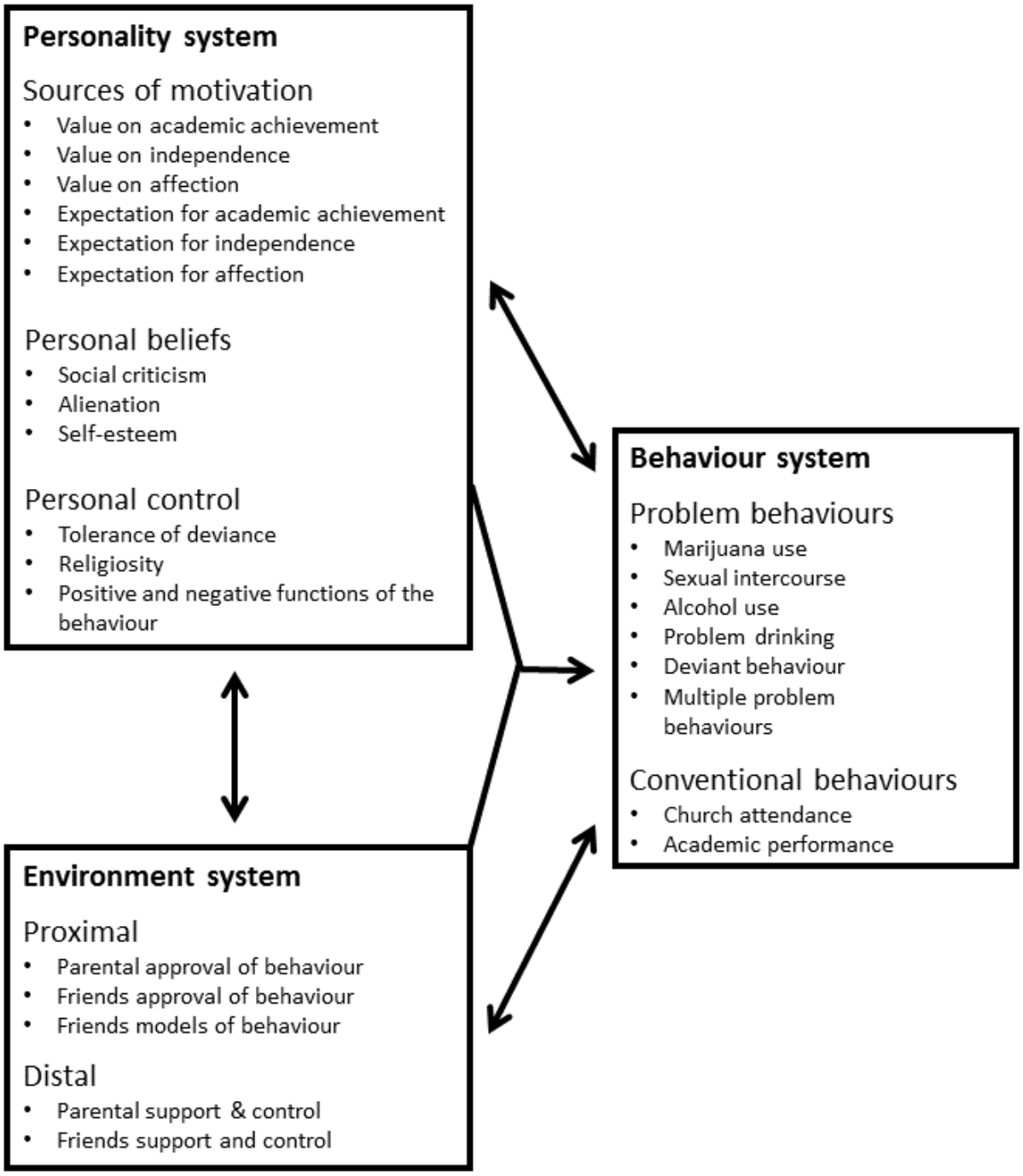


Figure 2. Conceptual structure of Problem Behavior Theory

Finally, the behavioural system describes the behaviour itself (Jessor & Jessor, 1977). Engaging in a problem behaviour is influenced by its personal meaning to the individual, its meaning within society (e.g., whether smoking is permitted or not), its relation to age and developmental status (e.g., age restrictions in tobacco use), the context in which it occurs, and its time in history (e.g., more restrictive attitudes towards smoking over the last 50 years; Jessor & Jessor, 1977). It is important to note that problem behaviours tend to be limited to a particular age, such that a behaviour defined as a problem within adolescence is not defined as a problem in young adulthood or adulthood; problem behaviours may also change with time and culture (Jessor & Jessor, 1977). As a result, problem behaviours tend to be those that are considered inappropriate for those within youth ages or that deviate from generally recognized social norms for a given society (Jessor & Jessor, 1977).

The important counterbalance to problem behaviour is conventional behaviour: those positive behaviours that protect against problem behaviours (Jessor & Jessor, 1977). The two conventional behaviours that have been most examined within this theory are religious involvement and academic achievement (Jessor & Jessor, 1977). Adolescents that rate highly in religiosity, academic achievement, and academic aspiration tend to have a lower risk of engaging in problem behaviours (Jessor & Jessor, 1977).

PBT has been found to be valid among youth in various cultures (Vazsonyi et al., 2010), and has been applied to a variety of risk behaviours including alcohol use and abuse (Jessor & Jessor, 1977), marijuana use (Jessor & Jessor, 1977), engaging in sexual behaviour (Jessor & Jessor, 1977), and cigarette smoking (Turbin et al., 2000). Recent evidence has demonstrated the existence of a “risk behaviour syndrome”, where risk behaviours tend to cluster together (Jessor, 1991). The risk behaviour syndrome emphasizes a comprehensive approach to addressing risk behaviours, rather than an approach that is restricted to specific risk behaviours (Jessor, 1991). It is the risk behaviour syndrome that best applies to the current research study since evidence suggests that youth concurrently use many tobacco and nicotine products. In addition to using previous literature, this project used PBT to guide the inclusion of sociodemographic and behavioural covariates and to aid in interpreting findings in light of a risk behaviour syndrome.

4.2 Ontario context

When conducting longitudinal studies, it is important to identify the larger context in which the research occurs. In the case of tobacco and nicotine product use, the larger program and policy

context can have a significant impact on baseline use rates of tobacco and nicotine products as well as changes in rates of use of these products. The current research project will focus on three years of longitudinal data from 70 secondary schools in Ontario, Canada. Since 1999, the prevalence of current tobacco cigarette smoking has almost halved among adult populations in Ontario, providing the province with the second lowest smoking prevalence in Canada (11.3%; Reid et al., 2017). During the same time period, rates of tobacco cigarette smoking also decreased substantially among youth populations; however, recently the smoking rate has remained relatively stable (9.7% among those 15-19 years; Reid et al., 2017). When comparing the prevalence of other tobacco and nicotine product use across Canada, Ontario has the lowest prevalence of ever use of cigarillos (18.3%) and e-cigarettes (14.9%), but higher rates of cigar (16.1%) and waterpipe use (14.9%) among youth 15-19 years (Czoli, Reid, et al., 2015; Reid, Hammond, Rynard, & Burkhalter, 2015).

The price of tobacco and nicotine products is an important factor that influences the use of these products, especially among youth populations that are more price sensitive (Chaloupka, Straif, & Leon, 2010). Although there have been significant increases in the average price per carton (200 tobacco cigarettes) since 2010, where the average price was $74.49, as of July 2016 the average price per carton was $97.12, the second lowest price in Canada (Non-Smokers' Rights Association, 2016). In addition to a low baseline cost, the total taxes applied to tobacco cigarettes were also the second lowest in Canada ($63.15 per 200 tobacco cigarettes; Non-Smokers' Rights Association, 2016). During the data collection period, the most recent tax increase occurred February 25, 2016 where the price of 200 tobacco cigarettes increased by $2.98 (Non-Smokers' Rights Association, 2016). Despite the recent increase in tobacco tax, Ontario continues to have the second lowest provincial excise tax per 200 tobacco cigarettes ($30.95; Non-Smokers' Rights Association, 2016).

Various provincial policies exist to prevent youth from smoking or being exposed to the harmful effects of secondhand smoke. In Ontario, the legal minimum age to purchase tobacco cigarettes is 19 years, meaning that the vast majority of high school-aged youth are underage to purchase tobacco cigarettes themselves (Reid et al., 2017). Despite this fact, many youth report purchasing tobacco cigarettes from a retail source (Reid et al., 2017). Social sources of cigarettes also represent a significant method of obtaining tobacco cigarettes for youth (Reid et al., 2017). Table 2 presents a summary of additional tobacco policies enacted in Ontario. During the data collection period, e-cigarettes with nicotine were not approved for sale in Canada, however e-cigarettes that did not contain nicotine and did not make a health claim were legal (Czoli, Reid, et al., 2015). Within

Ontario, Bill 45, the *Making Healthier Choices Act*, prohibits the sale of flavoured tobacco products (including e-cigarettes) and e-cigarettes to people under 19 years of age (Damerla, 2015). The promotion of e-cigarettes in places where e-cigarettes or tobacco products are sold is also prohibited, as is using e-cigarettes in locations where tobacco cigarettes are currently banned (Damerla, 2015).

Table 2. Summary of tobacco policies affecting Ontario, Canada up to July 1, 2016

Tobacco policy	Policy date
Graphic health warning labels with health messages	2000*
Smoke-free spaces (indoor restaurants and bars)	May 31, 2006
Smoke-free spaces (school grounds)	May 31, 2006
Promotion ban of cigarettes at point-of-sale (i.e., power walls)	May 31, 2008
Smoke-free spaces (vehicles carrying children <16 years old)	January 21, 2009
Advertising and marketing ban of cigarettes in newspapers and magazines	October 8, 2009*
Flavour ban on certain tobacco products	October 8, 2009*
Minimum packaging requirements for certain tobacco products	October 8, 2009*
New graphic health warning labels with health messages for cigarettes and little cigars	September 22, 2011*
Smoke-free spaces (outdoor restaurant and bar patios, public sports fields, playgrounds)	January 1, 2015
Promotion ban of e-cigarettes at point-of-sale	January 1, 2016
Smoke-free spaces (e-cigarettes in all places where cigarettes are banned)	January 1, 2016
Minimum age requirement for purchasing e-cigarettes	January 1, 2016

*Denotes a Federal policy
Data retrieved from *Tobacco Use in Canada: Patterns and Trends. Supplement: Tobacco Control Policies in Canada (2015 Edition)*

4.3 Data Source

The aforementioned research questions (see Chapter 3) were explored using linked longitudinal data from the COMPASS study (described in the sections that follow). The study sample (herein called the linked sample) included students in grade 9 at Year 2 that were linked across all three data collections (Year 2, Year 3, and Year 4). The 2013-14 COMPASS student questionnaire is included in 0.

4.3.1 The COMPASS study

COMPASS is a research platform that takes a systems approach to examine and evaluate how ongoing changes in programs, policies, and the physical environment affect youth health behaviours over time (Leatherdale, Brown, et al., 2014). COMPASS uses a variety of measurement tools to collect hierarchical data about student health behaviours, school health policies and programs, and the environment surrounding the school (Leatherdale, Bredin, & Blashill, 2014; Leatherdale, Brown, et al., 2014). Designed to provide school stakeholders with evidence to guide and evaluate school-based interventions related to a variety of health behaviours, COMPASS facilitates knowledge transfer and exchange by providing participating schools with a detailed report that compares school-specific health behaviour prevalence data to provincial and national norms or guidelines (Leatherdale, Brown, et al., 2014). Throughout the report, evidence-based suggestions for school-based interventions to improve student health outcomes are provided. Additionally, a knowledge broker associated with the project is assigned to each school to help identify action items and next steps (Leatherdale, Brown, et al., 2014). Additional details about the project are available online (https://uwaterloo.ca/compass-system/).

4.3.1.1 Sample selection

Beginning in 2012-13, a cohort of students attending 43 purposefully sampled schools across Ontario were identified and followed for four years (Thompson-Haile & Leatherdale, 2013). In 2013-14, an additional cohort of students from 36 purposefully samples schools across Ontario and 9 schools in Alberta were added to the sample (Bredin, Thompson-Haile, & Leatherdale, 2015). Included public schools were part of an English speaking school board, included grades 9 through 12, had a student population of at least 100 students per grade, and used active-information passive-consent parental permission protocols; inclusion criteria for private schools were similar except that they were not part of a school board (Thompson-Haile & Leatherdale, 2013).

4.3.1.2 Participant selection and recruitment

All grade 9 to 12 students in all sampled participating schools were eligible for participation. Sampled schools were recruited for participation following approval by the required school boards, with the exception of private schools. Active-information passive-consent parental permission protocols (passive consent) were used to recruit students. Parent(s) or guardian(s) of eligible students were mailed an information letter describing the COMPASS study and were asked to call a toll-free

number or email the COMPASS recruitment coordinator if they did not want their child to participate (Thompson-Haile & Leatherdale, 2013). Students also had the opportunity to decline participation on the day of the data collection (Thompson-Haile & Leatherdale, 2013). The University of Waterloo Office of Research Ethics and appropriate School Board and Public Health Ethics committees approved all procedures, including passive consent.

4.3.2 Survey protocols

Consistent with previous school-based surveys, the COMPASS questionnaire (Cq) was administered by classroom teachers on the data collection day (Thompson-Haile & Leatherdale, 2013). Teachers were provided with detailed instructions for implementing the survey to ensure consistency across sites and to protect student confidentiality (Thompson-Haile & Leatherdale, 2013). All students in attendance on the data collection day whose names were not on the "No permission lists" and who assented to participate in the study completed the survey during a single class period. Once completed, students sealed the Cq in an individual envelope and returned them to the classroom teacher, who then placed the entire class's individual envelopes into a classroom envelope (Thompson-Haile & Leatherdale, 2013). Each classroom envelope was returned to the school office where it was collected by the data collector and returned to the University of Waterloo for processing (Thompson-Haile & Leatherdale, 2013).

The Cq is a 12-page machine-readable paper questionnaire that is completed by participating students in the classroom setting (Bredin & Leatherdale, 2014). The survey takes about 30 minutes to complete and includes demographic questions, core measures (i.e., questions related to body weight, marijuana use, physical activity, alcohol use, tobacco use, and sedentary behaviour), and supplementary measures of interest to school stakeholders (i.e., questions related to eating behaviours, bullying, education outcomes, school connectedness, active commuting, and consumption of energy drinks; Bredin & Leatherdale, 2014).

4.3.2.1 Data linkage

The Cq includes a series of 5 questions that were used to develop a unique self-generated code to link individual student-level data over time (Bredin & Leatherdale, 2013). These measures were permitted for use with passive consent procedures, were relatively simple to complete, and maintained the anonymity of student participants by creating a unique 5-digit identifier that includes both numbers and letters (Bredin & Leatherdale, 2013; Qian, Battista, Bredin, Brown, & Leatherdale,

2015). Following validation testing (Bredin & Leatherdale, 2013), the following 5 questions were presented on the front of the Cq to ensure they were completed:

1. "The first letter of your **middle** name (if you have more than one middle name use your first middle name, if you don't have a middle name use "Z")."
2. "The name of the month in which you were born."
3. "The last letter of your full **last** name."
4. "The second letter of your full **first** name."
5. "The first initial of your mother's **first** name (think about the mother you see the most)."

These questions were selected based on existing research and the relative stability of answers over time (Bredin & Leatherdale, 2013). To further improve the linkage, students were asked "Did you attend this school last year?"; furthermore, students were matched within schools rather than across schools, reducing the linkage burden (Bredin & Leatherdale, 2013).

4.4 Measures

Tobacco use measures and student-level sociodemographic and modifiable characteristic measures used in the Cq were consistent with those used in other school-based surveys (Bredin & Leatherdale, 2014). The tobacco use measures used in this study have been shown to produce valid estimates of tobacco cigarette smoking among Canadian youth (Wong, Shields, Leatherdale, Malaison, & Hammond, 2012). Tobacco use measures were consistent across survey waves, with the exception of e-cigarettes (where a question was added to the Year 2 Cq) and bidis (where a question was removed from the Year 2 Cq).

4.4.1 Measures that assessed tobacco and nicotine product use

A variety of measure were used to assess tobacco and nicotine product use in each of the three studies. These measures were used to assess susceptibility to tobacco and nicotine product use (Study 1) and use of tobacco and nicotine products (Study 1, 2 and 3).

4.4.1.1 Measures that assessed susceptibility to tobacco and nicotine product use

Susceptibility to tobacco and nicotine product use among never-smoking students was assessed using three questions, as illustrated in Figure 3. Similar to previous research, never-smoking students who responded "definitely not" to questions 33, 34, and 35 were classified as *non-*

susceptible never smokers while all other response groupings were classified as *susceptible never smokers* (Pierce et al., 1996, 1995). "Non-susceptible never smokers" were coded as "0" and acted as the reference group, while "susceptible never smokers" were coded as "1".

33. Do you think in the future you <u>might try smoking</u> cigarettes?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

34. If one of your best friends were to offer you a cigarette, would you smoke it?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

35. At any time during the <u>next year</u> do you think you will smoke a cigarette?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

Figure 3. 2013-14 COMPASS questionnaire measure used to determine susceptibility to tobacco use

4.4.1.2 Measures that assessed tobacco and nicotine product use

Past 30-day use of tobacco and nicotine products was assessed using two questions. Current tobacco cigarette use was measured using one question: "On how many of the last 30 days did you smoke one or more cigarettes?" To be consistent with measures of current ATNP use, respondents that reported using tobacco cigarettes on any days in the last 30 were coded as "1", while those that did not report using cigarettes in the last 30 were coded as "0".

Current e-cigarette, CLC, cigar, SLT, and hookah use were measured using one multi-item question on ATNP use, as illustrated in Figure 4. Consistent with previous research in Canada (Cole & Leatherdale, 2014), respondents that currently used a specific ATNP (e.g., cigars) were coded as "1", while all other respondents were coded as "0". Responses for each ATNP of interest (e-cigarettes, CLCs, cigars, SLT, and hookah) were coded in this way.

44. In the last 30 days, did you use any of the following? *(Mark all that apply)*

- ○ Pipe tobacco
- ○ Cigarillos or little cigars (*plain or flavoured*)
- ○ Cigars (not including cigarillos or little cigars, *plain or flavoured*)
- ○ Roll-your-own cigarettes (tobacco only)
- ○ Loose tobacco mixed with marijuana
- ○ E-cigarettes (electronic cigarettes that look like cigarettes/cigars, but produce vapour instead of smoke)
- ○ Smokeless tobacco (chewing tobacco, pinch, snuff, or snus)
- ○ Nicotine patches, nicotine gum, nicotine lozenges, or nicotine inhalers
- ○ Hookah (water-pipe) to smoke tobacco
- ○ Hookah (water-pipe) to smoke herbal sheesha/shisha
- ○ Blunt wraps (a sheet or tube made of tobacco used to roll cigarette tobacco)
- ○ I have not used any of these things in the last 30 days

Figure 4. 2013-14 COMPASS questionnaire measure used to determine current alternative tobacco and nicotine product use

4.4.2 Measures that assessed sociodemographic characteristics

The Cq collects student-level sociodemographic information which was used to control for and identify student-level sociodemographic characteristics associated with the use of each ATNP. Detailed information about each sociodemographic characteristic is outlined below.

Gender: One question on the Cq asked about gender: "Are you female or male?" followed by a female and male response option.

Grade: One question on the Cq asked about grade: "What grade are you in?" followed by a list of relevant grades. Respondents who selected "grade 9" at baseline were selected as the sample for the studies.

Ethnicity: One question on the Cq asked about ethnicity: "How would you describe yourself? (Mark all that apply)" followed by a list of possible options (White, Black, Asian, Aboriginal [First Nations, Métis, Inuit], Latin American/Hispanic, Other). Due to low numbers across responses, some categories were grouped together in each manuscript.

Disposable income: One question on the Cq asked about disposable income: "About how much money do you usually get each week to spend on yourself or to save? (Remember to include all money from allowances and jobs like babysitting, delivering papers, etc.)". Due to low numbers across responses, some categories were grouped together in each manuscript.

4.4.3 Measures that assessed modifiable characteristics

The Cq also collects information which was used to identify student-level modifiable characteristics associated with the use of each ATNP for each study. Detailed information about each modifiable characteristic is outlined below.

Truancy: One question on the Cq asked "In the last 4 weeks, how many classes did you skip when you were not supposed to?" followed by a series of categories ("0 classes", "1 or 2 classes", "3 to 5 classes", "6 to 10 classes", "More than 20 classes"). Due to low numbers across responses, some categories were grouped together in each manuscript.

School connectedness: Six questions on the Cq asked about feelings of connectedness to the larger school community as an indication of personal beliefs. Respondents were asked to indicate how strongly they agreed or disagreed with each of the following statements: (1) "I feel close to people at my school." (2) "I feel I am part of my school." (3) "I am happy to be at my school." (4) "I feel the teachers at my school treat me fairly." (5) "I feel safe in my school." (6) "Getting good grades is important to me." Responses ranged from "strongly disagree" (coded as 1) to "strongly agree" (coded as 4). Consistent with previous research (Azagba & Asbridge, 2013), a school connectedness score was calculated by summing the responses for each item, where a higher score indicated greater school connectedness.

Social sources of tobacco: One question on the Cq asked about friends smoking behaviour: "Your closest friends are the friends you like to spend the most time with. How many of your closest friends smoke cigarettes?" (6 response options from "None" to "5 or more friends"). Due to low numbers across responses, some categories were grouped together in each manuscript.

Access to tobacco: One question on the Cq asked about the perceived ease of access to tobacco: "Do you think it would be difficult or easy for you to get cigarettes it you wanted to smoke?" (3 response options: "Difficult", "Easy", "I do not know"). Of note, this question was removed from the 2015-16 Cq.

Binge drinking: One question on the Cq measured self-reported binge drinking among those who indicated they have ever had a drink of alcohol: "In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?" (8 response options from "I have never done this" to "Daily or almost daily"). Due to low numbers across responses, some categories were grouped together in each manuscript.

Marijuana use: One question on the Cq measured self-reported marijuana use: “In the last 12 months, how often did you use marijuana or cannabis? (a joint, pot, week, hash)” (9 response options from “I have never used marijuana” to “Every day”). Due to low numbers across responses, some categories were grouped together in each manuscript.

Breakfast consumption: One question on the Cq measured self-reported breakfast consumption during the usual school week, which has been found to be protective against tobacco use (Vereecken et al., 2009): “In a usual school week (Monday to Friday), on how many days do you do the following? Eat breakfast.” (6 response options from “None” to “5 days”). Due to low numbers across responses, some categories were grouped together in each manuscript.

Meeting physical activity recommendation: Two questions on the Cq measured self-reported vigorous and moderate physical activity done during physical education class, lunch, after school, in the evenings, and during spare time, during each of the last 7 days. Regular physical activity has been found to be protective against tobacco use (Aaron et al., 1995; Kristjansson, Sigfusdottir, Allegrante, & Helgason, 2008; Pate, Heath, Dowda, & Trost, 1996). Based on Canadian recommendations for physical activity (Tremblay et al., 2016), students were categorized as meeting or not meeting physical activity recommendations.

4.5 Analysis

This dissertation project employed multiple statistical methods in order to answer each research question. Although a full description of the analytic approach for each manuscript can be found in Chapter 5, Chapter 6, Chapter 7, and Chapter 8, the sections that follow provide an overview of the analyses conducted for each research question. The objective of Study 1 was to examine the ability of current susceptibility measures to predict the use of ATNPs among a sample of Ontario secondary school youth. The primary analysis for this study involved calculating the sensitivity, specificity, PPV, and NPV for each measure of smoking susceptibility and for the combined smoking susceptibility construct for the use of each tobacco and nicotine product. Following calculation of the sensitivity, specificity, PPV, and NPV, this study identified individual-level sociodemographic and behavioural characteristics of non-smoking youth at baseline that used a tobacco or nicotine product one- and two-years later using generalized linear mixed models.

The objective of Study 2 was to identify latent classes of tobacco and nicotine product use. The primary analysis for this study involved conducting latent class analysis (LCA) to identify

mutually exclusive groups of individuals within a large population based on similar responses given to a measured variable (Lanza et al., 2007; Quek et al., 2013). LCA uses maximum likelihood to estimate parameters and assumes that data are missing at random (Lanza et al., 2007). A step-wise process compared the fit of a model with *k* classes to a model with *k*-1 classes, beginning with a two-class model. Consistent with previous research (Lanza et al., 2007; Quek et al., 2013), the optimal number of classes was determined using the following three criteria: (1) the Bayesian Information Criterion (BIC) and the model-adjusted BIC (adj-BIC); (2) the average posterior probabilities; and (3) model interpretability. Models with lower values of the BIC and the adj-BIC indicated better model fit and were selected over models with higher values of the BIC and the adj-BIC (Lanza et al., 2007; Quek et al., 2013). The average posterior probabilities evaluated the quality of the classification, while model interpretability considered expert opinion to ensure that each class could be distinguished from each other, the classes had a probability of membership greater than 0%, and a meaningful label could be used to describe each class (Lanza et al., 2007; Quek et al., 2013). Each student was assigned to a single class at each year based on the latent class with the highest posterior probability. Following identification of the classes, multinomial logistic regression models for nominal outcomes identified sociodemographic and behavioural characteristics associated with membership in each class, using the lowest risk class as a reference group.

The objective of Study 3 was to identify latent trajectory groups for the use of each tobacco and nicotine product. The primary analysis for this study involved conducting latent transition analysis (LTA). LTA is a group-based modeling technique that identifies distinct groups of individuals based on similar behavioural outcomes and changes that occur over time (Nagin, 1999; Nagin & Tremblay, 2001). LTA uses a mixture modeling approach to identify various group trajectories, estimate the shape of the trajectory, and estimate the proportion of the population that fits within each trajectory (Nagin & Tremblay, 2001). Consistent with previous research (Lanza & Collins, 2008; Nagin, 1999; Quek et al., 2013), the optimal number of groups was determined using the following criteria: (1) the BIC; (2) the average posterior probabilities; and (3) model interpretability. Models with lower values of the BIC indicated better model fit and were selected over models with higher values of the BIC (Lanza & Collins, 2008; Quek et al., 2013). The average posterior probabilities evaluated the quality of the classification, while model interpretability considered expert opinion to ensure that each group could be distinguished from each other, the groups had a probability of membership greater than 0%, and a meaningful label could be used to describe each group (Lanza & Collins, 2008; Quek et al., 2013). Each student was assigned to a single

group at each year based on the latent trajectory group with the highest posterior probability. Following identification of the groups, multinomial logistic regression models for nominal outcomes identified sociodemographic and behavioural characteristics associated with membership in each group, using the lowest risk group as a reference group.

Chapter 5

Manuscript 1

Exploring the predictive validity of the susceptibility to smoking construct for tobacco cigarettes, alternative tobacco products, and e-cigarettes

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5.1 Brief overview and purpose

The following Chapter includes a copy of the text from the published manuscript in *Nicotine & Tobacco Research*. Supplementary material included with this manuscript can be found in Appendix B

Supplementary material from Manuscript 1. Simple measures of youth susceptibility to future tobacco use have been developed (e.g., Pierce et al., 1996); however, the predictive validity of these measures for tobacco cigarette smoking among youth has not been tested within the Canadian context or since they were initially developed almost 20 years ago. Furthermore, it is unknown how well these measures can be used to predict the onset of ATNPs. The objective of this manuscript was to examine the ability of the tobacco cigarette susceptibility construct as a whole and each measure of susceptibility to future smoking to predict past 30 day use of 6 tobacco and nicotine products: tobacco cigarettes, e-cigarettes, CLCs, cigars, SLT, and hookah. This manuscript answered the following two research questions:

1. What is the sensitivity, specificity, PPV, and NPV of each measure of smoking susceptibility (i.e., S1: *Do you think in the future you might try smoking cigarettes?*; S2: *If one of your best friends was to offer you a cigarette, would you smoke it?*; and S3: *At any time during the next year do you think you will smoke a cigarette?*) for the use of (i) tobacco cigarettes, (ii) e-cigarettes, (iii) CLCs, (iv) cigars, (v) SLT, (vi) hookah, and (vii) any tobacco or nicotine product use?
2. What is the sensitivity, specificity, PPV, and NPV of the combined measure of smoking susceptibility (using questions S1-S3) for each of the aforementioned tobacco and nicotine products?

5.2 Overview

Introduction: Within tobacco prevention programming, it is useful to identify youth that are at risk for experimenting with various tobacco products and e-cigarettes. The susceptibility to smoking construct is a simple method to identify never-smoking students that are less committed to remaining smoke-free. However, the predictive validity of this construct has not been tested within the Canadian context or for the use of other tobacco products and e-cigarettes.

Methods: This study used a large, longitudinal sample of secondary school students that reported never using tobacco cigarettes and non-current use of alternative tobacco products or e-cigarettes at baseline in Ontario, Canada. The sensitivity, specificity, and positive and negative predictive values of the susceptibility construct for predicting tobacco cigarette, e-cigarette, cigarillo or little cigar, cigar, hookah, and smokeless tobacco use one and two years after baseline measurement were calculated.

Results: At baseline, 29.4% of the sample was susceptible to future tobacco product or e-cigarette use. The sensitivity of the construct ranged from 43.2% (smokeless tobacco) to 59.5% (tobacco cigarettes), the specificity ranged from 70.9% (smokeless tobacco) to 75.9% (tobacco cigarettes), and the positive predictive value ranged from 2.6% (smokeless tobacco) to 32.2% (tobacco cigarettes). Similar values were calculated for each measure of the susceptibility construct.

Conclusions: A significant number of youth that did not currently use tobacco products or e-cigarettes at baseline reported using tobacco products and e-cigarettes over a two-year follow-up period. The predictive validity of the susceptibility construct was high and the construct can be used to predict other tobacco product and e-cigarette use among youth.

Implications: This study presents the predictive validity of the susceptibility construct for the use of tobacco cigarettes among secondary school students in Ontario, Canada. It also presents a novel use of the susceptibility construct for predicting the use of e-cigarettes, cigarillos or little cigars, cigars, hookah, and smokeless tobacco among secondary school students in Ontario, Canada.

Key words: susceptibility to smoking; initiation; youth tobacco use; longitudinal research

5.3 Introduction

The prevalence of tobacco cigarette smoking has decreased dramatically within Canada since the early 2000's (Reid et al., 2015). Not only are fewer Canadian youth current smokers (Reid et al., 2015), but they are also less likely to be exposed to smoking due to strong tobacco control policies (e.g., smoke-free spaces) and fewer adult smokers. However, there remains a significant number of youth that continue to experiment with tobacco cigarettes, alternative tobacco products (such as cigarillos, little cigars, and hookah), and e-cigarettes. It is well-known that smoking tobacco products poses significant negative health effects (Chapman & Wu, 2014; Choi et al., 2012; Smith et al., 2011; Wray et al., 2012). Furthermore, nicotine is a very addictive substance (Benowitz, 2010) that can alter adolescent brain development (Smith et al., 2015; Yuan et al., 2015). Therefore, it would be beneficial to identify youth that are at risk for experimenting with various tobacco products and e-cigarettes in order to provide targeted programming to prevent smoking experimentation and nicotine addiction.

Simple methods that do not require biochemical validation have been developed to identify students that have never smoked tobacco cigarettes who are less committed to remaining smoke-free (Pierce et al., 1996, 1995). Given that intentions are a strong predictor of performing a behaviour (Ajzen, 1991), it follows that individuals who respond positively to questions about their intentions to start smoking cigarettes in the future and to smoke cigarettes if offered by friends, may be more likely to experiment with tobacco products and e-cigarettes. These never-smoking individuals are identified as susceptible to future smoking using the susceptibility construct (Pierce et al., 1996, 1995). As described elsewhere, Pierce and colleagues (1996, 1995) use responses to three smoking-related intention measures to determine if a never smoker is classified as "not susceptible to future smoking" or "susceptible to future smoking". In the domain of tobacco control prevention research, the ability to identify non-smoking youth who are most likely to become future smokers is a considerable asset for being able to target prevention resources to where they are needed the most (Leatherdale, 2012). Based on their initial study, a strong univariate relationship was found between positive responses to susceptibility questions and experimentation with and established smoking (Pierce et al., 1996). A validation study later identified the sensitivity (62.2%) and the specificity (49.6%) of the susceptibility construct (Strong et al., 2015).

Since its development, the susceptibility construct has been widely used in cross-sectional (e.g., Aslam, Zaheer, Rao, & Shafique, 2014; Dube, Arrazola, Lee, Engstrom, & Malarcher, 2013) and longitudinal studies (e.g., Forrester et al., 2007; Nodora et al., 2014) to identify students

susceptible to tobacco cigarette smoking. These studies have used the complete construct as well as variations that only include one or two questions from the construct to identify students susceptible to future tobacco cigarette smoking. However, given the significant changes that have occurred over the last 20 years to the tobacco control landscape via the implementation of prevention and cessation programs and policies and the expansion of the tobacco market to include other tobacco products and e-cigarettes, it is unknown whether the susceptibility construct is still valid for predicting the onset of tobacco cigarette smoking. Furthermore, the susceptibility construct has not be tested within the Canadian context where differences in policies for tobacco advertising, access, and taxation may affect the validity of using this construct. Given the variations in the number of questions used to assess susceptibility across studies, it would also be helpful to identify whether the full construct is needed or whether a single question performs adequately.

The susceptibility measures presented by Pierce and colleagues (1996, 1995) have been extensively used to identify future tobacco cigarette smokers. More recently, some studies have modified these measures to identify students susceptible to e-cigarettes (Bold et al., 2017; Krishnan-Sarin et al., 2015; Saddleson et al., 2015); cigars, cigarillos, or little cigars (Portnoy et al., 2014); and smokeless tobacco (Mathur et al., 2014; Portnoy et al., 2014). However, with the exception of one study (Bold et al., 2017), these studies have used a cross-sectional design, barring the examination of their predictive ability. It is well known that youth experiment with a variety of tobacco products and e-cigarettes, poly-use is common, and youth that experiment with tobacco products and/or e-cigarettes may share many characteristics in common. As a result, the tobacco cigarette susceptibility construct may predict the use of various tobacco products and/or e-cigarettes and not strictly tobacco cigarettes. Longitudinal approaches are necessary to assess the predictive ability of these measures and elucidate if they are reliable or whether alternative measures need to be developed for each product.

Given these gaps in the literature, this study examined the ability of the tobacco cigarette susceptibility construct as a whole and each measure of the susceptibility construct to predict ever and past 30 day use of tobacco cigarettes, as well as past 30 day use of 4 additional tobacco products (cigarillos or little cigars, cigars, hookah, and smokeless tobacco) and e-cigarettes, within a longitudinal sample of Canadian secondary school students through calculation of the sensitivity, specificity, positive predictive value, and negative predictive value.

5.4 Methods

COMPASS is a prospective cohort study designed to collect hierarchical longitudinal data from a sample of grade 9 to 12 secondary school students and the schools they attend in Ontario and Alberta, Canada (Leatherdale, Brown, et al., 2014). Data were collected annually from students in class time on the day of their school's scheduled data collection using the COMPASS questionnaire (Cq) in purposefully sampled schools that provided permission to use active-information passive-consent parental permission protocols (as described elsewhere (Thompson-Haile & Leatherdale, 2013)). The current study reports longitudinal student-level linked data from Year 2 (2013-14), Year 3 (2014-15), and Year 4 (2015-16) of the COMPASS host study given that (1) these three waves of data have the largest sample size (as described by Reel, Bredin, Battista, & Leatherdale, 2017), and (2) Year 2 was the fist time the Cq included a measure of e-cigarette use. For the purpose of our objectives, data from Year 2 will be considered "Baseline", Year 3 will be "Follow-up Year 1", and Year 4 will be "Follow-up Year 2". A full description of the COMPASS study and its methods is available online (www.compass.uwaterloo.ca) and in print (Leatherdale, Brown, et al., 2014). The COMPASS study received ethics approval from the University of Waterloo Research Ethics Board, as well as participating school board review panels.

5.4.1 Sample selection

At Baseline, 52,529 students in grades 9 to 12 were enrolled in the 79 participating schools in Ontario and 41,734 of them (79.5%) completed the Cq; 11,253 of these students were in grade 9. In Follow-up Year 1, 49,773 students in grades 9 to 12 were enrolled in the 78 participating schools in Ontario and 39,013 of them (78.7%) completed the Cq; 10,381 of these students were in grade 10. Finally, in Follow-up Year 2, 46,458 students in grades 9 to 12 were enrolled in the 72 participating schools in Ontario and 37,106 of them (79.9%) completed the Cq; 9168 of these students were in grade 11. Missing data were primarily a result of student absenteeism the day of the data collection and students on spare (N=29,806; 20.0% of total); relatively few data were missing due to student or parent refusal (N=1101; 0.7% of total). Using the unique code generated by each student to link their data over time (Bredin & Leatherdale, 2013), 4651 students in grade 9 were linked across all 3 years of study (linked sample; 41.3%); 6602 students in grade 9 did not have data for each data collection year (unlinked sample). A comparison of demographic and behavioural characteristics of the linked sample to the unlinked sample can be found in Supplementary Table 18. Given that we were interested in identifying students that were susceptible to using tobacco products and e-cigarettes,

grade 9 students that reported ever using tobacco cigarettes (even just a puff; N=400) or another tobacco product or e-cigarette in the last 30 days (N=134) were excluded from these analyses. An additional 250 students were excluded due to missing demographic (age or gender; N=9) or outcome variables (tobacco product use or susceptibility; N=241), leaving a final linked sample of 3867 students that had never smoked, not used an alternative tobacco product within the last 30 days, and not used e-cigarettes within the last 30 days at baseline (herein called current non-tobacco/e-cigarette users).

5.4.2 Measures

The Cq uses items with demonstrated reliability and validity for current smoking (Wong et al., 2012) and smoking susceptibility among never smokers (Pierce et al., 1996). Susceptibility to future tobacco cigarette smoking among current non-tobacco/e-cigarette users was derived by three previously validated measures (Pierce et al., 1996) that asked respondents:

"Do you think in the future you might try smoking cigarettes?" (S1-Try)

"If one of your best friends was to offer you a cigarette, would you smoke it?" (S2-Offer)

"At any time during the next year do you think you will smoke a cigarette?" (S3-Smoke)

Students indicated the degree to which they agreed with each statement on a Likert scale ranging from "definitely not" to "definitely yes". Consistent with the algorithm proposed by Pierce and colleagues (1996, 1995), current non-tobacco/e-cigarette users who responded "definitely not" to all three questions were classified as "not susceptible to future tobacco/e-cigarette use", while all other response groupings were classified as "susceptible to future tobacco/e-cigarette use". Only measures that assessed susceptibility to future tobacco cigarette smoking were included in the Cq. Responses to this measure of susceptibility to future tobacco cigarette smoking were also used to identify students susceptible to future use of alternative tobacco products and e-cigarettes.

Experimentation with tobacco cigarettes was measured with a single question: "Have you ever tried cigarette smoking, even just a few puffs?" Similarly, experimentation with alternative tobacco products and e-cigarettes was measured with a single multi-item question. This question measured current use of each alternative tobacco product and e-cigarettes among respondents: "In the last 30 days, did you use any of the following? (Mark all that apply)", followed by a list of products other than tobacco cigarettes: cigarillos or little cigars (plain or flavoured), cigars (not including cigarillos or little cigars, plain or flavoured), e-cigarettes (electronic cigarettes that look like cigarettes/cigars, but produce vapour instead of smoke), smokeless tobacco (chewing tobacco, pinch,

snuff, or snus), hookah (water-pipe) to smoke tobacco, hookah (water-pipe) to smoke herbal sheesha/shisha. Although this measure of use is different from that for tobacco cigarettes (i.e., use in the last 30 days versus ever use), it is a common measure of alternative tobacco product and e-cigarette use and it may measure more regular use rather than experimentation. A comparison of the sensitivity, specificity, PPV, and NPV for different measures of tobacco cigarette smoking (ever use, past 30-day use, smoked 100 cigarettes in life) is presented in Supplementary Table 19. For our analyses, any respondents with all items missing from this question of alternative tobacco product and e-cigarette use had alternative tobacco product and e-cigarette use set to missing; additionally, respondents that indicated using hookah to smoke tobacco or to smoke herbal sheesha/shisha were combined and identified as "hookah users".

5.4.3 Analysis

Given that students that smoke tend to drop out of longitudinal studies (Siddiqui, Flay, & Hu, 1996) which could affect the analyses, chi-square tests compared the baseline demographic and behavioural characteristics of the linked and unlinked samples (see Supplementary Table 18). A higher proportion of students that were linked across all three years were female, had less spending money, were not susceptible to future smoking, and did not have any friends that smoked cigarettes at baseline. Tobacco product use was assessed at Follow-up Year 1 and Follow-up Year 2 among students susceptible and not susceptible to future tobacco/e-cigarette use at Baseline. Consistent with a previous validation study (Strong et al., 2015), the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the tobacco cigarette susceptibility construct (as a whole, and each of the three measures of the construct) were calculated for ever and past 30 day use of tobacco cigarettes, as well as past 30 day use of 4 additional tobacco products (cigarillos or little cigars, cigars, hookah, and smokeless tobacco) and e-cigarettes in Follow-up Year 1 and Follow-up Year 2. The sensitivity was defined as the percentage of students who reported currently using each tobacco product or e-cigarette at follow-up who were identified as susceptible to future tobacco/e-cigarette use. Similarly, the specificity was defined as the percentage of students who reported not currently using each tobacco product or e-cigarette at follow-up who were identified as not susceptible to future tobacco/e-cigarette use. Finally, the PPV was defined as the percentage of students identified as susceptible to future tobacco/e-cigarette use who reported currently using each tobacco product or e-cigarette at follow-up, while the NPV was defined as the percentage of students

identified as not susceptible to future tobacco/e-cigarette use who did not report currently using each tobacco product or e-cigarette at follow-up.

5.5 Results

5.5.1 Self-reported tobacco or e-cigarette use at follow-up

Among current non-tobacco/e-cigarette users at Baseline, 29.4% were susceptible to future tobacco/e-cigarette use. By Follow-up Year 1, 13.6% of current non-tobacco/e-cigarette users at Baseline reported using any tobacco product or e-cigarette. By Follow-up Year 2, the percentage of students that reported using any tobacco product or e-cigarette increased by 67% to 22.8%. Figure 5 presents the prevalence of tobacco product or e-cigarette use at Follow-up Year 1 and Follow-up Year 2. The most frequently used products in Follow-up Year 1 were tobacco cigarettes (8.7%), e-cigarettes (5.5%), and cigarillos or little cigars (CLC, 2.9%). Similarly, the most frequently used products at Follow-up Year 2 were tobacco cigarettes (17.4%), e-cigarettes (6.7%), and CLC (5.3%). The increase in prevalence of use of tobacco products and e-cigarettes was not uniform across products. Between Follow-up Year 1 and Follow-up Year 2 the prevalence of use of tobacco cigarettes doubled, the prevalence of use of CLC increased by 82.8%, and the prevalence of hookah use increased by 68.4%; the prevalence of use of e-cigarettes only increased by 21.8%.

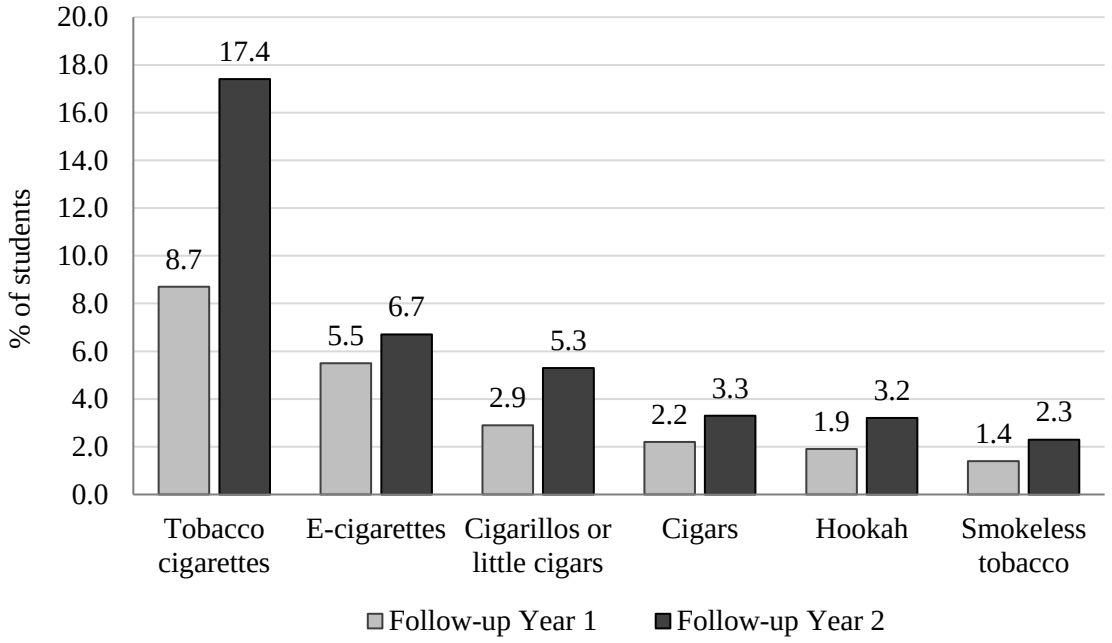

Figure 5. Self-reported tobacco product and e-cigarette use at Follow-up Year 1 and Follow-up Year 2 among never tobacco/e-cigarette users at Baseline, 2013-16 COMPASS study

5.5.2 Classification accuracy of the susceptibility construct

Table 3 presents the sensitivity, specificity, PPV, and NPV for the tobacco cigarette susceptibility construct (presented by Pierce and colleagues) at Follow-up Year 1 and Follow-up Year 2 for each tobacco product and e-cigarettes. At both Follow-up Year 1 and Follow-up Year 2, the sensitivity, specificity, and NPV of the construct was high (over 50%, 70%, and 80%, respectively). At Follow-up Year 1, the sensitivity of the construct was highest for tobacco cigarettes (59.5%), hookah (57.5%), and smokeless tobacco (56.6%). At Follow-up Year 2, the sensitivity of the construct was highest for tobacco cigarettes (54.6%), e-cigarettes (51.5%), and hookah (51.2%). At Follow-up Year 1, the specificity of the construct was highest of tobacco cigarettes (73.5%), e-cigarettes (72.0%), and CLC (71.3%). Similarly, at Follow-up Year 2 the specificity of the construct was highest for tobacco cigarettes (75.9%), e-cigarettes (72.2%), and CLC (71.8%). Across all products, the NPV of the susceptibility construct decreased between Follow-up Year 1 and Follow-up Year 2. The PPV of the susceptibility construct varied between products and usually increased between Follow-up Year 1 and Follow-up Year 2. At Follow-up Year 1, the PPV of the construct was highest for tobacco cigarettes (17.7%), e-cigarettes (10.0%), and CLC (5.0%). Similarly, at Follow-up

Year 2, the PPV of the construct was highest for tobacco cigarettes (32.2%), e-cigarettes (11.8%), and CLC (9.1%). Overall, the susceptibility construct was able to predict 25.6% of students that reported using any tobacco product or e-cigarette at Follow-up Year 1 and 39.5% of students that reported using any tobacco product or e-cigarette at Follow-up Year 2.

Table 3. Sensitivity, specificity, positive predictive value, and negative predictive value of the susceptibility construct at Follow-up Year 1 and Follow-up Year 2 for each tobacco product or e-cigarette, 2013-16 COMPASS study

Tobacco product or e-cigarette	Sensitivity (%)		Specificity (%)		PPV (%)		NPV (%)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Tobacco cigarettes	59.5	54.6	73.5	75.9	17.7	32.2	95.0	88.8
E-cigarettes	53.1	51.5	72.0	72.2	10.0	11.8	96.3	95.4
Cigarillos or little cigars	50.9	50.5	71.3	71.8	5.0	9.1	98.0	96.3
Cigars	56.0	49.6	71.2	71.3	4.1	5.6	98.6	97.7
Hookah	57.5	51.2	71.2	71.4	3.7	5.6	98.9	97.8
Smokeless tobacco	56.6	43.2	71.0	70.9	2.6	3.4	99.2	98.2
Any tobacco product or e-cigarette	55.2	51.1	74.7	77.0	25.6	39.5	91.4	84.3

Table 4. Sensitivity, specificity, positive predictive value, and negative predictive value of each susceptibility measure at Follow-up Year 1 and Follow-up Year 2 for each tobacco product or e-cigarette, 2013-16 COMPASS study

Tobacco product or e-cigarette	S1-Try								S2-Offer								S3-Smoke							
	Sensitivity (%)		Specificity (%)		PPV (%)		NPV (%)		Sensitivity (%)		Specificity (%)		PPV (%)		NPV (%)		Sensitivity (%)		Specificity (%)		PPV (%)		NPV (%)	
	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
Tobacco cigarettes	52.7	47.7	78.6	80.8	19.0	34.3	94.6	88.1	47.2	40.6	83.7	85.6	21.7	37.2	94.3	87.3	41.8	34.7	86.6	88.0	23.0	37.8	94.0	86.5
E-cigarettes	43.4	44.2	77.0	77.3	9.9	12.4	95.9	95.1	39.2	35.0	82.2	82.2	11.3	12.4	95.9	94.6	31.6	29.7	85.0	85.1	10.9	12.5	95.5	94.4
Cigarillos or little cigars	42.3	41.9	76.4	76.9	5.1	9.1	97.8	96.0	39.3	36.3	81.6	82.0	6.0	10.1	97.8	95.8	30.4	27.5	84.5	84.8	5.5	9.1	97.6	95.4
Cigars	47.6	39.4	76.4	76.4	4.3	5.4	98.5	97.4	45.8	34.9	81.6	81.6	5.2	6.0	98.6	97.4	34.5	22.2	84.5	84.3	4.7	4.6	98.3	97.0
Hookah	48.6	42.4	76.4	76.5	3.8	5.7	98.7	97.5	46.6	33.6	81.6	81.5	4.6	5.7	98.8	97.3	34.3	30.7	84.5	84.6	4.1	6.2	98.5	97.4
Smokeless tobacco	45.3	34.1	76.2	76.1	2.6	3.2	99.0	98.0	39.6	31.8	81.3	81.3	2.9	3.8	99.0	98.1	22.6	18.2	84.2	84.2	2.0	2.6	98.7	97.8
Any tobacco product or e-cigarette	47.7	44.0	79.6	81.7	26.9	41.3	90.6	83.3	41.6	36.9	84.6	86.3	29.9	44.1	90.2	82.3	36.7	31.6	87.4	88.7	31.4	44.9	89.7	81.6

S1-Try: "Do you think in the future you might try smoking cigarettes?"
S2-Offer: "If one of your best friends was to offer you a cigarette, would you smoke it?"
S3-Smoke: "At any time during the next year do you think you will smoke a cigarette?

5.5.3 Classification accuracy of each susceptibility measure

Table 4 presents the sensitivity, specificity, PPV, and NPV for each of the three tobacco cigarette susceptibility measures (S1-Try, S2-Offer, S3-Smoke) at Follow-up Year 1 and Follow-up Year 2 for each tobacco product and e-cigarettes. At both Follow-up Year 1 and Follow-up Year 2 the specificity of S1-Try, S2-Offer, and S3-Smoke was high (over 70%); however, the sensitivity of S1-Try, S2-Offer, and S3-Smoke was lower than that for the overall susceptibility construct. The PPV of S1-Try, S2-Offer, and S3-Smoke varied between products and increased between Follow-up Year 1 and Follow-up Year 2, while the NPV of S1-Try, S2-Offer, and S3-Smoke decreased between Follow-up Year 1 and Follow-up Year 2.

5.6 Discussion

This study identified that a significant number of youth that did not report current tobacco/e-cigarette use at baseline progressed to try smoking, use an alternative tobacco product, or use e-cigarettes over a two-year follow-up period. In the current sample, over one in ten current non-smoking students reported using a tobacco product or e-cigarette within one year of follow-up, and almost one in four students reported using a tobacco product or e-cigarette within two years of follow-up. It is apparent that many students use tobacco products or e-cigarettes during secondary school, even those that would not be identified as “at risk” (i.e., not susceptible) to future tobacco product or e-cigarette use. The vast majority of tobacco product or e-cigarette users were students that were identified as “at risk” (i.e., susceptible) to future tobacco product or e-cigarette use, indicating that methods of measuring susceptibility to future smoking are still useful and could identify those that would benefit the most from school-based tobacco prevention programming.

We found that the tobacco cigarette susceptibility construct predicted tobacco cigarette use among youth that did not report current tobacco/e-cigarette use in Ontario, Canada over a two-year follow-up period, suggesting that this susceptibility construct is valid for identifying non-smoking Ontario youth who are at the greatest risk of future tobacco cigarette use. Compared to the sensitivity (62.2%) and the specificity (49.6%) of the susceptibility construct calculated in a previous validation study that also used a longitudinal design (Strong et al., 2015), the sensitivity of the construct in the current study was lower and both the specificity and PPV were higher. Differences in assessing tobacco cigarette smoking between the current study (ever use) and the previous validation study (smoking 100 cigarettes in life) may explain some of these differences, especially the higher PPV

calculated in the current study. Alternatively, age differences of the sample populations at baseline and follow-up between the current study and the previous validation study may account for some of these differences; the current study identified smoking status one and two years later, when the sample was still in secondary school. In contrast, the study by Strong and colleagues identified smoking status three and six years later, when the sample was in young adulthood (2015). Finally, differences in tobacco control programs and policies across the two jurisdictions (California, USA versus Ontario, Canada) and over time (1996 versus 2014) may explain the reduced sensitivity and increased specificity and PPV. Differences in the tobacco control policy and program environment would also impact the baseline prevalence of use of these products among youth, which would impact later experimentation among susceptible and not susceptible youth. Given the potential influence of these differences, this construct should continue to be evaluated using different populations. Although the PPV of the construct was highest for tobacco cigarettes, it was still only able to predict about 17% of tobacco cigarette ever users one year later and 32% of tobacco cigarette ever users two years later. Additionally, the sensitivity values indicate that only about half of smokers were identified as "at risk" at baseline. It is evident that there is still knowledge to be gained about the smoking susceptibility construct and methods to identify those at risk of using tobacco cigarettes.

These data also illustrate that the tobacco cigarette susceptibility construct is transferrable to other products besides tobacco cigarettes. The results identify that the tobacco cigarette susceptibility construct best predicted e-cigarette use and CLC use; although the PPV for both products was lower than that for tobacco cigarettes (due to a lower prevalence of use), the sensitivity and specificity were both similar to that of tobacco cigarettes. Therefore, creating additional susceptibility measures specific to these products may not be necessary. Recent studies have begun to modify the susceptibility questions to identify students susceptible to the use of other tobacco products and e-cigarettes (Bold et al., 2017; Krishnan-Sarin et al., 2015; Mathur et al., 2014; Portnoy et al., 2014; Saddleson et al., 2015). Only one study used a longitudinal design to identify whether susceptibility measures specific to e-cigarettes predicted future e-cigarette use among youth (Bold et al., 2017). To our knowledge the sensitivity, specificity, PPV, and NPV of these measures have not been calculated. This study represents the first to explore the predictive validity of the original tobacco cigarette susceptibility construct for alternative tobacco products and e-cigarettes. Future studies should continue to compare the relative effectiveness of the original tobacco cigarette susceptibility construct to susceptibility measures that are specific to each tobacco product or e-cigarettes.

In addition to validating the tobacco cigarette susceptibility construct as a whole, these results illustrate that each susceptibility measure (S1-Try, S2-Offer, and S3-Smoke) was predictive of tobacco product and e-cigarette use. This suggests that although each measure asks about different situations where students could be tempted to try a tobacco product or e-cigarette, they all measure underlying intention to smoke in the future. Therefore, all three measures of the susceptibility construct or a single question from the construct could be used to measure susceptibility. This has important implications for survey development where the possibility of using a single question to measure susceptibility would reduce the burden on subjects while still providing useful data. However, it should be noted that given the differences in the sensitivity, specificity, PPV and NPV of each measure, the choice of which measure to use should be considered carefully. For example, the sensitivity of S1-Try was always highest of all the measures, while the sensitivity of S3-Smoke was always the lowest of all the measures. Therefore, when the sensitivity of the measure is valued, S1-Try should be selected rather than S2-Offer or S3-Smoke. In contrast, the specificity was high and relatively stable across tobacco products, e-cigarettes, and measures. Therefore, specificity is less useful in determining which measure to include. The three measures of susceptibility may also perform differently depending on the measure of frequency of tobacco product or e-cigarette use; based on one study of susceptibility to e-cigarette use and initiation and current use six months later, being offered an e-cigarette by a friend was more predictive of e-cigarette initiation, while thinking about using an e-cigarette in the future was more predictive of current e-cigarette use (Bold et al., 2017). Additional evidence is needed for the reliability and validity of each measure of tobacco cigarette susceptibility and the tobacco cigarette susceptibility construct overall.

This study fills a much needed research gap with respect to the use of the tobacco cigarette susceptibility construct in Canada. Despite not having been validated for use in this context, numerous Canadian studies have used this construct to identify students at risk for using tobacco cigarettes and sociodemographic and behavioural characteristics associated with being susceptible to using tobacco cigarettes (Azagba & Asbridge, 2013; Kaai, Brown, Leatherdale, Manske, & Murnaghan, 2014; Leatherdale, Wong, Manske, & Colditz, 2008). The results from this large longitudinal study indicate that the tobacco cigarette susceptibility construct is valid for use among Canadian youth populations. The Cq collected data on a range of tobacco products and e-cigarettes, which allowed for the investigation of a novel use of the tobacco cigarette susceptibility construct for predicting the use of alternative tobacco products and e-cigarettes. Additionally, the use of passive

consent procedures maximized the number of students that participated from each school, increasing the sample size available for analysis.

Although there are numerous strengths with this study, there are some limitations. The largest limitation rests with our measure of alternative tobacco product and e-cigarette use, which only assessed use within the last 30 days and not ever use. This measure also differed from our assessment of tobacco cigarette use (ever use). The more sensitive measure of tobacco cigarette use likely improved the positive predictive value that was calculated for tobacco cigarettes relative to the other products; however, the different measure of frequency of use did not have a noticeable impact on the calculated sensitivity or specificity as shown by the similar calculated values across tobacco products and e-cigarettes (also compare with Supplementary Table 19). The measure of alternative tobacco product and e-cigarette use also reduced our ability to limit the baseline sample to never tobacco/e-cigarette users. We excluded students that reported using an alternative tobacco product or e-cigarette in the past 30 days from the Baseline sample, but some students may have tried alternative tobacco products or e-cigarettes in the past but not within the last 30 days; this would increase their susceptibility to future use. We expect that keeping these students in the sample would have had a limited effect on these analyses given that prevalence rates of alternative tobacco product and e-cigarette use among this young population remain low (Reid et al., 2017) and the majority of alternative tobacco product and e-cigarette users also report using tobacco cigarettes (Brooks et al., 2008; Saunders & Geletko, 2012). Given that our sample at Baseline excluded students that reported ever using a tobacco cigarette, the vast majority of students would never have used a tobacco product or e-cigarette. Finally, a single question measured the use of each alternative tobacco product and e-cigarettes within the past 30 days, which may not reflect usual use or initiation of each product.

Other limitations are common to longitudinal studies of tobacco use. Consistent with previous evidence (Qian et al., 2015; Siddiqui et al., 1996), the linked sample differed significantly on all demographic and behavioural characteristics from the unlinked sample (see Supplementary Table 18). Given that tobacco users tend to drop-out of longitudinal studies (Siddiqui et al., 1996), the current results may be an underestimate of the predictive validity of the tobacco cigarette susceptibility construct. This study relied on self-reported smoking behaviours; therefore, the validity of responses cannot be guaranteed. However, self-reported tobacco use measures have previously been demonstrated to be reliable and valid (Fendrich, Mackesy-Amiti, Johnson, Hubbell, & Wislar, 2005; Wong et al., 2012) and students were ensured that their responses were confidential. Furthermore, limitations in the study design meant that data collections only occurred yearly, potentially missing

critical developmental periods or life events that lead to smoking experimentation. Finally, the COMPASS study used a convenience sample of students; therefore, the results may not be generalizable to all youth in Ontario or Canada. However, given the longitudinal nature of the study and the large school and student sample size, the results have important implications for current research and practice.

5.7 Conclusion

A significant number of youth that did not report current tobacco product or e-cigarette use at baseline reported using tobacco products and e-cigarettes over a two-year follow-up period. Methods to identify youth at risk for using various tobacco products and e-cigarettes continue to be warranted. The predictive validity of the tobacco cigarette susceptibility construct for tobacco cigarette, alternative tobacco product, and e-cigarette use among youth current non-tobacco/e-cigarette users over a two-year follow-up period was high. Furthermore, the predictive validity of each measure of the tobacco cigarette susceptibility construct for tobacco cigarettes, alternative tobacco product, and e-cigarette use was also high for youth current non-tobacco/e-cigarette users. The tobacco cigarette susceptibility construct can be used to identify students at risk of using various tobacco products and e-cigarettes within Ontario, Canada. Future studies should continue to explore methods of identifying students at risk for using various tobacco products and e-cigarettes in order to inform and tailor tobacco prevention programs.

Chapter 6

Manuscript 2

Exploring susceptibility as a predictor of future tobacco product use

Status: Submitted to *Social Science & Medicine – Population Health*

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6.1 Brief overview and purpose

The following Chapter includes a copy of the manuscript submitted to *Social Science & Medicine – Population Health*. This Chapter builds off Chapter 5 to further explore measures of susceptibility to future smoking. Given that the previous Chapter provides evidence for the predictive validity of the susceptibility construct, this manuscript included susceptibility to future smoking as a predictor in the models. Additional knowledge about the relation of measures of susceptibility to individual-level and sociodemographic and modifiable characteristics furthers our understanding of youth susceptibility to using tobacco, aids in the identification of youth who are most susceptible to tobacco and nicotine use, and promotes the development of additional prevention activities targeted to other tobacco and nicotine products. The objective of this manuscript was to identify the individual-level sociodemographic and behavioural characteristics that place youth at risk for initiating and using 6 tobacco and nicotine products: tobacco cigarettes, e-cigarettes, CLCs, cigars, SLT, and hookah. This manuscript answered the following research question:

1. What individual-level sociodemographic and modifiable characteristics place youth at risk for experimenting with (i.e., use within the last 30 days) each of the aforementioned tobacco and nicotine products?

6.2 Overview

Purpose: In addition to cigarettes, some youth experiment with alternative tobacco products (ATPs) including e-cigarettes, cigarillos or little cigars, cigars, hookah, and smokeless tobacco. However, our knowledge of factors that predict future use of ATPs is limited. The current study identified the association between (1) the susceptibility construct, (2) each measure of the susceptibility construct, and (3) behavioural factors and the onset of ATPs.

Methods: A sample of 9th grade students from Ontario, Canada that reported never using tobacco cigarettes and not currently using ATPs (n=3867) was identified at baseline (2013-14) and followed for two consecutive years (2014-15 and 2015-16). We used generalized linear mixed models to identify the association between factors at baseline and ATP use in the last 30 days at each follow-up wave.

Results: Baseline susceptibility to future smoking was strongly associated with the use of each ATP at both follow-up waves. A positive response to the question of smoking a cigarette if offered by a friend was associated with the use of each ATP at both follow-up waves. Students that had friends that smoked cigarettes, believed that it would be easy to get cigarettes, or reported binge drinking at baseline were at higher odds of reporting using an ATP at follow-up.

Conclusions: The susceptibility construct was predictive of ATP use in addition to cigarette use and could be used to predict youth that would use ATPs. Secondary schools should address the use of all tobacco products through school policies and multi-substance use prevention programs.

Key words: youth tobacco use; cohort study; alternative tobacco products; electronic cigarette; susceptibility to smoking

6.3 Introduction

The prevalence of ever and current use of cigarettes decreased substantially among Canadian youth over the last 15 years (Reid, Hammond, Rynard, Madill, & Burkhalter, 2017). However, the same reductions have not been evident for the use of alternative tobacco products (ATPs) such as e-cigarettes, cigarillos and little cigars (CLCs), cigars, hookah, and smokeless tobacco (SLT); in fact, the use of some ATPs has increased dramatically among youth populations. For example, the early 2000s saw a large increase in the use of CLCs among Canadian youth: by 2008 over 12% of secondary school-aged youth reported using CLCs in the last 30 days (Reid et al., 2017). More recently, e-cigarettes and hookah have gained popularity among both smokers and non-smokers. In 2013, 2.6% of Canadian youth reported using e-cigarettes in the last 30 days (Czoli, Reid, Rynard, & Hammond, 2015), while provincial data indicate that 7.2% of Ontario youth reported using e-cigarettes in the last 30 days (Czoli, Hammond, Reid, Cole, & Leatherdale, 2015). Similarly, in 2013, 3% of Canadian youth reported using a hookah to smoke tobacco in the last 30 days (Reid et al., 2017), and over 4% of Ontario youth reported using a hookah in the last 30 days (Czoli, Hammond, et al., 2015).

The use of ATPs is noteworthy for a variety of reasons. Some youth may only use ATPs and not cigarettes, meaning they may not be impacted by conventional prevention programs that specifically target cigarette smokers. As a result, these youth may still use ATPs and become addicted to nicotine, which may increase their risk of also using cigarettes. In fact, there is evidence that the use of ATPs can lead to the initiation and escalation of smoking cigarettes (Jaber et al., 2015; Leventhal et al., 2015; Soneji et al., 2017), and concurrent use of multiple products (Brooks, Gaier Larkin, Kishore, & Frank, 2008; Saunders & Geletko, 2012). Finally, many ATPs have similar negative health effects as tobacco cigarettes. For example, using a hookah to smoke tobacco is associated with lung cancer, respiratory illness, and the development of chronic obstructive pulmonary disease (Akl et al., 2010; Raad et al., 2011), while using cigars is associated with an increased risk of various cancers and coronary heart disease (Baker et al., 2000; Iribarren, Tekawa, Sidney, & Friedman, 1999; Shapiro, Jacobs, & Thun, 2000; Wyss et al., 2013). Additional tobacco control programs and policies may be necessary to prevent initiation, reduce escalation, and promote cessation of all tobacco products among youth populations. However, in order to design effective programs and policies we must first increase our understanding of the youth that use these products.

Identifying the youth most at-risk of initiating tobacco product use represents an important first step in preventing the uptake of these products. The susceptibility construct (Pierce, Choi, Gilpin,

Farkas, & Merritt, 1996; Pierce, Farkas, Evans, & Gilpin, 1995), which is commonly used in survey research, can identify students that have never smoked cigarettes who are less committed to remaining smoke-free in the future. A few studies (e.g., Krishnan-Sarin, Morean, Camenga, Cavallo, & Kong, 2015; Portnoy, Wu, Tworek, Chen, & Borek, 2014) have modified this construct to identify students at risk of using ATPs (e.g., e-cigarettes, CLCs, SLT), and to our knowledge only one used a longitudinal sample (Bold, Kong, Cavallo, Camenga, & Krishnan-Sarin, 2017). It would be helpful to identify whether additional measures of susceptibility specific to each product are necessary or whether the current construct (which assesses susceptibility to *cigarette* smoking) is also predictive of later ATP use. Given that many studies do not use the full susceptibility construct, it would also be beneficial to identify whether there are differences in the predictive power of each measure of the construct to inform future research.

In addition to the susceptibility construct, it would also be helpful to identify the behavioural characteristics of at-risk individuals that initiate ATP use to tailor prevention programs and resources. According to Problem Behaviour Theory, risk behaviours tend to cluster together as a "risk behaviour syndrome" (Jessor, 1991). It is possible that youth that initiate cigarette use share many characteristics in common with those that initiate ATP use that would be amenable to comprehensive prevention programming. Previous Canadian research has identified behavioural factors associated with the use of various tobacco products among youth populations (e.g., Czoli, Leatherdale, & Rynard, 2013; Kennedy, Leatherdale, Burkhalter, & Ahmed, 2011; Leatherdale, Rios, Elton-Marshall, & Burkhalter, 2011); however, these studies are cross-sectional and are not able to identify factors associated with the onset of use of each product.

Therefore, the objectives of this study were to (1) identify the association between the susceptibility construct and onset of ATPs, (2) identify the associated between each measure of the susceptibility construct and onset of ATPs, and (3) identify other behavioural factors associated with onset of ATPs at two time points (early and later) within a longitudinal sample of Canadian secondary school students.

6.4 Methods

6.4.1 Study Design

COMPASS is a prospective cohort study (2012-2021) that collects longitudinal data from a convenience sample of Canadian secondary schools and the 9th to 12th grade students within them

(Leatherdale, Brown, et al., 2014). The current study reports longitudinal student-level linked data from Year 2 (2013-14), Year 3 (2014-15), and Year 4 (2015-16) of the COMPASS host study. Consistent with our previous analysis (Cole, Kennedy, Chaurasia, & Leatherdale, 2017), "baseline" included data from Year 2 when students were in 9th grade, "Follow-up Year 1" (FY1) included data from Year 3 when students were in 10th grade, and "Follow-up Year 2" (FY2) included data from Year 4 when students were in 11th grade. Year 1 data (2012-13) from the COMPASS host study are not included given the substantially smaller sample size during the initial rollout of the study. A full description of the COMPASS study and its methods is available online (www.compass.uwaterloo.ca) and in print (Leatherdale, Brown, et al., 2014). The COMPASS study received ethics approval from the University of Waterloo Research Ethics Board, as well as participating school board review panels.

6.4.1.1 Sample selection

A full description of the sample selection and a comparison of the characteristics of students in the linked and unlinked sample (where the unlinked sample had a higher proportion of students that were male, had more spending money, were susceptible to future smoking, and had more friends that smoked cigarettes at baseline) are described previously (Cole et al., 2017). Student data were linked over time using a unique code generated by each student (Bredin & Leatherdale, 2013). At baseline, 4651 students in 9th grade from 70 secondary schools in Ontario, Canada were linked across all 3 years of study (linked sample; 41.3% of participating students); 6602 students in 9th grade at baseline did not have data for each data collection year (unlinked sample). In order to identify characteristics associated with the use each tobacco product, 9th grade students that reported ever using cigarettes (even just a puff) or past 30 day use of ATPs at baseline (n=534) were excluded from these analyses. Additional students were excluded due to missing responses to demographic questions at baseline or missing responses to outcome variables at FY1 or FY2 (n=250). The final linked sample included 3867 students that had never smoked and not used an ATP in the last 30 days at baseline (herein called "non-tobacco users").

6.4.2 Measures

6.4.2.1 Outcome variables

The COMPASS questionnaire (Cq) items have demonstrated reliability and validity for current smoking among youth (Wong et al., 2012). Experimentation with ATPs was measured with a

single multi-item question that measured past 30-day use of each ATP among respondents: “In the last 30 days, did you use any of the following? (Mark all that apply)”, followed by a list of ATPs (e-cigarettes, CLCs, cigars, hookah, and SLT). For our analyses, respondents that indicated using hookah to smoke tobacco or to smoke herbal sheesha/shisha were combined and identified as “hookah users”. To be consistent and for ease of comparison, we also examined past 30-day use of cigarettes.

6.4.2.2 Explanatory variables

Consistent with previous research, smoking susceptibility among non-tobacco users was derived by three previously validated measures that used the original wording proposed by Pierce and colleagues (Pierce et al., 1996):

S1-Try: “Do you think in the future you might try smoking cigarettes?”;

S2-Offer “If one of your best friends was to offer you a cigarette, would you smoke it?”; and

S3-Smoke “At any time during the next year do you think you will smoke a cigarette?”.

Consistent with previous research (Cole et al., 2017; Pierce et al., 1996), non-tobacco users who responded “definitely not” to all three questions were classified as “not susceptible” to future tobacco use for the susceptibility construct, while all other response groupings were classified as “susceptible” to future tobacco use. Similarly, non-tobacco users who responded “definitely not” to a particular question (S1-Try, S2-Offer, or S3-Smoke) were classified as “not susceptible” for that particular question, while any other response to a question was classified as “susceptible”.

The Cq also collects student-level sociodemographic and behavioural data consistent with national tobacco surveillance tools (Elton-Marshall et al., 2011). We controlled for gender, self-reported ethnicity, and baseline disposable income in all models. According to the Problem Behavior Theory (Jessor & Jessor, 1977), a variety of modifiable factors influence tobacco use, some of which are included in the Cq and allowed us to explore the association with the onset of ATPs. Social environmental factors of interest included the number of friends that smoke cigarettes (none versus any) and the perceived ease of getting cigarettes (“Difficult” versus “Easy” versus “I do not know”). Risk behaviours tend to cluster together as a “risk behavior syndrome” (Jessor, 1991). Therefore, we were interested in investigating the association of binge drinking (never versus ever binge drank) and marijuana use (never versus ever used) with the onset of ATPs. Non-substance use risk factors included the number of classes skipped in the last 4 weeks (none versus any). Some factors may protect against tobacco use; therefore, we included the number of school days breakfast was eaten (5

days versus <5 days), and whether a student met weekly Canadian physical activity guidelines (Tremblay et al., 2016) in the models to explore potential protective effects.

6.4.3 Statistical analyses

Self-reported ATP use was identified at FY1 and FY2. Within the sample of non-tobacco users, we identified 2861 students (74.0% of the sample) that reported never trying a cigarette (even a puff) and never using an ATP in the last 30 days at FY1 and FY2; these "abstainers" formed the reference group. We hypothesized that risk and protective factors may differ at each follow-up wave (i.e., more strongly predict ATP onset at FY1 than at FY2). To explore the potential impact of these differences, we identified *early users* of ATPs (i.e., tobacco product use at FY1) and *later users* of ATPs (i.e., tobacco product use at FY2). In order to identify factors associated with early use of ATPs, some students were excluded from the analyses at FY1 that reported using any tobacco product in FY2 but not FY1 (n=621 to 953). Similarly, in order to identify factors associated with later use of ATPs, some students were excluded from the analyses at FY2 that reported using any tobacco product in FY1 but not FY2 (n=470 to 918). Figure 6 summarizes how these samples were identified for this study.

Simple descriptive statistics examined the characteristics of abstainers relative to early and later users. We tested for differences in the baseline characteristics of abstainers and those that used an ATP using chi-square tests. Generalized linear mixed models (using PROC GLIMMIX) assessed the association between baseline responses to the susceptibility construct and each measure of the susceptibility construct to early and later use of each ATP in independent cross-sectional models, adjusting for the behavioural factors of interest and controlling for student clustering within schools. It was hypothesized that there was individual heterogeneity in the influence of susceptibility on tobacco product use; therefore, for the use of each ATP at each follow-up year, a random intercept model and a random intercept and slope model were estimated to identify the best fitting model. In some cases, the variance component associated with the random slope (susceptibility) was estimated to be zero; therefore we used a random intercept model to account for the heterogeneity. SAS version 9.4 was used for all analyses.

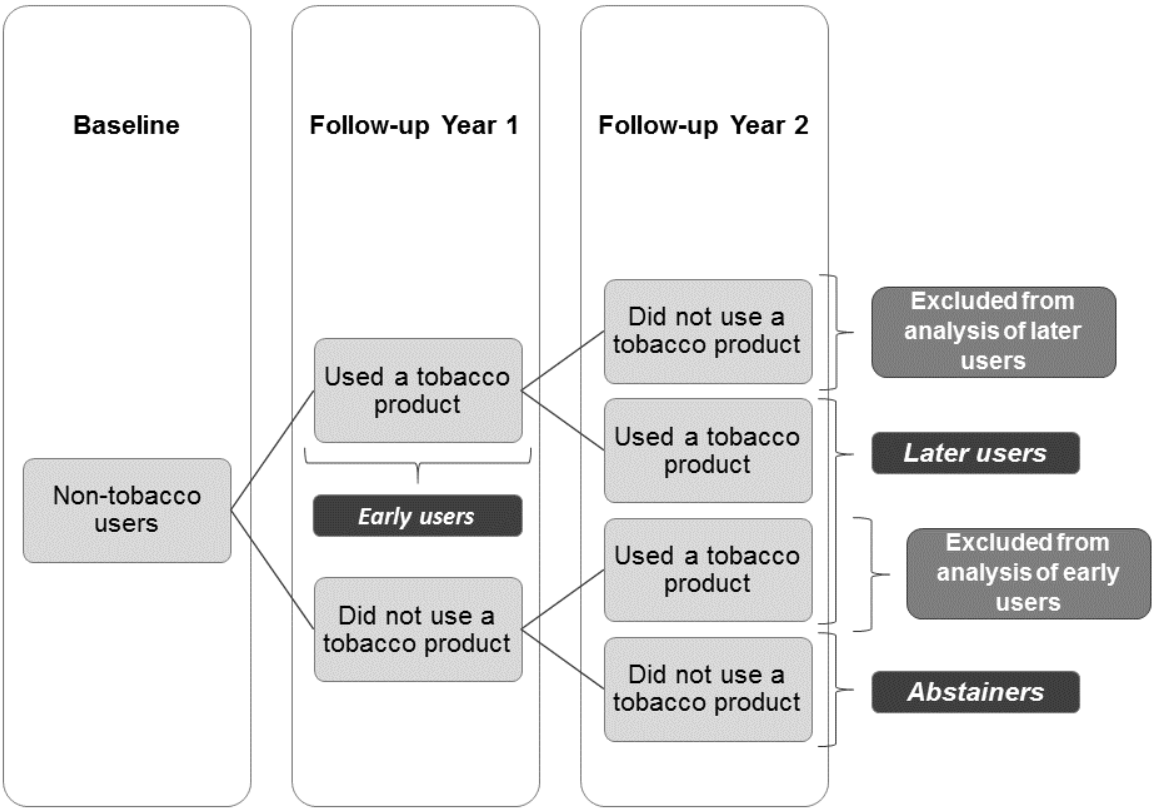

Figure 6. Flow diagram showing sample selection, 2013-16 COMPASS study

6.5 Results

Table 5 presents the characteristics at baseline of abstainers and early users of an ATP, while Table 6 presents the characteristics at baseline of abstainers and later users of an ATP. Across all ATPs and at both time points (FY1 and FY2), a higher proportion of students that were susceptible to future cigarette smoking reported use of an ATP. Additionally, a higher proportion of students that were susceptible to future cigarette smoking for each measure of the susceptibility construct reported use of all ATPs. With respect to other behavioural factors, early and later users were different from abstainers: with the exception of early use of smokeless tobacco, a higher proportion of students that reported use of all other products had friends that smoked cigarettes. Across all products, a higher proportion of students that reported ever binge drinking or ever using marijuana reported early or later use of an ATP. Furthermore, a higher proportion of students that reported skipping at least one class in the last 4 weeks reported early or later use of an ATP.

Adjusted odds ratio (AOR) estimates for student characteristics associated with early use of an ATP are presented in Table 7, while AOR estimates for student characteristics associated with later use of an ATP are presented in Table 8. Many factors were common across all ATPs and both time points (FY1 and FY2). Susceptibility was strongly associated with early use of each product (AOR 2.57 to 3.99), implying that susceptible students were at an increased odds of using an ATP in the future relative to non-susceptible students, controlling for all other variables. Susceptibility was also associated with later use of each product (AOR 1.72 to 2.91), although to a lesser degree than with early use of each product. Having friends that smoked cigarettes at baseline and perceiving that it would be easy to get cigarettes at baseline were both positively associated with early and later use of many ATPs. Students that reported binge drinking at baseline were at higher odds of reporting early and later use of an ATP relative to students that did not binge drink. With the exception of hookah and SLT, students that reported skipping classes in the last 4 weeks at baseline had higher odds of early use of an ATP relative to students that did not skip any classes (AOR 2.01 to 2.68); in contrast, skipping classes at baseline was not associated with the odds of later use of an ATP.

Table 9 presents the AOR estimates for the association between responses to each susceptibility question and early and later use of each ATP. In general, baseline responses to S2-Offer were the strongest predictor of early (AOR 1.83 to 3.04) and later use of an ATP (AOR 1.61 to 2.47). Interestingly, students whose responses to S1-Try indicated susceptibility to future smoking had significantly higher odds of later use of an ATP but not early use, and students whose responses to S3-Smoke indicated susceptibility to future smoking had significantly lower odds of early (AOR 0.37) and later SLT use (AOR 0.42).

Table 5. Baseline characteristics of abstainers and early users of a tobacco product, 2013-16 COMPASS study

		Abstainers[a] (n=2861)	Cigarette smokers[b] (n=84)		E-cigarette users[c] (n=213)		CLC smokers[d] (n=112)		Cigar smokers[e] (n=84)		Hookah users[f] (n=73)		SLT users[g] (n=53)		Any tobacco product users[h] (n=385)	
		(%)	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value
Susceptibility construct	Not susceptible	77.7	44.1	51.8 (1) P<0.001	47.0	101.5 (1) P<0.001	49.1	49.2 (1) P<0.001	44.1	51.8 (1) P<0.001	42.5	49.6 (1) P<0.001	43.4	34.7 (1) P<0.001	49.6	140.5 (1) P<0.001
	Susceptible	22.3	56.0		53.1		50.9		56.0		57.5		56.6		50.4	
Susceptibility measure: S1-Try	Not susceptible	82.4	49.4	58.4 (1) P<0.001	56.6	84.4 (1) P<0.001	57.7	43.5 (1) P<0.001	52.4	49.0 (1) P<0.001	51.4	45.2 (1) P<0.001	54.7	27.0 (1) P<0.001	57.7	126.8 (1) P<0.001
	Susceptible	17.6	50.6		43.4		42.3		47.6		48.6		45.3		42.3	
Susceptibility measure: S2-Offer	Not susceptible	86.8	51.2	84.4 (1) P<0.001	60.9	103.7 (1) P<0.001	60.7	59.9 (1) P<0.001	54.2	70.2 (1) P<0.001	53.4	65.4 (1) P<0.001	60.4	30.6 (1) P<0.001	62.8	144.3 (1) P<0.001
	Susceptible	13.2	48.8		39.2		39.3		45.8		46.6		39.6		37.2	
Susceptibility measure: S3-Smoke	Not susceptible	89.2	63.9	50.5 (1) P<0.001	68.4	78.9 (1) P<0.001	69.6	40.1 (1) P<0.001	65.5	44.9 (1) P<0.001	65.8	38.5 (1) P<0.001	77.4	7.4 (1) P<0.01	70.6	103.0 (1) P<0.001
	Susceptible	10.9	36.1		31.6		30.4		34.5		34.3		22.6		29.4	
Number of friends that smoke cigarettes	None	87.3	58.3	58.2 (1) P<0.001	70.4	46.9 (1) P<0.001	77.7	8.7 (1) P=0.003	77.4	7.0 (1) P=0.008	65.8	28.6 (1) P<0.001	79.3	3.0 (1) P=0.085	71.2	70.3 (1) P<0.001
	Any	12.7	41.7		29.6		22.3		22.6		34.3		20.8		28.8	
Perceived ease of getting cigarettes	Difficult	22.4	10.7	44.7 (2) P<0.001	16.4	78.1 (2) P<0.001	12.6	49.4 (2) P<0.001	8.3	45.8 (2) P<0.001	20.6	10.8 (2) P=0.005	13.2	8.7 (2) P=0.013	15.6	96.4 (2) P<0.001
	Easy	20.1	50.0		46.0		47.8		50.0		35.6		35.9		42.5	
	I do not know	57.5	39.3		37.6		39.6		41.7		43.8		50.9		41.9	
Self-reported binge drinking	Never	89.8	50.0	129.0 (1) P<0.001	68.5	87.2 (1) P<0.001	64.3	71.0 (1) P<0.001	58.3	82.2 (1) P<0.001	68.5	33.9 (1) P<0.001	60.4	47.2 (1) P<0.001	66.0	170.6 (1) P<0.001
	Ever	10.2	50.0		31.5		35.7		41.7		31.5		39.6		34.0	
Self-reported marijuana use	Never	98.2	89.2	33.6 (1) P<0.001	92.0	36.0 (1) P<0.001	90.1	35.0 (1) P<0.001	90.4	25.7 (1) P<0.001	86.1	51.2 (1) P<0.001	88.5	25.7 (1) P<0.001	91.2	67.0 (1) P<0.001
	Ever	1.8	10.8		8.0		9.9		9.6		13.9		11.5		8.9	
Number of classes skipped in the last 4 weeks	None	95.4	81.9	30.6 (1) P<0.001	82.5	62.7 (1) P<0.001	83.8	29.9 (1) P<0.001	81.9	30.6 (1) P<0.001	83.3	21.7 (1) P<0.001	84.6	12.9 (1) P<0.001	85.1	64.5 (1) P<0.001
	Any	4.6	18.1		17.5		16.2		18.1		16.7		15.4		14.9	
Number of school days ate breakfast	< 5 days	44.4	58.3	6.4 (1) P=0.011	58.8	16.4 (1) P<0.001	46.9	0.3 (1) P=0.611	42.9	0.08 (1) P=0.779	58.3	5.5 (1) P=0.019	42.3	0.09 (1) P=0.763	55.9	17.9 (1) P<0.001
	5 days	55.6	41.7		41.2		53.2		57.1		41.7		57.7		44.1	
Meets Canadian physical activity recommendations	No	52.5	39.5	5.3 (1) P=0.021	37.3	18.0 (1) P<0.001	41.1	5.7 (1) P=0.017	30.1	16.2 (1) P<0.001	36.1	7.6 (1) P=0.006	32.1	8.7 (1) P=0.003	37.5	30.3 (1) P<0.001
	Yes	47.5	60.5		62.7		58.9		69.9		63.9		67.9		62.5	

S1-Try: "Do you think in the future you might try smoking cigarettes?"
S2-Offer: "If one of your best friends was to offer you a cigarette, would you smoke it?"
S3-Smoke: At any time during the next year do you think you will smoke a cigarette?"
[a] Abstainers did not report using a tobacco product at Baseline, FY1, and FY2.
[b] n=922 students excluded that reported using any tobacco product in FY2 but not in FY1
[c] n=793 students excluded that reported using any tobacco product in FY2 but not in FY1
[d] n=894 students excluded that reported using any tobacco product in FY2 but not in FY1
[e] n=922 students excluded that reported using any tobacco product in FY2 but not in FY1
[f] n=933 students excluded that reported using any tobacco product in FY2 but not in FY1
[g] n=953 students excluded that reported using any tobacco product in FY2 but not in FY1
[h] Products included cigarettes, e-cigarettes, CLCs, cigars, hookah, and SLT; n=621 students excluded that reported using any tobacco product in FY2 but not in FY1

Table 6. Baseline characteristics of abstainers and later users of a tobacco product, 2013-16 COMPASS study

		Abstainers[a] (n=2861)	**Cigarette smokers[b] (n=216)**		**E-cigarette users[c] (n=260)**		**CLC smokers[d] (n=204)**		**Cigar smokers[e] (n=127)**		**Hookah users[f] (n=125)**		**SLT users[g] (n=88)**		**Any tobacco product users[h] (n=536)**	
		(%)	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value	(%)	X^2 (df) p-value
Susceptibility construct	Not susceptible	77.7	42.1	136.3 (1) P<0.001	48.5	109.4 (1) P<0.001	49.5	82.6 (1) P<0.001	50.4	50.5 (1) P<0.001	48.8	55.6 (1) P<0.001	56.8	21.1 (1) P<0.001	49.8	179.4 (1) P<0.001
	Susceptible	22.3	57.9		51.5		50.5		49.6		51.2		43.2		50.1	
Susceptibility measure: S1-Try	Not susceptible	82.4	49.3	137.8 (1) P<0.001	55.8	106.8 (1) P<0.001	58.1	72.3 (1) P<0.001	60.6	38.4 (1) P<0.001	57.6	48.8 (1) P<0.001	65.9	15.8 (1) P<0.001	57.6	165.2 (1) P<0.001
	Susceptible	17.6	50.7		44.2		41.9		39.4		42.4		34.1		42.4	
Susceptibility measure: S2-Offer	Not susceptible	86.8	54.6	158.2 (1) P<0.001	65.0	88.2 (1) P<0.001	63.7	80.2 (1) P<0.001	65.1	46.6 (1) P<0.001	66.4	41.0 (1) P<0.001	68.2	24.8 (1) P<0.001	63.7	170.1 (1) P<0.001
	Susceptible	13.2	45.4		35.0		36.3		34.9		33.6		31.8		36.3	
Susceptibility measure: S3-Smoke	Not susceptible	89.2	61.9	133.8 (1) P<0.001	70.3	77.9 (1) P<0.001	72.6	49.9 (1) P<0.001	77.8	15.5 (1) P<0.001	69.4	45.2 (1) P<0.001	81.8	4.7 (1) P=0.031	69.7	142.1 (1) P<0.001
	Susceptible	10.9	38.1		29.7		27.5		22.2		30.7		18.2		30.3	
Number of friends that smoke cigarettes	None	87.3	65.7	76.1 (1) P<0.001	70.4	55.9 (1) P<0.001	75.5	22.5 (1) P<0.001	75.6	14.4 (1) P<0.001	68.8	34.9 (1) P<0.001	68.2	26.9 (1) P<0.001	72.6	76.08 (1) P<0.001
	Any	12.7	34.3		29.6		24.5		24.4		31.2		31.8		27.4	
Perceived ease of getting cigarettes	Difficult	22.4	18.1	48.7 (2) P<0.001	20.4	49.0 (2) P<0.001	18.6	48.4 (2) P<0.001	13.4	35.0 (2) P<0.001	23.2	34.4 (1) P<0.001	14.8	16.2 (2) P<0.001	20.3	80.1 (2) P<0.001
	Easy	20.1	40.3		38.5		40.7		41.7		40.8		37.5		37.5	
	I do not know	57.5	41.7		41.2		40.7		44.9		36.0		47.7		42.2	
Self-reported binge drinking	Never	89.8	58.8	178.6 (1) P<0.001	65.8	128.9 (1) P<0.001	59.8	160.5 (1) P<0.001	55.9	136.3 (1) P<0.001	68.0	57.9 (1) P<0.001	60.2	76.0 (1) P<0.001	64.7	234.1 (1) P<0.001
	Ever	10.2	41.2		34.2		40.2		44.1		32.0		39.8		35.3	

		Abstainers[a] (n=2861)	Cigarette smokers[b] (n=216)		E-cigarette users[c] (n=260)		CLC smokers[d] (n=204)		Cigar smokers[e] (n=127)		Hookah users[f] (n=125)		SLT users[g] (n=88)		Any tobacco product users[h] (n=536)	
Self-reported marijuana use	Never	98.2	89.8	62.3 (1) P<0.001	93.9	22.0 (1) P<0.001	89.2	67.5 (1) P<0.001	92.9	17.7 (1) P<0.001	90.4	35.9 (1) P<0.001	87.5	48.2 (1) P<0.001	92.3	59.8 (1) P<0.001
	Ever	1.8	10.2		6.2		10.8		7.1		9.6		12.5		7.7	
Number of classes skipped in the last 4 weeks	None	95.4	88.4	20.2 (1) P<0.001	88.8	20.9 (1) P<0.001	87.3	25.6 (1) P<0.001	83.3	35.9 (1) P<0.001	86.2	21.0 (1) P<0.001	88.6	8.4 (1) P=0.004	87.2	53.3 (1) P<0.001
	Any	4.6	11.6		11.2		12.8		16.7		13.8		11.4		12.8	
Number of school days ate breakfast	5 days	55.6	37.3	26.7 (1) P<0.001	49.6	3.4 (1) P=0.064	50.0	2.4 (1) P=0.124	57.9	0.3 (1) P=0.605	41.1	10.1 (1) P=0.002	59.1	0.4 (1) P=0.516	43.2	27.6 (1) P<0.001
	< 5 days	44.4	62.7		50.4		50.0		42.1		58.9		40.9		56.8	
Meets Canadian physical activity recommendations	No	52.5	41.4	9.9 (1) P<0.002	38.0	19.6 (1) P<0.001	40.1	11.6 (1) P<0.001	40.0	7.5 (1) P=0.006	42.4	4.9 (1) P=0.027	30.7	16.3 (1) P<0.001	41.4	22.0 (1) P<0.001
	Yes	47.5	58.6		62.0		59.9		60.0		57.6		69.3		58.6	

S1-Try: "Do you think in the future you might try smoking cigarettes?"
S2-Offer: "If one of your best friends was to offer you a cigarette, would you smoke it?"
S3-Smoke: At any time during the next year do you think you will smoke a cigarette?"
[a] Abstainers did not report using a tobacco product at Baseline, FY1, and FY2.
[b] n=790 students excluded that reported using any tobacco product in FY1 but not in FY2
[c] n=746 students excluded that reported using any tobacco product in FY1 but not in FY2
[d] n=802 students excluded that reported using any tobacco product in FY1 but not in FY2
[e] n=879 students excluded that reported using any tobacco product in FY1 but not in FY2
[f] n=881 students excluded that reported using any tobacco product in FY1 but not in FY2
[g] n=918 students excluded that reported using any tobacco product in FY1 but not in FY2
[h] Products included cigarettes, e-cigarettes, CLCs, cigars, hookah, and SLT; n=470 students excluded that reported using any tobacco product in FY1 but not in FY2

Table 7. Adjusted odds ratio estimates for student characteristics associated with early use of a tobacco product, 2013-16 COMPASS study

		Adjusted Odds Ratio[a] (95% CI)						
		Model 1: Early use of cigarettes	**Model 2: Early use of e-cigarettes**	**Model 3: Early use of CLCs**	**Model 4: Early use of cigars**	**Model 5: Early use of hookah**	**Model 6: Early use of SLT**	**Model 7: Early use of any product[b]**
Susceptibility to future cigarette smoking	Not susceptible	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Susceptible	2.43 (1.45, 4.05)***	2.73 (1.90, 3.93)***	2.57 (1.65, 4.00)***	3.21 (1.94, 5.32)***	3.32 (1.90, 5.80)***	3.99 (2.11, 7.53)***	2.48 (1.91, 3.24)***
Number of friends that smoke cigarettes	None	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Any	2.47 (1.44, 4.22)**	1.78 (1.22, 2.58)**	1.03 (0.60 (1.77)	1.08 (0.58, 2.00)	2.24 (1.28, 3.90)**	1.06 (0.49, 2.32)	1.66 (1.24, 2.22)***
Perceived ease of getting cigarettes	Difficult	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Easy	3.37 (1.53, 7.41)**	2.18 (1.39, 3.41)***	3.02 (1.57, 5.80)***	4.23 (1.80, 9.93)***	1.13 (0.56, 2.29)	1.64 (0.63, 4.27)	2.09 (1.47, 2.97)***
	I do not know	1.73 (0.78, 3.82)	0.99 (0.64, 1.54)	1.32 (0.69, 2.53)	1.86 (0.79, 4.38)	0.91 (0.47, 1.76)	1.49 (0.60, 3.68)	1.11 (0.79, 1.56)
Binge drinking status	Never binged	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Ever binged	4.57 (2.69, 7.77)***	2.16 (1.47, 3.16)***	3.07 (1.88, 5.03)***	3.73 (2.16, 6.42)***	1.93 (1.05, 3.54)*	4.11 (2.09, 8.10)***	2.69 (2.01, 3.60)***
Marijuana use status	Never used marijuana	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Ever used marijuana	1.14 (0.44, 2.97)	1.35 (0.67, 2.71)	1.89 (0.81, 4.39)	1.27 (0.48, 3.33)	2.53 (1.05, 6.11)*	1.52 (0.48, 4.77)	1.54 (0.89, 2.65)
Number of classes skipped in the last 4 weeks	None	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Any	2.95 (1.49, 5.86)**	2.51 (1.56, 4.03)***	2.48 (1.30, 4.72)**	2.68 (1.33, 5.43)**	1.91 (0.90, 4.04)	2.38 (0.95, 5.93)	2.14 (1.44, 3.18)***
Number of school days ate breakfast	< 5 days	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	5 days	0.71 (0.42, 1.18)	0.62 (0.44, 0.86)**	1.02 (0.66, 1.57)	1.16 (0.70, 1.93)	0.67 (0.39, 1.13)	1.08 (0.58, 2.02)	0.70 (0.54, 0.90)**
Meets Canadian physical activity recommendations	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Yes	1.59 (0.96, 2.63)	1.72 (1.24, 2.38)**	1.33 (0.86, 2.04)	2.12 (1.26, 3.58)**	1.59 (0.94, 2.70)	1.74 (0.92, 3.31)	1.64 (1.28, 2.10)***

* p<0.05 ** p<0.01 *** p<0.001; [a] All models controlled for gender, ethnicity, and self-reported disposable income at baseline; [b] Products included cigarettes, e-cigarettes, CLCs, cigars, hookah, and SLT

Model 1 (random intercept): Early use of cigarettes (n=79), Did not use cigarettes (n=2694); Model 2 (random intercept with random slope): Early use of e-cigarettes (n=202), Did not use e-cigarettes (n=2694); Model 3 (random intercept): Early use of CLCs (n=107), Did not use CLCs (n=2694); Model 4 (random intercept): Early use of cigars (n=80), Did not use cigars (n=2694); Model 5 (random intercept with random slope): Early use of a hookah (n=69), Did not use a hookah (n=2694); Model 6 (random intercept): Early use of SLT (n=50), Did not use SLT (n=2694); Model 7 (random intercept with random slope): Early use of a tobacco product (n=371), Did not use a tobacco product (n=2694)

Table 8. Adjusted odds ratio estimates for student characteristics associated with later use of a tobacco product, 2013-16 COMPASS study

		Adjusted Odds Ratio[a] (95% CI)						
		Model 1: Later use of cigarettes	**Model 2: Later use of e-cigarettes**	**Model 3: Later use of CLCs**	**Model 4: Later use of cigars**	**Model 5: Later use of hookah**	**Model 6: Later use of SLT**	**Model 7: Later use of any product[b]**
Susceptibility to future cigarette smoking	Not susceptible	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Susceptible	3.14 (2.26, 4.36)***	2.79 (2.03, 3.83)***	2.56 (1.75, 3.74)***	2.55 (1.54, 4.21)***	2.51 (1.68, 3.76)***	1.72 (1.03, 2.86)*	2.56 (2.06, 3.20)***
Number of friends that smoke cigarettes	None	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Any	1.94 (1.35, 2.78)***	1.75 (1.25, 2.45)**	1.21 (0.81, 1.81)	1.31 (0.80, 2.16)	1.75 (1.12, 2.72)*	2.12 (1.23, 3.65)**	1.50 (1.15, 1.94)**
Perceived ease of getting cigarettes	Difficult	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Easy	1.63 (1.04, 2.57)*	1.52 (1.03, 2.25)*	1.63 (1.04, 2.57)*	2.13 (1.16, 3.93)*	1.36 (0.83, 2.26)	1.60 (0.78, 3.28)	1.44 (1.07, 1.93)*
	I do not know	1.03 (0.67, 1.59)	0.85 (0.58, 1.23)	0.91 (0.59, 1.40)	1.20 (0.67, 2.17)	0.63 (0.38, 1.03)	1.20 (0.61, 2.36)	0.87 (0.67, 1.15)
Binge drinking status	Never binged	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Ever binged	3.27 (2.28, 4.70)***	3.07 (2.20, 4.28)***	3.90 (2.72, 5.59)***	4.38 (2.80, 6.84)***	2.11 (1.32, 3.35)**	4.25 (2.46, 7.37)***	3.07 (2.39, 3.95)***
Marijuana use status	Never used marijuana	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Ever used marijuana	1.65 (0.86, 3.18)	0.99 (0.49, 1.97)	1.92 (1.00, 3.68)	0.96 (0.39, 2.36)	1.56 (0.71, 3.45)	1.94 (0.78, 4.83)	1.33 (0.80, 2.21)
Number of classes skipped in the last 4 weeks	None	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Any	1.27 (0.73, 2.21)	1.39 (0.84, 2.29)	1.45 (0.84, 2.50)	2.33 (1.26, 4.31)**	1.83 (1.00, 3.36)	1.53 (0.66, 3.56)	1.70 (1.18, 2.46)**
Number of school days ate breakfast	< 5 days	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	5 days	0.65 (0.46, 0.90)*	0.93 (0.69, 1.25)	0.97 (0.69, 1.34)	1.35 (0.88, 2.06)	0.69 (0.46, 1.03)	1.16 (0.71, 1.89)	0.74 (0.59, 0.92)**
Meets Canadian physical activity recommendations	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Yes	1.36 (0.98, 1.87)	1.63 (1.22, 2.17)**	1.48 (1.07, 2.05)*	1.33 (0.89, 2.01)	1.43 (0.96, 2.11)	1.93 (1.17, 3.17)**	1.44 (1.16, 1.78)***

* p<0.05 ** p<0.01 *** p<0.001; [a] All models controlled for gender, ethnicity, and self-reported disposable income at baseline; [b] Products included cigarettes, e-cigarettes, CLCs, cigars, hookah, and SLT

Model 1 (random intercept): Later use of cigarettes (n=206), Did not use cigarettes (n=2694); Model 2 (random intercept with random slope): Later use of e-cigarettes (n=250), Did not use e-cigarettes (n=2694); Model 3 (random intercept with random slope): Later use of CLCs (n=194), Did not use CLCs (n=2694); Model 4 (random intercept with random slope): Later use of cigars (n=121), Did not use cigars (n=2694); Model 5 (random intercept): Later use of a hookah (n=121), Did not use a hookah (n=2694); Model 6 (random intercept): Later use of SLT (n=87), Did not use SLT (n=2694)
Model 7 (random intercept): Later use of a tobacco product (n=512), Did not use a tobacco product (n=2694)

Table 9. Adjusted odds ratio estimates for the association between each measure of susceptibility and early and later use of a tobacco product, 2013-16 COMPASS study

		Adjusted Odds Ratio[a] (95% CI)						
		Cigarette use[b]	**E-cigarette use[c]**	**CLC use[d]**	**Cigar use[e]**	**Hookah use[f]**	**SLT use[g]**	**Any product use[h]**
Early use of each product								
Susceptibility measure: S1-Try	Not susceptible	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Susceptible	1.44 (0.70, 2.96)	1.62 (1.02, 2.56)*	1.67 (0.89, 3.12)	1.85 (0.89, 3.86)	1.76 (0.86, 3.62)	2.79 (1.22, 6.37)*	1.72 (1.21, 2.46)**
Susceptibility measure: S2-Offer	Not susceptible	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Susceptible	3.04 (1.48, 6.25)**	1.98 (1.24, 3.16)**	2.09 (1.10, 3.96)*	2.73 (1.33, 5.58)**	2.75 (1.33, 5.70)**	2.90 (1.27, 6.61)*	1.83 (1.26, 2.64)**
Susceptibility measure: S3-Smoke	Not susceptible	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Susceptible	0.85 (0.39, 1.83)	1.12 (0.67, 1.87)	0.94 (0.47, 1.89)	0.92 (0.43, 1.97)	0.96 (0.45, 2.04)	0.37 (0.15, 0.93)*	1.03 (0.69, 1.55)
Later use of each product								
Susceptibility measure: S1-Try	Not susceptible	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Susceptible	1.86 (1.18, 2.93)**	2.01 (1.34, 3.01)***	1.81 (1.14, 2.86)*	1.87 (1.05, 3.34)*	1.87 (1.08, 3.22)*	1.48 (0.73, 2.98)	1.77 (1.31, 2.41)***
Susceptibility measure: S2-Offer	Not susceptible	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Susceptible	2.23 (1.39, 3.55)***	1.61 (1.05, 2.46)*	1.90 (1.17, 3.10)**	2.29 (1.26, 4.18)**	1.28 (0.72, 2.29)	2.47 (1.22, 5.00)*	1.74 (1.26, 2.42)***
Susceptibility measure: S3-Smoke	Not susceptible	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Susceptible	1.16 (0.71, 1.91)	1.11 (0.70, 1.76)	0.87 (5.1, 1.46)	0.51 (0.26, 1.01)	1.24 (0.67, 2.31)	0.42 (0.18, 0.98)*	1.12 (0.78, 1.59)

* p<0.05 ** p<0.01 *** p<0.001; S1-Try: "Do you think in the future you might try smoking cigarettes?"; S2-Offer: "If one of your best friends was to offer you a cigarette, would you smoke it?"; S3-Smoke: At any time during the next year do you think you will smoke a cigarette?"

[a] All models controlled for gender, ethnicity, self-reported disposable income, number of friends that smoke cigarettes, perceived ease of getting cigarettes, binge drinking, marijuana use, number of classes skipped in the last 4 weeks, number of school days ate breakfast, and physical activity level at baseline.

[b] Model 1 (random intercept): Early use of cigarettes (n=77), Did not use cigarettes (n=2683); Model 2 (random intercept): Later use of cigarettes (n=205), Did not use cigarettes (n=2683)

[c] Model 3 (random intercept): Early use of e-cigarettes (n=200), Did not use e-cigarettes (n=2683); Model 4 (random intercept): Later use of e-cigarettes (n=249), Did not use e-cigarettes (n=2683)

[d] Model 5 (random intercept): Early use of CLCs (n=107), Did not use CLCs (n=2683); Model 6 (random intercept): Later use of CLCs (n=194), Did not use CLCs (n=2683)

[e] Model 7 (random intercept): Early use of cigars (n=79), Did not use cigars (n=2683); Model 8 (random intercept): Later use of cigars (n=119), Did not use cigars (n=2683)

[f] Model 9 (random intercept): Early use of a hookah (n=69), Did not use a hookah (n=2683); Model 10 (random intercept): Later use of a hookah (n=120), Did not use a hookah (n=2683)

[g] Model 11 (random intercept): Early use of SLT (n=50), Did not use SLT (n=2683); Model 12 (random intercept): Later use of SLT (n=87), Did not use SLT (n=2683)

[h] Products included cigarettes, e-cigarettes, CLCs, cigars, hookah, and SLT; Model 13 (random intercept): Early use of a tobacco product (n=368), Did not use a tobacco product (n=2683); Model 14 (random intercept): Later use of a tobacco product (n=510), Did not use a tobacco product (n=2683)

6.6 Discussion

Consistent with previous research (Choi, Gilpin, Farkas, & Pierce, 2001; Huang, Hollis, Polen, Lapidus, & Austin, 2005; Pierce et al., 1996; Pierce, Distefan, Kaplan, & Gilpin, 2005; Prokhorov et al., 2002), the results of this study indicate that susceptibility was a strong predictor of both early and later use of cigarettes. Additionally, these results reveal that the susceptibility construct is a strong predictor of the use of each ATP both one- and two-years later, even though the measures are specific to cigarette smoking and even after controlling for a variety of common covariates and behavioural factors. This suggests that alternative measures of susceptibility to future smoking may not be necessary, although additional work comparing such measures is needed. Given that (1) the susceptibility construct identifies students who are less committed to remaining smoke-free in the future (Cole et al., 2017; Pierce et al., 1996, 1995), (2) students that initiate smoking are different in many characteristics from those that do not, and (3) students tend to use multiple products (Czoli, Hammond, et al., 2015; Lee, Hebert, Nonnemaker, & Kim, 2015; Soneji, Sargent, & Tanski, 2014), it is not surprising that the original susceptibility construct can be used to identify and predict youth that will use ATPs in addition to cigarettes. It is clear that measures of susceptibility to future smoking continue to be useful to identify students that may benefit the most from tobacco prevention programs in order to continue to reduce the risk of tobacco-related harms.

The results of this study also indicate that there was a differential effect of each measure of the susceptibility construct: positive baseline responses to smoking a cigarette if offered by a friend were the strongest predictor of early and later use of an ATP. A previous study of susceptibility to e-cigarette use also identified that positive responses to using an e-cigarette if offered by a friend were predictive of e-cigarette initiation (Bold et al., 2017). The influence of peer smoking on smoking initiation has been well documented (Huang et al., 2005; Nguyen, Gildengorin, Gregorich, McPhee, & Kaplan, 2008; Pierce et al., 1996, 2005) and was also supported in our models (i.e., having friends that smoke cigarettes was a strong predictor of both early and later use of many ATPs). Close friends may pressure youth to experiment with various products and provide opportunities for never-smoking youth to try ATPs through various social situations (Hammal et al., 2016; Richter, Caraballo, Gupta, & Pederson, 2008). Additional research is needed to identify where students typically obtain different tobacco products, whether that be from friends, family members, or retailers close to the school. Such knowledge could inform the development of school policies that prohibit possession of tobacco products on campus grounds, zoning policies that restrict selling tobacco products close to secondary

schools, or closed campus policies that prohibit students from leaving the campus during school hours. For instance, research has previously demonstrated links between tobacco retailer densities surrounding schools and youth smoking outcomes among Canadian youth (Chan & Leatherdale, 2011; Leatherdale & Strath, 2007).

Consistent with Problem Behavior Theory, the results of this study support the strong association between ATP use, alcohol use, and marijuana use. Cross-sectional (Leatherdale & Burkhalter, 2012; Morean et al., 2016) and longitudinal (Jackson, Sher, Cooper, & Wood, 2002; Nelson, Van Ryzin, & Dishion, 2015) evidence indicates that risk behaviours tend to cluster together and it is hard to find a youth smoker who doesn't report also consuming alcohol and/or marijuana (Leatherdale & Burkhalter, 2012). Of note, binge drinking was strongly associated with early and later use of all ATPs in addition to cigarettes. Alcohol use may encourage experimentation with tobacco products because it inhibits decision-making and a youth's ability to remain committed to being smoke-free. Given that alcohol is the substance most widely used by youth in Canada (Leatherdale & Burkhalter, 2012), addressing alcohol use and binge drinking behaviours through school- and community-based programs may help to further reduce rates of ATP use by reducing the number of students that start using these products. It may also have the impact of improving the success of existing tobacco control efforts. The potential synergistic effect of substance use prevention programming on co-occurring substance use among youth would require evaluation. Marijuana use may also encourage experimentation with ATPs through a similar pathway to alcohol use. Within the current sample, few 9th grade students reported ever using marijuana at baseline, which may have limited our ability to identify a positive relationship with ATP use. However, given the pending legalization of marijuana in Canada (Canada & Health Canada, 2016), additional surveillance data are needed to identify the potential relationship between ATP use and marijuana use.

In addition to substance use behaviours, some behaviours promote or protect against early and later use of ATPs. Students that reported skipping classes in the last 4 weeks were at greater odds of early use of almost all ATPs. When skipping classes, students may be exposed to ATPs, especially if they have friends that smoke. School-based programs and policies could discourage students from skipping classes and/or leaving school property during school hours in order to reduce rates of ATP use. Our model results also suggest that some factors may differ between particular product users. Eating breakfast every day of the school week was a protective behaviour in our models and reduced the odds of early use of e-cigarettes and any tobacco product and later use of cigarettes and any

tobacco product. Students may skip breakfast for a variety of reasons including a lack of time in the morning, not feeling hungry in the morning, and the desire to lose weight (Patte & Leatherdale, 2016). Based on these data, school-based education campaigns that raise awareness about the importance of eating breakfast every day for health and weight and school breakfast programs that provide low-to-no-cost breakfast for all students may be important avenues for preventing tobacco product use among youth. Additionally, students that were more physically active were more likely to report early use of e-cigarettes, cigars, and any tobacco product and later use of e-cigarettes, CLCs, SLT, and any tobacco product. These students could be rationalizing negative behaviors (i.e., tobacco product use) with positive behaviours (i.e., being physically active). Some students could also be exposed to ATP use through sports teams and clubs during celebrations and team parties. Additional research is needed to identify the occasions where physically active youth use these products in order to develop more targeted interventions.

6.6.1 Study limitations & strengths

The largest limitation of this study rests with the measure of ATP use, which only assessed use within the last 30 days. Although efforts were made to limit the baseline sample to those that had never used ATPs, some students may have tried ATPs in the past which could affect their susceptibility to future smoking (Barrington-Trimis et al., 2018). However, the prevalence of ATP use among this young population remains low (Reid et al., 2017), the majority of ATP users also report using cigarettes (Brooks et al., 2008; Saunders & Geletko, 2012), and those who may have tried an ATP but not continued using may not be the largest concern from a public health perspective. Given that our sample at baseline excluded students that reported ever using a cigarette, the vast majority of students would never have used an ATP. Consistent with previous evidence (Qian, Battista, Bredin, Brown, & Leatherdale, 2015; Siddiqui, Flay, & Hu, 1996), there were baseline differences between the linked and unlinked samples where a greater proportion of students that were not linked across the three time points were male, had more spending money, were susceptible to future smoking, and had friends that smoked cigarettes. Given that tobacco users tend to drop out of longitudinal studies (Siddiqui et al., 1996) and risk behaviours tend to cluster together (Fix et al., 2014; Morean et al., 2016), the current results may be an underestimate of the association between behavioural characteristics and future ATP use. This study relied on self-reported smoking behaviours; however, self-reported tobacco use measures have previously been demonstrated to be reliable and valid (Fendrich et al., 2005; Wong et al., 2012) and students were ensured that their responses were

confidential. Assessment of tobacco product use only occurred annually. As noted in a systematic review (Wellman et al., 2016), yearly assessments may miss critical milestones in the progression from never use to daily tobacco use, and future studies should include more frequent assessment of susceptibility and tobacco use. Finally, the COMPASS study used a convenience sample of students; therefore, the results may not be generalizable to all youth in Ontario or Canada. However, given the longitudinal nature of the study and the large school and student sample size, the results have important implications for current research and practice.

This study improves our understanding of the generalizability of the susceptibility construct and each measure of the susceptibility construct to ATPs. The longitudinal design of this study is particularly unique given that longitudinal data for the use of ATPs are lacking. The COMPASS questionnaire collects data on a range of health behaviours and the use of multiple ATPs, which allowed for the investigation of the relationship between various health behaviours and early and later use of multiple ATPs. The identification of a group of students that did not report tobacco product use throughout the study period provides a clean reference group of non-users for comparison. Additionally, the use of passive consent procedures maximized the number of students that participated from each school, increasing the sample size available for analysis.

Chapter 7

Manuscript 3

Identifying behavioural characteristics of tobacco product and e-cigarette use clusters: A repeat cross-sectional analysis

Status: Under review in *Addictive Behaviors*

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7.1 Brief overview and purpose

The following Chapter includes a copy of the manuscript under review in *Addictive Behaviors*. Supplementary material included with this manuscript submission can be found in Supplementary material from Manuscript 3. A variety of tobacco and nicotine products are currently available in Ontario for youth to use. However, there is a lack of evidence for the combinations of tobacco and nicotine products commonly used by youth in Ontario, and whether youth from different tobacco usage classes share similar sociodemographic and behavioural characteristics. Knowledge of the combinations of tobacco and nicotine products that are commonly used by youth in Ontario could promote the development of additional prevention activities targeted to specific groups of youth. The objective of this manuscript was to identify the tobacco and nicotine product use clusters for three data collection years among a sample of Ontario secondary school students. This manuscript answered the following research questions:

1. How does the use of various tobacco and nicotine products cluster for each data collection year?
2. How do the behavioural clusters identified in question 1 differ by sociodemographic and modifiable characteristics for each data collection year?

7.2 Overview

Background: Youth may use a variety of tobacco products and e-cigarettes. However, there is a lack of evidence for the combinations of tobacco products and e-cigarettes commonly used by youth in Canada and whether youth from different usage classes share similar characteristics.

Methods: A cohort of 9th grade students from Ontario, Canada was identified at baseline (2013-14) of the COMPASS study (n=4651). Classes of youth that currently use similar combinations of tobacco products and e-cigarettes were identified at baseline, one (FY1) and two years later (FY2) using latent class analysis. Multinomial logistic regression models identified demographic and behavioural characteristics (e.g., environmental influences, substance use behaviours, etc.) of youth in current tobacco and e-cigarette use classes relative to youth in non-current use classes.

Results: At baseline, a three-class model was identified as best, while a four-class model was identified at FY1 and FY2. A non-current use group and a polyproduct use group were identified every year. Students that reported having friends that smoked cigarettes, binge drinking, and using marijuana were more likely to be classified into a current use class.

Conclusions: Tobacco cigarettes were more likely to be used with other products than on their own. A polyproduct use group was identified across all three survey waves and the prevalence of this group increased over time. Given that many youth in this study used more than one tobacco product or e-cigarette and commonly reported binge drinking and using marijuana, prevention and cessation activities should address the use of multiple products.

Key words: adolescence; latent class analysis; tobacco use; electronic cigarette

7.3 Introduction

A variety of tobacco and nicotine products are available in the Canada market, including tobacco cigarettes, pipe tobacco, cigarillos or little cigars, cigars, smokeless tobacco, hookah, and more recently e-cigarettes. Although the sale of tobacco products and e-cigarettes is prohibited to those under the age of 19 years in Ontario, Canada, many youth still report accessing and using these products. Single product use is common, however there are some youth that use more than one product concurrently (i.e., polyproduct users). For example, evidence from one study in the USA identified that although 11.4% of 9th grade students reported currently using only one tobacco product or e-cigarette, 4.1% reported currently using two products and 4.0% reported currently using three or more products, and the prevalence of polyproduct use increased over time (Huh & Leventhal, 2016). Although tobacco products and e-cigarettes can be used in many different combinations, tobacco cigarettes are typically one of the products that are used among polyproduct users (Soneji, Sargent, & Tanski, 2014). Multiple USA studies have found that the dual use of tobacco cigarettes and cigars/cigarillos/little cigars is most common (Bombard, Rock, Pederson, & Asman, 2008; Everett, Malarcher, Sharp, Husten, & Giovino, 2000; Fix et al., 2014; Lee, Hebert, Nonnemaker, & Kim, 2015; Soneji et al., 2014); other popular combinations of products include tobacco cigarettes and smokeless tobacco (Bombard et al., 2008), tobacco cigarettes and hookah (Soneji et al., 2014), and more recently, tobacco cigarettes and e-cigarettes (Soneji et al., 2014).

Some studies have identified sociodemographic and behavioural factors associated with polyproduct use. Most of the research to date has focused on youth populations in the USA (Brooks, Gaier Larkin, Kishore, & Frank, 2008; Horn, Gao, Dino, & Kamal-Bahl, 2000; Mushtaq, Williams, & Beebe, 2012; Schuster, Hertel, & Mermelstein, 2013; Simon, Sussman, Dent, Burton, & Flay, 1993). However, variations in the number and types of products included in the analyses and contextual differences in the popularity of different products between jurisdictions make it difficult to identify common themes across the research. Some studies have focused on identifying characteristics (e.g., age, gender, social influences) of dual users [e.g., dual tobacco cigarette and cigar users (Brooks et al., 2008), dual tobacco cigarette and smokeless tobacco users (Horn et al., 2000; Mushtaq et al., 2012; Simon et al., 1993)], while other studies have focused on identifying characteristics of polyproduct users without specifying particular combinations of products (e.g., Bombard et al., 2008; Fix et al., 2014; Lee et al., 2015; Soneji et al., 2014).

Latent class analysis is a relatively new technique that identifies mutually exclusive groups of individuals that respond in similar ways to given variables within a large population (Lanza, Collins, Lemmon, & Schafer, 2007; Quek et al., 2013). Multiple studies have begun to use this technique to identify common groups of tobacco product and e-cigarette use (e.g., Gilreath et al., 2016; Harrell, Naqvi, Plunk, Ji, & Martins, 2017; Huh & Leventhal, 2016; Morean et al., 2016; Nasim, Blank, Cobb, &

Eissenberg, 2012; Simon et al., 2017). To date, all of the studies have identified groups of product users among youth populations in the USA (Gilreath et al., 2016; Harrell et al., 2017; Huh & Leventhal, 2016; Morean et al., 2016; Nasim et al., 2012; Simon et al., 2017); there is currently an absence of similar work about polyproduct use data from other jurisdictions. Additionally, to our knowledge, few of these studies have examined the association between class membership and other risk (e.g., alcohol or marijuana use) or protective behaviours (e.g., breakfast consumption or physical activity). Given that historically youth concurrently used more than one tobacco product and products such as e-cigarettes are increasing in reported use (e.g., Gilreath et al., 2016; Huh & Leventhal, 2016), it is important to identify whether there are certain groups of youth that use certain combinations of products and the sociodemographic and behavioural characteristics of these groups. Given these gaps in the literature, this study identified the tobacco product and e-cigarette clusters for three data collection years among a sample of Canadian secondary school students.

7.4 Materials and methods

COMPASS is a prospective cohort study (2012-2021) that collects hierarchical longitudinal data from a convenience sample of Canadian 9th to 12th grade students (Leatherdale, Brown, et al., 2014). The current study reports longitudinal student-level linked data from Year 2 (2013-14), Year 3 (2014-15), and Year 4 (2015-16) of the COMPASS host study. Consistent with our previous analysis (Cole, Kennedy, Chaurasia, & Leatherdale, 2017), "baseline" for the present study included data from Year 2 when students were in 9th grade, "Follow-up Year 1" (FY1) included data from Year 3 when students were in 10th grade, and "Follow-up Year 2" (FY2) included data from Year 4 when students were in 11th grade. Due to the substantially smaller sample size during initial rollout of the study and the fact that e-cigarette use data were not initially collected in the questionnaire, Year 1 data (2012-13) are not included. A full description of the COMPASS study and its methods is available online (www.compass.uwaterloo.ca) and in print (Leatherdale, Brown, et al., 2014). The COMPASS study received ethics approval from the University of Waterloo Research Ethics Board, as well as participating school board review panels.

7.4.1 Sample selection

Student data were linked over time using a unique code generated by each student (Bredin & Leatherdale, 2013). Only students that identified being in 9th grade at Baseline and that had data for each follow-up year were included, leaving a sample of 4651 students from 70 secondary schools in Ontario, Canada (linked sample; 41.3% of participating students); 6602 students did not have data for each follow-up year (unlinked sample).

7.4.2 Measures

The COMPASS questionnaire (Cq) items have demonstrated reliability and validity for current smoking among youth (Wong et al., 2012). Current tobacco cigarette use was measured with a single question: "On how many of the last 30 days did you smoke one or more cigarettes?" Students that reported using cigarettes on at least one of the last 30 days were identified as "current users", while students that did not report using cigarettes on at least one of the last 30 days (including never users) were identified as "non-current users". Similarly, experimentation with alternative tobacco products and e-cigarettes was measured with a single multi-item question that measured past 30-day use of each product (e.g., e-cigarettes, cigarillos or little cigars, cigars, pipe tobacco, smokeless tobacco, and hookah) among respondents. For each alternative tobacco product or e-cigarette, those that reported using a product within the last 30 days were identified as "current users", while students that did not report using the product within the last 30 days were identified as "non-current users". For our analyses, respondents that indicated using hookah to smoke tobacco or to smoke herbal sheesha/shisha were combined and identified as "hookah users".

The Cq also collects student-level sociodemographic and behavioural data consistent with national tobacco surveillance tools (Elton-Marshall et al., 2011). We controlled for baseline gender and race and explored the influence of current spending money (i.e., amount of spending money reported at each year) on class membership at each year. Social environmental factors can influence the availability of tobacco/nicotine products for youth. Measures of interest included the number of friends that smoke tobacco cigarettes reported at each year and the school connectedness score at each year [continuous score between 6 and 24, with higher scores indicating greater school connectedness (Azagba & Asbridge, 2013)]. Behavioural factors of interest included both substance use measures and non-substance use measures. It is well-established that youth commonly use multiple substances, including tobacco/nicotine products, alcohol, and marijuana (Costello, Leatherdale, Ahmed, Church, & Cunningham, 2012; Leatherdale & Burkhalter, 2012). Therefore, we included self-reported binge drinking and marijuana use at each year. We also included the number of classes skipped in the last 4 weeks reported at each year. Finally, we included the number of school days breakfast was eaten reported at each year and the amount of time spent doing moderate and/or vigorous physical activity over the past week at each year as possible protective factors.

7.4.3 Analysis

Self-reported tobacco product and e-cigarette use was identified at each year. Simple descriptive statistics identified the prevalence of use of each product at each year and the number of products used in the last 30 days at each year. We used latent class analyses (LCA) to identify mutually exclusive groups

of individuals based on similar responses to a measured variable (Lanza et al., 2007; Quek et al., 2013). LCA uses maximum likelihood to estimate parameters (Lanza et al., 2007). We used a step-wise process that compared the fit of a model with *k* classes to a model with *k*-1 classes to identify the best fitting model. Consistent with previous research (Lanza et al., 2007; Quek et al., 2013), we used the Bayesian Information Criterion (BIC) and the model-adjusted BIC (adj-BIC) to identify the best fitting model, while considering the values of the average posterior probabilities and model interpretability. Consistent with previous research, probabilities between 0.50 and 1.00 were considered "high", those between 0.10 and 0.49 were "moderate", and those between 0.00 and 0.09 were considered "near-zero" (Harrell et al., 2017). At each year, we identified the number of latent classes that best described the data using PROC LCA in SAS. We controlled for student-level clustering within schools during model selection.

Each student was assigned to a single class at each year based on the latent class with the highest posterior probability. Descriptive statistics examined the characteristics of students within each class at each year. We tested for differences in the characteristics of members of each class using chi-square tests. Due to low response numbers across many measures, responses within explanatory variables were collapsed across categories. Multinomial logistic regression models for nominal outcomes (using PROC GLIMMIX) identified the sociodemographic and behavioural characteristics of students in classes, using the non-current use class as a reference group at each data collection year. All regression models controlled for student-level clustering within schools. SAS version 9.4 was used for all analyses.

7.5 Results

Overall, 25.1% of students reported currently using a tobacco product or e-cigarette at some point during the study period. Figure 7 presents the prevalence of current tobacco product and e-cigarette use at each data collection year. The most frequently used products throughout the study period were tobacco cigarettes, e-cigarettes, and cigarillos or little cigars (CLCs). The prevalence of current use of most products almost doubled between baseline and FY1, and almost tripled between baseline and FY2. By FY2, 18.8% of students reported currently using a tobacco product or e-cigarette. Most notably, the prevalence of current use of e-cigarettes surpassed that of tobacco cigarettes at baseline and in FY1 before matching that of tobacco cigarettes in FY2.

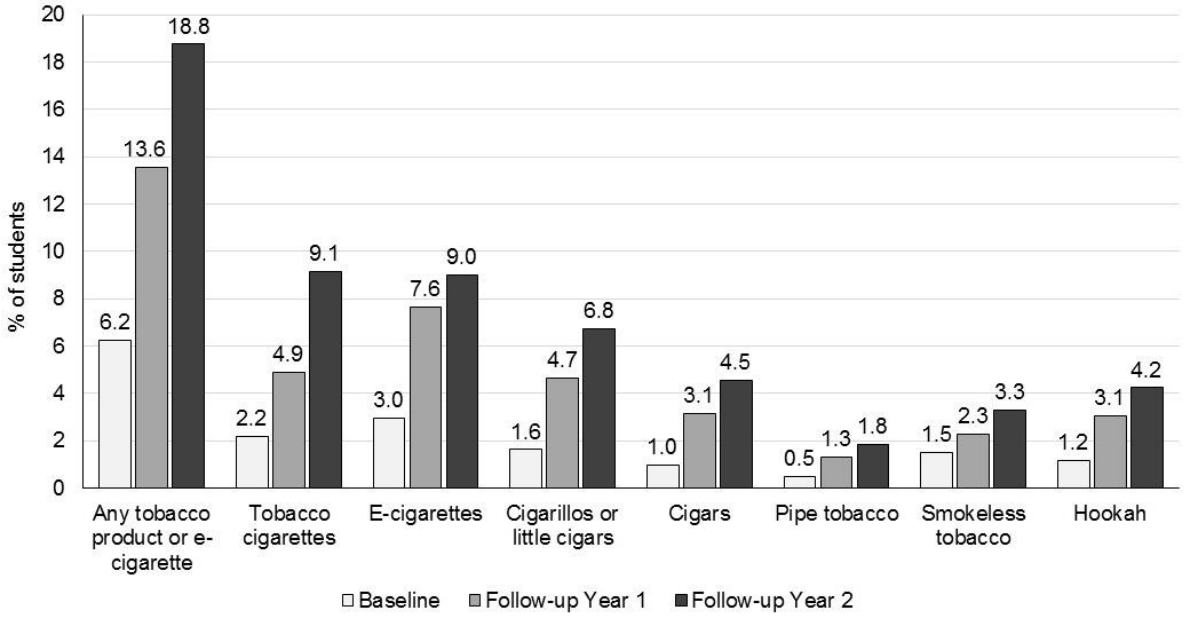

Figure 7. Self-reported tobacco product and e-cigarette use in the last 30 days at baseline, Follow-up Year 1, Follow-up Year 2, 2013-16 COMPASS study

Table 10 presents the proportion of students that reported using one or more products within the last 30 days at baseline, FY1, and FY2, overall and by gender. Over time, fewer students reported using zero products within the last 30 days and more students reported using multiple products within the last 30 days; this was particularly true for male students relative to female students.

Table 10. Number of products used in the last 30 days at baseline, Follow-up Year 1, and Follow-up Year 2, 2013-16 COMPASS study

Number of products used*	Baseline (%)			Follow-up Year 1 (%)			Follow-up Year 2 (%)		
	Overall	Female	Male	Overall	Female	Male	Overall	Female	Male
0	93.8	94.37	93.09	86.4	89.54	83.06	81.3	85.58	76.64
1	3.7	3.33	4.15	7.1	6.34	7.85	9.6	8.59	10.61
2	1.6	1.58	1.56	3.2	2.58	3.79	4.0	3.50	4.64
3	0.5	0.33	0.58	1.6	0.96	2.27	2.3	1.42	3.25
4+	0.5	0.38	0.62	1.8	0.58	3.03	2.8	0.92	4.86

*possible products included: tobacco cigarettes, e-cigarettes, cigarillos or little cigars, cigars, pipe tobacco, smokeless tobacco, or hookah

Fit statistics for the class models at baseline, FY1, and FY2 can be found in Supplementary Table 20. Based on the low BIC, low adj-BIC, the average posterior probabilities, and the ease of model interpretability, a 3-class model was selected as the best fitting model at baseline, a 4-class model was

selected in FY1, and a 4-class model was selected in FY2. Figure 8a-c presents the probabilities of currently using each tobacco product or e-cigarette for the 3-class (baseline) and 4-class models (FY1, FY2). Notably, there was a difference in the number and types of classes that were identified at each year. At baseline, the identified classes were (1) non-current users (94.9%); (2) current tobacco cigarette, cigarillo or little cigar (CLC), and e-cigarette users (4.7%); and (3) current polyproduct users (0.3%). At FY1, identified classes were (1) non-current users (89.7%); (2) current e-cigarette users (5.2%); (3) current dual tobacco cigarette and CLC users (4.3%); and (4) current polyproduct users (0.8%). At FY2, identified classes were (1) non-current users (86.6%); (2) current dual tobacco cigarette and e-cigarette users (9.7%); (3) current tobacco cigarette, CLC, cigar, and e-cigarette users (2.7%); and (4) current polyproduct users (1.0%). A non-current user and a polyproduct user class were consistently identified across all three years. While an exclusive tobacco cigarette use class was not apparent in these analyses, an exclusive e-cigarette use class was first apparent in FY1 but did not remain in FY2.

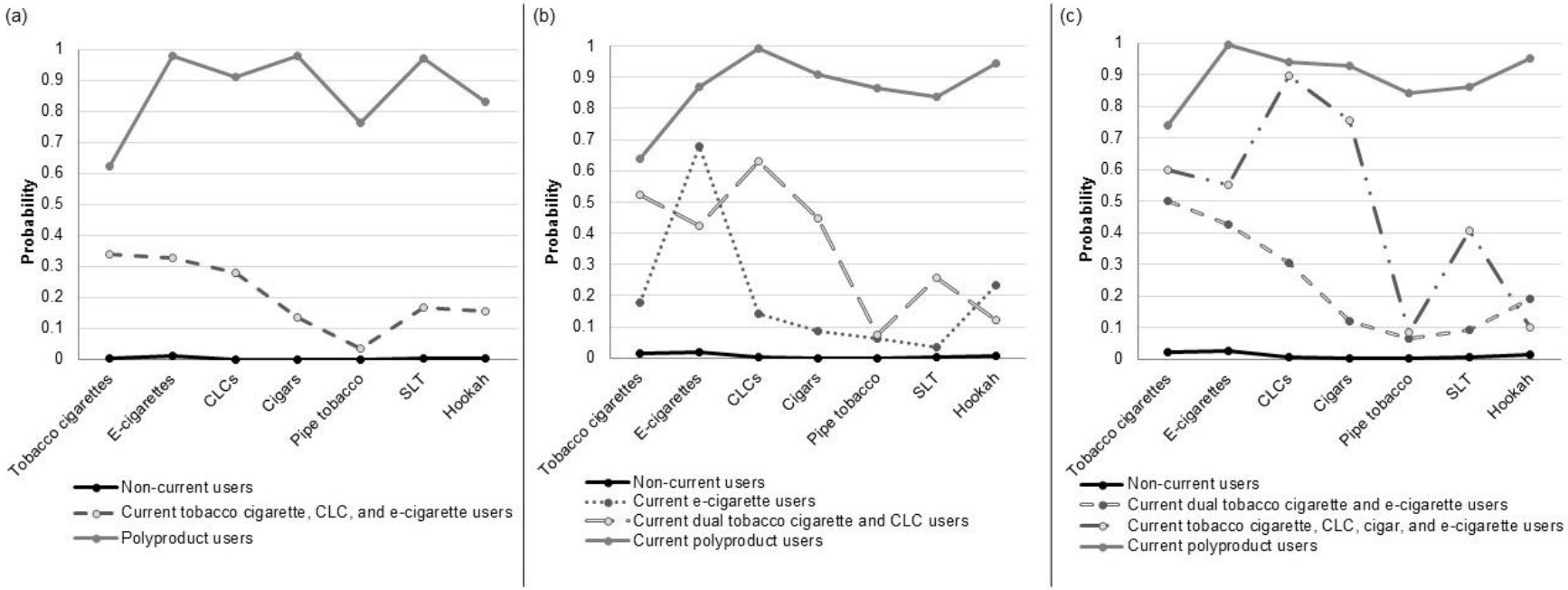

Figure 8. Probabilities of using each tobacco product or e-cigarette (in the last 30 days) (a) for the 3-class model at baseline, (b) for the 4 class model at Follow-up Year 1, and (c) for the 4 class model at Follow-up Year 2, 2013-16 COMPASS study

Descriptive statistics for characteristics of students in the identified classes at each year can be found in Supplementary Table 21-Supplementary Table 23. Table 11-Table 13 present the multinomial logistic regression model results comparing the characteristics at baseline of students in the current use classes against those in the non-current use classes at each data collection year. Results from these repeated cross-sectional analyses suggest that having friends that smoked cigarettes was associated with higher odds of being classified into a current use class [Odds Ratio (OR) 1.61-5.68]. Students that reported ever binge drinking and ever using marijuana also had higher odds of being classified into a current use class (OR 3.29-7.67 and OR 4.05-32.11, respectively). Finally, students that reported skipping classes in the last 4 weeks had higher odds of being classified into a current use class (OR 1.57-3.95).

Table 11. Student-level sociodemographic and behavioural characteristics associated with membership in current use classes relative to the non-current use class (reference) at baseline, 2013-14 COMPASS study

		CLASS 2 Current cigarette, CLC, and e-cigarette users	**CLASS 3** Current polyproduct users
		OR (95%CI)	OR (95%CI)
Environmental variables			
Number of friends that smoke cigarettes	None	1.00	1.00
	Any	3.06 (2.04, 4.59)***	3.76 (0.89, 15.79)
School connectedness score (each unit increase)		0.92 (0.86, 0.98)**	0.90 (0.73, 1.11)
Behavioural factors (substance use)			
Binge drinking status	Never binged	1.00	1.00
	Ever binged	3.44 (2.23, 5.32)***	1.79 (0.44, 7.20)
Marijuana use status	Never used marijuana	1.00	1.00
	Ever used marijuana	9.97 (6.54, 15.21)***	8.17 (1.79, 37.32)**
Behavioural factors (non-substance use)			
Number of classes skipped in the last 4 weeks	None	1.00	1.00
	Any	1.94 (1.24, 3.02)**	3.95 (1.02, 15.27)*
Number of school days ate breakfast	Less than 5 days	1.00	1.00
	Everyday (5 days)	0.78 (0.51, 1.20)	0.98 (0.25, 3.92)
Meets Canadian physical activity recommendations	No	1.00	1.00
	Yes	1.00 (0.68, 1.48)	0.67 (0.18, 2.49)
Sociodemographic characteristics			
Gender	Female	1.00	1.00
	Male	1.37 (0.91, 2.05)	1.73 (0.45, 6.69)
Ethnicity	White	1.00	1.00

		CLASS 2 Current cigarette, CLC, and e-cigarette users	**CLASS 3** Current polyproduct users
	Other	1.56 (1.01, 2.41)*	3.98 (0.99, 15.99)
Spending money	Zero / I Don't Know	1.00	1.00
	$1-$20	0.99 (0.61, 1.59)	2.15 (0.40, 11.47)
	More than $20	1.46 (0.88, 2.42)	1.33 (0.18, 9.69)

* p<0.05 ** p<0.01 *** p<0.001
Model: Class 2 (n=155) versus Class 1 (n=4147)
Model: Class 3 (n=12) versus Class 1 (n=4147)
All models controlled for student-level clustering within schools (n=70)

Table 12. Student-level sociodemographic and behavioural characteristics associated with membership in current use classes relative to the non-current use class (reference) at Follow-up Year 1, 2014-15 COMPASS study

		CLASS 2 Current e-cigarette users	**CLASS 3** Current dual tobacco cigarette and CLC users	**CLASS 4** Current polyproduct users
		OR (95%CI)	OR (95%CI)	OR (95%CI)
Environmental variables				
Number of friends that smoke cigarettes	None	1.00	1.00	1.00
	Any	1.61 (1.20, 2.17)**	5.02 (3.32, 7.57)***	5.68 (2.25, 14.36)***
School connectedness score (each unit increase)		0.94 (0.90, 0.99)*	0.96 (0.90, 1.02)	0.86 (0.77, 0.97)*
Behavioural factors (substance use)				
Binge drinking status	Never binged	1.00	1.00	1.00
	Ever binged	3.29 (2.33, 4.64)***	7.67 (4.12, 14.28)***	4.64 (1.24, 17.36)*
Marijuana use status	Never used marijuana	1.00	1.00	1.00
	Ever used marijuana	4.05 (2.96, 5.55)***	5.87 (3.79, 9.07)***	32.11 (7.09, 145.41)***
Behavioural factors (non-substance use)				
Number of classes skipped in the last 4 weeks	None	1.00	1.00	1.00
	Any	1.57 (1.14, 2.17)**	1.76, 1.17, 2.66)**	1.89, 0.81, 4.44)
Number of school days ate breakfast	Less than 5 days	1.00	1.00	1.00
	Everyday (5 days)	0.95, 0.71, 1.28)	1.20 (0.80, 1.79)	1.25 (0.54, 2.91)
Meets Canadian physical activity recommendations	No	1.00	1.00	1.00
	Yes	0.99 (0.75, 1.32)	1.49 (0.99, 2.24)	1.53 (0.61, 3.83)
Sociodemographic characteristics				
Gender	Female	1.00	1.00	1.00
	Male	2.11 (1.57, 2.83)***	6.95 (4.40, 10.99)***	23.35 (6.49, 84.07)***
Ethnicity	White	1.00	1.00	1.00

		CLASS 2 Current e-cigarette users	**CLASS 3** Current dual tobacco cigarette and CLC users	**CLASS 4** Current polyproduct users
	Other	1.11 (0.80, 1.55)	0.53 (0.31, 0.92)*	0.30 (0.08, 1.07)
Spending money	Zero / I Don't Know	1.00	1.00	1.00
	$1-$20	1.63 (1.12, 2.36)*	1.18 (0.66, 2.09)	0.87 (0.22, 3.44)
	More than $20	1.44 (0.98, 2.10)	1.97 (1.17, 3.34)*	3.20 (1.04, 9.85)*

* p<0.05 ** p<0.01 *** p<0.001
Model 1: Class 2 (n=252) versus Class 1 (n=3911)
Model 2: Class 3 (n=151) versus Class 1 (n=3911)
Model 3: Class 4 (n=31) versus Class 1 (n=3911)
All models controlled for student-level clustering within schools (n=70)

Table 13. Student-level sociodemographic and behavioural characteristics associated with membership in current use classes relative to the non-current use class (reference) at Follow-up Year 2, 2015-16 COMPASS study

		CLASS 2 Current dual cigarette and e-cigarette users	**CLASS 3** Current cigarette, CLC, cigar, and e-cigarette users	**CLASS 4** Current polyproduct users
		OR (95%CI)	OR (95%CI)	OR (95%CI)
Environmental variables				
Number of friends that smoke cigarettes	None	1.00	1.00	1.00
	Any	3.36 (2.51, 4.51)***	4.30 (2.73, 6.78)***	4.22 (1.92, 9.28)***
School connectedness score (each unit increase)		0.96 (0.92, 1.00)	1.03 (0.97, 1.10)	0.94 (0.86, 1.03)
Behavioural factors (substance use)				
Binge drinking status	Never binged	1.00	1.00	1.00
	Ever binged	4.91 (2.95, 8.19)***	4.97 (2.21, 11.18)***	1.60 (0.61, 4.18)
Marijuana use status	Never used marijuana	1.00	1.00	1.00
	Ever used marijuana	6.04 (4.21, 8.66)***	8.03 (4.54, 14.19)***	10.67 (3.53, 32.21)***
Behavioural factors (non-substance use)				
Number of classes skipped in the last 4 weeks	None	1.00	1.00	1.00
	Any	2.47 (1.85, 3.30)***	1.46 (0.96, 2.24)	3.41 (1.57, 7.37)**
Number of school days ate breakfast	Less than 5 days	1.00	1.00	1.00
	Everyday (5 days)	0.77 (0.57, 1.05)	1.22 (0.97, 1.89)	0.98 (0.47, 2.05)
Meets Canadian physical activity recommendations	No	1.00	1.00	1.00
	Yes	1.20 (0.91, 1.58)	1.45 (0.94, 2.24)	0.96 (0.47, 1.93)
Sociodemographic characteristics				
Gender	Female	1.00	1.00	1.00

		CLASS 2 Current dual cigarette and e-cigarette users	**CLASS 3** Current cigarette, CLC, cigar, and e-cigarette users	**CLASS 4** Current polyproduct users
	Male	2.17 (1.63, 2.89)***	7.85 (4.57, 13.50)***	13.36 (4.58, 38.98)***
Ethnicity	White	1.00	1.00	1.00
	Other	1.24 (0.88, 1.75)	0.79 (0.44, 1.41)	1.62 (0.74, 3.52)
Spending money	Zero / I Don't Know	1.00	1.00	1.00
	$1-$20	1.18 (0.74, 1.89)	1.03 (0.43, 2.50)	0.88 (0.23, 3.41)
	More than $20	1.42 (0.97 ,2.08)	2.54 (1.30, 4.96)**	2.02 (0.75, 5.47)

* p<0.05 ** p<0.01 *** p<0.001
Model 1: Class 2 (n=288) versus Class 1 (n=3943)
Model 2: Class 3 (n=116) versus Class 1 (n=3943)
Model 3: Class 4 (n=36) versus Class 1 (n=3943)
All models controlled for student-level clustering within schools (n=70)

7.6 Discussion

Tobacco product and e-cigarette use continues to be prevalent among youth populations in Ontario. The data in this study indicate that one quarter of youth reported currently using a tobacco product and/or e-cigarette at some point during the study period, and almost 1 in 10 youth reported currently using multiple products when they were in 11th grade. Additionally, the prevalence of use of each product significantly increased over time; between 9th and 10th grade the prevalence of use of many products doubled, and between 9th and 11th grade the prevalence of use of many products tripled. The current study took a novel approach to detecting cross-sectional latent classes of tobacco product and e-cigarette use across three waves of a large longitudinal study. By identifying classes of product use for a cohort of students over time, we discovered different classes of products used by students at each data collection year, suggesting that tailored tobacco prevention messaging may be necessary for students in different grades to address the use of popular products. Furthermore, given the dramatic increases in current use over time, consistent prevention messaging may be important throughout secondary school to discourage the initiation and escalation of tobacco product and e-cigarette use.

Interestingly, consistent with results from the USA (e.g., Gilreath et al., 2016; Huh & Leventhal, 2016; Morean et al., 2016; Simon et al., 2017) an exclusive tobacco cigarette group was not apparent in these analyses, and tobacco cigarette smoking was more often grouped with the use of other tobacco products and e-cigarettes. There are a variety of possible reasons for polyproduct use being common in these data, including increased experimentation with various products in this age group, policies that restrict access to tobacco cigarettes [including tobacco taxes, clean-air policies, and age restrictions (Levy, Chaloupka, & Gitchell, 2004)], and perceptions of reduced harm for other tobacco products and e-cigarettes (Choi et al., 2012; Smith et al., 2011; Wray et al., 2012). It is clear that school-based prevention

and cessation programs should address the use of other tobacco products and e-cigarettes in addition to tobacco cigarettes; additional approaches are needed to prevent youth from experimenting with various products during secondary school given the negative effects of nicotine on the developing brain (Smith et al., 2015; Yuan et al., 2015) and the risk of long-term addiction.

Consistent with previous research (Gilreath et al., 2016; Huh & Leventhal, 2016; Morean et al., 2016; Simon et al., 2017), the current analysis identified a group of non-current users at each year, and this class had the largest membership at each year. However, the data also indicate that membership in this class decreased over time as students progressed through secondary school and tried various tobacco products and/or e-cigarettes. Given that many youth did not report using a tobacco product or e-cigarette in the last 30 days, additional research should identify protective factors among this group of students and novel school-based prevention approaches that could prevent future use of products. Furthermore, given the fluid nature of tobacco product and e-cigarette use in this age group, additional research is needed to identify the various products and trajectories of use to differentiate between experimental users (that try a product but do not continue using it) and regular users (that try a product and become addicted). Understanding those who transition into new product use, or even more importantly, out of using products, would be valuable insight for informing future prevention initiatives.

Similarly, the current analysis identified polyproduct users every year, which also supports previous findings (Gilreath et al., 2016; Harrell et al., 2017; Huh & Leventhal, 2016; Morean et al., 2016; Simon et al., 2017). Polyproduct use was common in this age group, and there was always a subgroup of youth that were at highest risk of using multiple products. These youth might be at higher risk of nicotine dependence given their use of other tobacco products or e-cigarettes in addition to tobacco cigarettes (Timberlake, 2008). Previous evidence indicates that polyproduct users are more likely to report tobacco cravings within the first five minutes of waking up in the morning, one sign of nicotine dependence (Harrell et al., 2017). Membership in the polyproduct use class also increased over time as students progressed through secondary school and tried additional products. Prevention programs should draw awareness to the risks of using any tobacco product or e-cigarette, while cessation activities should address and discourage the use of other tobacco products and e-cigarettes in addition to tobacco cigarettes.

In addition to identifying clusters of product use, this study identified behavioural characteristics associated with membership in each class. These data indicate that peer influences are important for using tobacco products and e-cigarettes. Students that reported having friends that smoked cigarettes were consistently more likely to be classified into a current use class and particularly into the polyproduct use class. Friend groups may influence the decision to use tobacco products or e-cigarettes by providing access to novel products and opportunities to experiment with various products, particularly in social

situations (Hammal et al., 2016; Richter, Caraballo, Gupta, & Pederson, 2008). Additional research is needed to identify both where various tobacco products and e-cigarettes are obtained and when these products are commonly used by youth. This knowledge could then inform policies that restrict access to these products by youth and programs that discourage the use of these products by youth.

It is well established that risk behaviours tend to cluster together, and in addition to tobacco products and e-cigarettes, many youth experiment with alcohol and marijuana. In the current study, students that reported binge drinking and using marijuana were consistently more likely to be classified into a current use class and particularly into the polyproduct use class. This association was stronger for marijuana use rather than binge drinking. By inhibiting decision-making, both alcohol and marijuana may encourage the use of tobacco products and e-cigarettes. Tobacco may also be mixed with marijuana when it is smoked, aiding in the development of nicotine addiction (Humfleet & Haas, 2004). It is clear that multi-substance use school and community programming is important. Additional data are needed to identify the pathways between tobacco product and e-cigarette use and marijuana use, particularly given the pending legalization of marijuana in Canada (Canada & Health Canada, 2016).

7.6.1 Strengths and limitations

This study fills a much needed research gap with respect to the use of tobacco products and e-cigarettes among youth in Canada, particularly given the recent popularity of e-cigarette use. To our knowledge, this study represents the first in Canada to identify latent classes of tobacco product and e-cigarette use among secondary school students. The longitudinal design of this study is a unique approach to identifying latent classes of product use over time in a cohort of youth. The Cq collects data on a range of health behaviours and the use of multiple products, which allowed us to include a variety of tobacco products when identifying latent classes. Furthermore, we were able to investigate the association between latent class membership and other health behaviours, which has largely been absent in the literature.

Although there are many strengths with this study, there are some limitations. We were limited in our measure of alternative tobacco product and e-cigarette use (i.e., use within the last 30 days), which may not represent usual use of these products. Furthermore, this measure does not provide any indication of frequency of use or whether products are used individually or in combination. Future research should explore how and when these products are used. The use of a longitudinal sample may have influenced the latent classes that we found, particularly given that tobacco users tend to drop out of longitudinal studies (Siddiqui et al., 1996) and risk behaviours tend to cluster together (Fix et al., 2014; Morean et al., 2016). LCA is a relatively new analysis technique and there are no standard criteria for model selection, meaning that a different approach and interpretation could identify other classes of product use. However, our

approach was consistent with previous studies that have used LCA. Although this study relied on self-reported smoking behaviours, these measures have been shown to be reliable and valid (Fendrich et al., 2005; Wong et al., 2012) and students were ensured that their responses were confidential. Data collections only occurred yearly and may have missed critical developmental periods or life events that lead to smoking experimentation. Finally, the results may not be generalizable to all youth in Ontario or Canada given that the COMPASS study used a convenience sample of students. Future analyses should verify these findings using additional Canadian data sources.

7.6.2 Conclusions

The prevalence of use of various tobacco products and e-cigarettes increased significantly among youth populations during secondary school, and an increasing number of youth reported using more than one tobacco product or e-cigarette over time. Tobacco cigarette use was more often grouped with other tobacco product and e-cigarette use than on its own. As a result, additional prevention and cessation programs may be necessary to discourage polyproduct use. Some differences in class profiles were identified over three consecutive years, suggesting there may be differences in product preferences as students age. Multi-substance use school and community programming continues to be important given the classes identified and that alcohol and marijuana use were important factors associated with class membership.

Chapter 8

Manuscript 4

Identifying latent trajectory groups describing the use of five tobacco products and e-cigarettes

Status: Submitted to *Journal of Adolescent Health*

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8.1 Brief overview and purpose

The following Chapter includes a copy of the manuscript submitted to *Journal of Adolescent Health*. Supplementary material included with this manuscript submission can be found in Appendix D

Supplementary material from Manuscript 4. Following the initiation of tobacco and nicotine products, youth progress through a series of stages (Flay et al., 1983; Leventhal & Cleary, 1980) that result in different smoking trajectories. Although there is some evidence for the various patterns of use of tobacco cigarettes, there is a lack of evidence for use trajectories of ATNPs. This Chapter builds off previous Chapters by describing the patterns of use of each tobacco and nicotine product. Given the results of Chapter 5 and Chapter 6, measures of susceptibility to future smoking were included when identifying trajectory groups. Identifying the various stages of tobacco and nicotine product use and when they occur could improve the content and delivery timing of tobacco prevention programs to match particular stages of tobacco initiation and experimentation. Additional knowledge of the similarities and differences between the trajectories of various tobacco and nicotine products and the sociodemographic and modifiable factors associated with each trajectory could be informative to school-based tobacco prevention and cessation programs. The objectives of this manuscript were to (1) identify the number of trajectories that describe use patterns of 6 products (i.e., tobacco cigarettes, e-cigarettes, CLCs, cigars, SLT, and hookah), and (2) to identify the characteristics that were associated with membership to each trajectory pattern. This manuscript answered the following research questions:

1. For each tobacco and nicotine product, namely (i) tobacco cigarettes, (ii) e-cigarettes, (iii) CLCs, (iv) cigars, (v) SLT, and (vi) hookah, how many distinct latent trajectory groups described the patterns of use among youth?

2. What individual-level sociodemographic and modifiable characteristics predicted membership to each trajectory group?

8.2 Overview

Purpose: Multiple studies have identified stages in the progression from non-susceptible never smoker to daily smoker; however, similar stages in the use of other tobacco products (including e-cigarettes) are lacking. This study identified the number of trajectories that described use patterns of six tobacco products and identified the characteristics that were associated with membership to each trajectory group.

Methods: This study used longitudinal, linked data from 9th grade students at baseline (n=4651) over three years (2013-2016) of the COMPASS study to identify latent trajectory groups for six tobacco products (cigarettes, e-cigarettes, cigarillos or little cigars, cigars, smokeless tobacco, and hookah). Each student was assigned to a single trajectory group, and multinomial logistic regression models identified the baseline characteristics associated with membership in each trajectory group.

Results: Across all products, five groups of users were identified: *non-susceptible non-users*, *non-susceptible puffers*, *stable low intenders*, *escalating experimenters*, and *consistent current users*. Having friends that smoked cigarettes, use of another tobacco product, binge drinking, marijuana use, skipping classes, and breakfast consumption were factors associated with trajectory group membership.

Conclusions: We identified the same five latent trajectories for the use of each product. Although many students had the highest probability of remaining in the same group over time, some transitions in group membership were evident. Youth in different trajectory groups shared many characteristics in common, but some factors may differentiate between groups. Consistent prevention programming is needed throughout secondary school to discourage tobacco product use.

Implications & contributions: This is the first study that described patterns of e-cigarette, cigarillo or little cigar, cigar, hookah, and smokeless tobacco use. Youth with different use patterns shared many characteristics in common, but some factors differentiated between groups. Prevention programming is needed throughout secondary school to discourage tobacco product use.

Key words: adolescence; latent trajectory analysis; tobacco use; electronic cigarette;

8.3 Background

It is well-established that youth progress through a series of stages of smoking before becoming established cigarette smokers (Flay, d'Avernas, Best, Kersell, & Ryan, 1983; Leventhal & Cleary, 1980). Using latent trajectory analysis, studies have identified the common paths that adolescents take during initiation, experimentation, and cessation of cigarette smoking with the goal of improving the content and delivery timing of tobacco prevention and cessation programs (Audrain-McGovern et al., 2004; Bernat, Erickson, Widome, Perry, & Forster, 2008; Colder et al., 2001; Karp, O'Loughlin, Paradis, Hanley, & DiFranza, 2005; Orpinas, Lacy, Nahapetyan, Dube, & Song, 2015; Pollard, Tucker, Green, Kennedy, & Go, 2010; Rosendahl, Galanti, & Gilljam, 2008; Soldz & Cui, 2002; Stanton, Flay, Colder, & Mehta, 2004). Generally, between three (e.g., White, Johnson, & Buyske, 2000; White, Pandina, & Chen, 2002) and six (e.g., Bernat et al., 2008; Pollard et al., 2010; Soldz & Cui, 2002) trajectory groups of cigarette smoking have been identified; most trajectory analyses report groups of never smokers, experimental smokers, late-onset smokers, and continuous smokers. However, previous studies have only used responses given to measures of cigarette smoking frequency, such as the number of days an individual smoked or the number of cigarettes smoked over a given time period, to identify trajectory groups and have not included measures of risk of future smoking (i.e., susceptibility to smoking) even though non-smokers are the largest identifiable group. Including measures of susceptibility to future smoking when identifying trajectory groups would help to identify the progression from no interest in smoking to experimentation and continued use.

A number of studies have also identified the characteristics of youth in each group to differentiate between trajectory groups. Youth that reported positive attitudes to tobacco use (Bernat et al., 2008; Soldz & Cui, 2002), smoking by parents (Bernat et al., 2008; Colder et al., 2001; Rosendahl et al., 2008) and peers (Audrain-McGovern et al., 2004; Bernat et al., 2008; Karp et al., 2005; Pollard et al., 2010; Rosendahl et al., 2008; Stanton et al., 2004), other substance use (Audrain-McGovern et al., 2004; Orpinas et al., 2015; Soldz & Cui, 2002; Stanton et al., 2004), and lower academic achievement (Audrain-McGovern et al., 2004; Karp et al., 2005; Soldz & Cui, 2002) were more likely to be in a cigarette trajectory group than a non-use group. Furthermore, the strength of these associations was generally higher among those in a higher use group (e.g., continuous smokers) relative to a lower use group (e.g., experimental smokers). Additional knowledge of the characteristics associated with membership in each trajectory, and particularly factors that protect against membership in trajectories that lead to tobacco product use, could be informative to current tobacco prevention and cessation programs.

Although there has been considerable attention on the various stages in cigarette smoking progression and development, there is a lack of evidence for similar stages in the use of other tobacco products (e.g., e-cigarettes, cigarillos or little cigars, hookah) and the characteristics that differentiate between trajectory groups. Given evidence of a "risk behaviour syndrome", where risk behaviours tend to cluster together (Jessor, 1991), it is possible that youth tobacco product users share many characteristics in common regardless of the type of product they use. To our knowledge, only a single study of Swedish youth examined trajectories for a tobacco product other than cigarettes (Rosendahl et al., 2008). This study identified three trajectory groups for snus use among a sample of Swedish students: (1) sustained trial users, (2) late escalaters, and (3) early escalaters (Rosendahl et al., 2008). This study also identified a variety of characteristics that differentiated between trajectory groups. Female students were less likely to be in trajectories of high snus use, while students with at least one parent that used tobacco were more likely to be in trajectories of high snus use (Rosendahl et al., 2008).

Given the lack of evidence for patterns of use of other tobacco products, the objectives of this study were to (1) identify the number of trajectories that described use patterns of six tobacco products (cigarettes, e-cigarettes, cigarillos or little cigars, cigars, hookah, and smokeless tobacco), and (2) to identify the characteristics that were associated with membership to each trajectory pattern, among a cohort of Canadian secondary school students.

8.4 Methods

8.4.1 Sample selection

The current study used longitudinal, linked data from three years (2013-2016) of the COMPASS study (Leatherdale, Brown, et al., 2014). Consistent with our previous analysis (Cole et al., 2017), "baseline" included data from Year 2 (2013-2014) when students were in 9th grade, "Follow-up Year 1" (FY1) included data from Year 3 (2014-2015) when students were in 10th grade, and "Follow-up Year 2" (FY2) included data from Year 4 (2015-2016) when students were in 11th grade. Year 2 was the first year that e-cigarette use data were collected. Using a unique code generated by each student (Bredin & Leatherdale, 2013), a sample of 4651 students in 9th grade at baseline, from 70 secondary schools in Ontario, Canada, that had data for each follow-up year were linked over time (41.3% of participating students). A full description of the COMPASS study and its methods is available online (www.compass.uwaterloo.ca) and in print (Leatherdale, Brown, et al.,

2014). The COMPASS study received ethics approval from the University of Waterloo Research Ethics Board, as well as participating school board review panels.

8.4.2 Measures

The COMPASS questionnaire (Cq) includes items with demonstrated reliability and validity for tobacco use among youth (Cole et al., 2017; Wong et al., 2012). Smoking susceptibility was assessed using three previously validated measures (Cole et al., 2017; Pierce, Choi, Gilpin, Farkas, & Merritt, 1996). Students responded to each question on a Likert scale ranging from "definitely not" to "definitely yes". Current cigarette use was measured with a single question: "On how many of the last 30 days did you smoke one or more cigarettes?" Students that reported using cigarettes on at least one of the last 30 days were identified as "current users", while students that did not report using cigarettes on at least one of the last 30 days (including never users) were identified as "non-current users". A measure of current versus non-current cigarette use rather than frequency of use was used to be consistent with our measures of other tobacco product use. Experimentation with other tobacco products was measured with a single multi-item question that measured past 30-day use of each product of interest (i.e., e-cigarettes, cigarillos or little cigars, cigars, hookah, and smokeless tobacco). For each product, those that reported using within the last 30 days were identified as "current users", while students that did not report using the product within the last 30 days were identified as "non-current users". For our analyses, respondents that indicated using hookah to smoke tobacco or to smoke herbal sheesha/shisha were combined and identified as "hookah users".

The Cq also collects student-level sociodemographic and behavioural data consistent with national tobacco surveillance tools (Elton-Marshall et al., 2011). Students reported their gender, ethnicity, and the amount of spending money at baseline. Consistent with Problem Behaviour Theory (Jessor & Jessor, 1977), we were interested in identifying risk and protective factors that influence tobacco use trajectory membership. Social environmental factors of interest included the number of friends that smoke tobacco cigarettes (none vs any) and the school connectedness score at baseline [continuous score between 6 and 24, with higher scores indicating greater school connectedness (Azagba & Asbridge, 2013)]. Given that youth commonly use multiple substances (Costello et al., 2012; Leatherdale & Burkhalter, 2012), we included self-reported binge drinking (never vs ever) and marijuana use (never vs ever) at baseline. We also included a measure of current use of any other tobacco product other than the product included in the trajectory analysis to examine the use of multiple products. Other factors of interest included the number of classes skipped in the last 4 weeks

(none vs any), the number of school days breakfast was eaten (less than 5 days vs 5 days), and whether the student met Canadian recommendations for weekly physical activity at baseline [no vs yes (Tremblay et al., 2016)].

8.4.3 Analysis

We conducted latent trajectory analysis (LTA, using PROC LTA) to identify distinct groups of individuals based on similar behavioural outcomes over time (Nagin & Tremblay, 2001). This analytic technique models changes in the development of a behaviour over time and identifies the best number of groups that describe the data (Nagin, 1999; Nagin & Tremblay, 2001). We input three measures of smoking susceptibility and one measure of tobacco product use when identifying trajectory groups. LTA uses a mixture modeling approach to identify various group trajectories, estimate the shape of the trajectory, and estimate the proportion of the population that fits within each trajectory (Nagin & Tremblay, 2001). To identify the best fitting model, we used a step-wise process that compared the fit of a model with *k* groups to a model with *k*-1 groups. Consistent with previous research (Nagin, 1999; Nagin & Tremblay, 2001), we used the Bayesian Information Criterion (BIC), average posterior probabilities and model interpretability to evaluate model fit. Models with lower values of the BIC suggest better model fit and were selected over models with higher values of the BIC (Quek et al., 2013). The average posterior probabilities evaluate the quality of the classification based on each individual's probability of being a member of each trajectory group (Nagin, 1999; Quek et al., 2013). Model interpretability considers expert opinion to ensure that each group can be distinguished from each other, the groups have a probability of membership greater than 0%, and a meaningful label can be used to describe each group (Lanza, Collins, Lemmon, & Schafer, 2007).

Each student was assigned to a single trajectory group based on the latent group with the highest posterior probability. Descriptive statistics examined the baseline characteristics of students assigned to each trajectory group. We tested for differences in the characteristics of members of each group using chi-square tests for categorical outcomes and F-tests for continuous outcomes. Multinomial logistic regression models for nominal outcomes (using PROC GLIMMIX) identified the baseline characteristics of students assigned to each trajectory group at baseline, controlling for student reported gender, ethnicity, and baseline spending money, and student-level clustering within schools. SAS version 9.4 was used for all analyses.

8.5 Results

Table 14 presents the fit statistics for latent trajectory models, while Figure 9a-f presents the prevalence of latent groups for models of use for each of the six tobacco products. Based on the low BIC value, the prevalence of latent groups, and the ease of model interpretability, a 5-group model was selected as the best fitting model for each product. Item-response probabilities for each 5-group model can be found in Supplementary Table 24-Supplementary Table 29. The 5 identified groups are:

Group 1 - *Non-susceptible non-users*: over time, students in this group indicated the lowest probability of having ever puffed a cigarette, intentions to smoke in the future, and of current use of a tobacco product

Group 2 - *Non-susceptible puffers*: over time, students in this group indicated a high probability of having ever puffed a cigarette, but low intentions to smoke in the future and a low probability of current use of a tobacco product

Group 3 - *Stable low intenders*: over time, students in this group indicated a low probability of having ever puffed a cigarette, stable low intentions to smoke in the future, and a low probability of current use of a tobacco product

Group 4 - *Escalating experimenters*: over time, more students in this group indicated having ever puffed a cigarette, intentions to smoke in the future, and current use of a tobacco product

Group 5 - *Consistent current users*: over time, students in this group indicated having the highest probability of having ever puffed a cigarette, intentions to smoke in the future, and of current use of a tobacco product

Table 14. Fit statistics for latent trajectory models of tobacco cigarette, e-cigarette, cigarillo or little cigar, cigar, hookah, and smokeless tobacco use, 2013-16 COMPASS study

Number of latent classes	Log-likelihood	Degrees of freedom	AIC	BIC
Tobacco cigarette use				
2	-27906.12	4095928	15448.21	15905.80
3	-24862.69	4095886	9445.34	10173.61
4	-24285.51	4095840	8382.99	9407.72
5	**-23704.37**	**4095790**	**7320.70**	**8667.67**
6	-23492.52	4095736	7005.01	8700.00
7	-23259.17	4095678	6654.31	8723.10
E-cigarette use				

Number of latent classes	Log-likelihood	Degrees of freedom	AIC	BIC
2	-28863.94	4095928	15407.72	15865.30
3	-26486.73	4095886	10737.30	11465.56
4	-25933.02	4095840	9721.88	10746.61
5	**-25427.39**	**4095790**	**8810.62**	**10157.59**
6	-25219.86	4095736	8503.55	10198.54
7	-25019.58	4095678	8218.99	10287.79
Cigarillo or little cigar use				
2	-28042.77	4095928	14717.07	15174.66
3	-25598.58	4095886	9912.71	10640.97
4	-25050.72	4095840	8908.99	9933.71
5	**-24523.09**	**4095790**	**7953.71**	**9300.68**
6	-24313.74	4095736	7643.03	9338.02
7	-24110.42	4095678	7352.38	9421.18
Cigar use				
2	-27491.05	4095928	14077.05	14534.64
3	-25105.99	4095886	9390.94	10119.21
4	-24628.96	4095840	8528.87	9553.60
5	**-24046.12**	**4095790**	**7463.21**	**8810.18**
6	-23839.87	4095736	7158.71	8853.70
7	-23645.10	4095678	6885.17	8953.96
Hookah use				
2	-27544.69	4095928	14166.43	14624.02
3	-25201.52	4095886	9564.09	10292.36
4	-24728.07	4095840	8709.19	9733.92
5	**-24136.29**	**4095790**	**7625.63**	**8972.60**
6	-23940.84	4095736	7342.74	9037.73
7	-23745.34	4095678	7067.73	9136.52
Smokeless tobacco use				
2	-27320.64	4095928	13957.44	14415.03
3	-24978.19	4095886	9356.54	10084.80
4	-24500.03	4095840	8492.22	9516.95
5	**-23918.26**	**4095790**	**7428.69**	**8775.66**
6	-23714.45	4095736	7129.05	8824.04
7	-23518.84	4095678	6853.83	8922.63

Note: bolded line represents the selected model

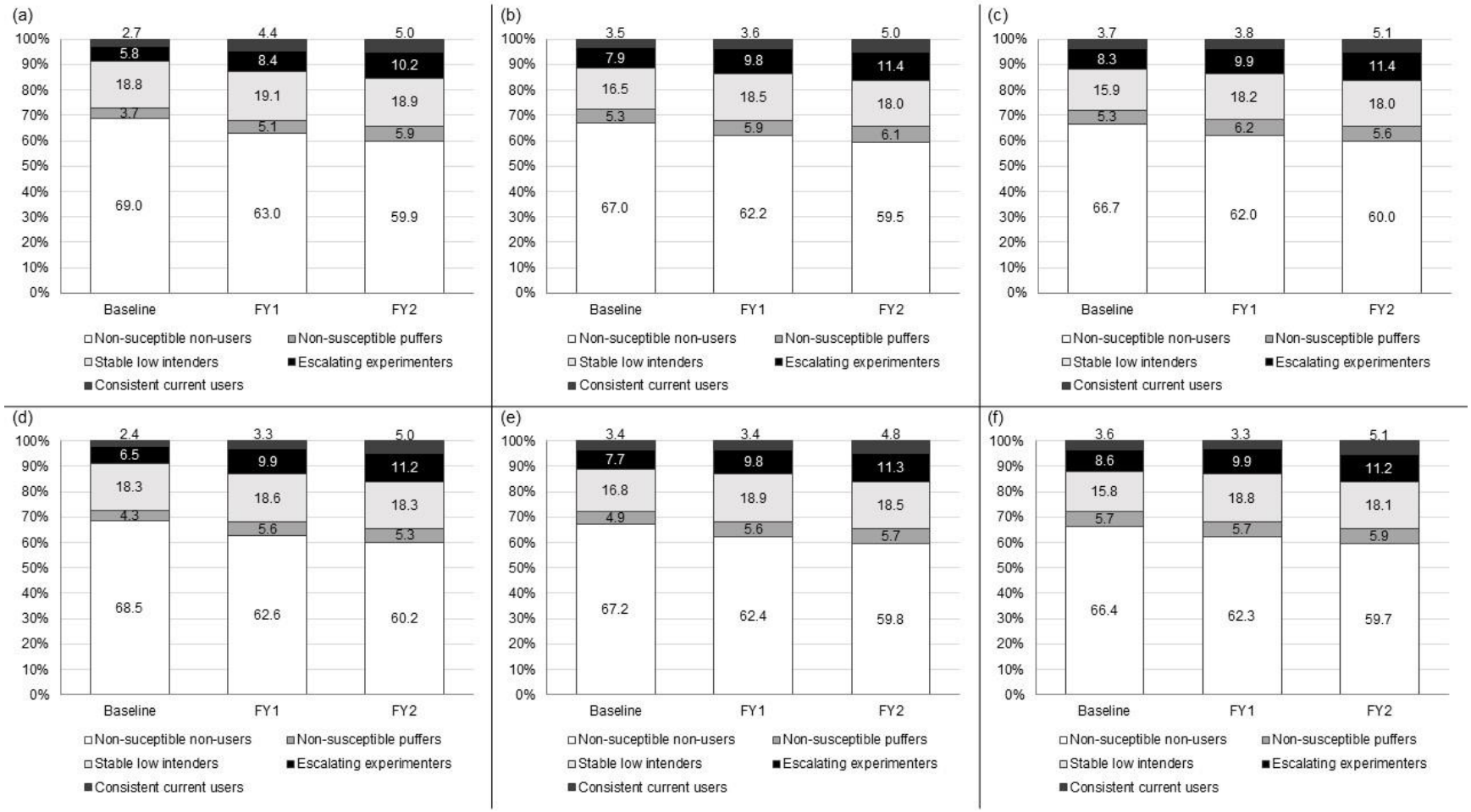


Figure 9. Prevalence of latent trajectory groups for the 5-group model of (a) cigarette use, (b) e-cigarette use, (c) cigarillo or little cigar use, (d) cigar use, (e) hookah use, and (f) smokeless tobacco use, 2013-16 COMPASS study

Table 15 and Table 16 present the transition probabilities between trajectory groups between baseline and FY1 and between FY1 and FY2 for the 5-group models of each tobacco product. Across all products and time points, students had the highest probability of remaining in the same trajectory group; the most stable trajectory group was the *non-susceptible non-users*. Between all time points, students had a moderate probability of transitioning to a lower risk group (from *stable low intenders* to *non-susceptible non-users*, and from *consistent current users* to *escalating experimenters*) or to a higher risk group (from *non-susceptible puffers* to *escalating experimenters*).

Table 15. Transition probabilities between baseline and Follow-up Year 1 for the 5-group models of cigarette, e-cigarette, cigarillo or little cigar, cigar, hookah, and smokeless tobacco use, 2013-16 COMPASS study

	Follow-up Year 1				
Baseline	Non-susceptible non-users	Non-susceptible puffers	Stable low intenders	Escalating experimenters	Consistent current users
Cigarette use					
Non-susceptible non-users	0.8324	0.0164	0.1150	0.0241	0.0121
Non-susceptible puffers	0.0000	0.6595	0.0463	0.2124	0.0818
Stable low intenders	0.2695	0.0458	0.5257	0.1382	0.0208
Escalating experimenters	0.0714	0.0769	0.1889	0.4340	0.2287
Consistent current users	0.0292	0.0780	0.0189	0.2945	0.5795
E-cigarette use					
Non-susceptible non-users	0.8446	0.0113	0.1096	0.0257	0.0088
Non-susceptible puffers	0.0000	0.6422	0.0460	0.2498	0.0620
Stable low intenders	0.3112	0.0152	0.5698	0.1012	0.0026
Escalating experimenters	0.0556	0.1602	0.1738	0.4821	0.1283
Consistent current users	0.0385	0.0622	0.0392	0.3769	0.4832
Cigarillo or little cigar use					
Non-susceptible non-users	0.8420	0.0140	0.1078	0.0265	0.0097
Non-susceptible puffers	0.0088	0.6454	0.0355	0.2468	0.0636
Stable low intenders	0.3242	0.0212	0.5578	0.0963	0.0005
Escalating experimenters	0.0614	0.1457	0.2139	0.4549	0.1241

	Follow-up Year 1				
Baseline	Non-susceptible non-users	Non-susceptible puffers	Stable low intenders	Escalating experimenters	Consistent current users
Consistent current users	0.0363	0.0700	0.0355	0.3926	0.4657
Cigar use					
Non-susceptible non-users	0.8338	0.0166	0.1129	0.0279	0.0089
Non-susceptible puffers	0.0231	0.6332	0.0613	0.2311	0.0513
Stable low intenders	0.2721	0.0419	0.5248	0.1479	0.0134
Escalating experimenters	0.0476	0.1359	0.1523	0.5118	0.1524
Consistent current users	0.0416	0.0522	0.0034	0.3893	0.5135
Hookah use					
Non-susceptible non-users	0.8425	0.0107	0.1123	0.0257	0.0088
Non-susceptible puffers	0.0001	0.6515	0.0523	0.2445	0.0516
Stable low intenders	0.3071	0.0185	0.5709	0.0980	0.0055
Escalating experimenters	0.0592	0.1432	0.1850	0.4984	0.1142
Consistent current users	0.0389	0.0665	0.0382	0.4031	0.4534
Smokeless tobacco use					
Non-susceptible non-users	0.8514	0.0058	0.1112	0.0239	0.0078
Non-susceptible puffers	0.0003	0.6386	0.0458	0.2541	0.0612
Stable low intenders	0.3238	0.0084	0.5917	0.0745	0.0015
Escalating experimenters	0.0674	0.1542	0.1961	0.4799	0.1025
Consistent current users	0.0380	0.0672	0.0420	0.4405	0.4122

Table 16. Transition probabilities between Follow-up Year 1 and Follow-up Year 2 for the 5-group models of cigarette, e-cigarette, cigarillo or little cigar, cigar, hookah, and smokeless tobacco use, 2013-16 COMPASS study

	Follow-up Year 2				
Follow-up Year 1	Non-susceptible non-users	Non-susceptible puffers	Stable low intenders	Escalating experimenters	Consistent current users
Cigarette use					
Non-susceptible non-users	0.8572	0.0147	0.1044	0.0163	0.0075

	Follow-up Year 2				
Follow-up Year 1	Non-susceptible non-users	Non-susceptible puffers	Stable low intenders	Escalating experimenters	Consistent current users
Non-susceptible puffers	0.0390	0.6235	0.0551	0.2306	0.0517
Stable low intenders	0.2751	0.0319	0.5597	0.0899	0.0434
Escalating experimenters	0.0298	0.1081	0.1591	0.5575	0.1456
Consistent current users	0.0481	0.0721	0.0000	0.3702	0.5095
E-cigarette use					
Non-susceptible non-users	0.8654	0.0075	0.1023	0.0171	0.0077
Non-susceptible puffers	0.0208	0.6244	0.0291	0.2726	0.0531
Stable low intenders	0.2797	0.0314	0.5662	0.0877	0.0349
Escalating experimenters	0.0191	0.1135	0.1031	0.6120	0.1523
Consistent current users	0.0487	0.0728	0.0000	0.3131	0.5653
Cigarillo or little cigar use					
Non-susceptible non-users	0.8718	0.0002	0.1028	0.0169	0.0084
Non-susceptible puffers	0.0561	0.6000	0.0305	0.2639	0.0495
Stable low intenders	0.2840	0.0277	0.5674	0.0838	0.0371
Escalating experimenters	0.0226	0.1152	0.1103	0.6080	0.1439
Consistent current users	0.0444	0.0748	0.0000	0.3148	0.5660
Cigar use					
Non-susceptible non-users	0.8666	0.0041	0.1042	0.0164	0.0087
Non-susceptible puffers	0.0581	0.5853	0.0348	0.2718	0.0500
Stable low intenders	0.2775	0.0280	0.5666	0.0901	0.0379
Escalating experimenters	0.0296	0.1001	0.1037	0.6061	0.1606
Consistent current users	0.0459	0.0726	0.0000	0.2989	0.5826
Hookah use					
Non-susceptible non-users	0.8687	0.0025	0.1041	0.0168	0.0079
Non-susceptible puffers	0.0000	0.6539	0.0431	0.2531	0.0499
Stable low intenders	0.2780	0.0319	0.5614	0.0924	0.0365

	Follow-up Year 2				
Follow-up Year 1	Non-susceptible non-users	Non-susceptible puffers	Stable low intenders	Escalating experimenters	Consistent current users
Escalating experimenters	0.0163	0.1096	0.1135	0.6126	0.1480
Consistent current users	0.0461	0.0767	0.0000	0.3136	0.5637
Smokeless tobacco use					
Non-susceptible non-users	0.8630	0.0092	0.1029	0.0163	0.0086
Non-susceptible puffers	0.0491	0.5992	0.0311	0.2730	0.0475
Stable low intenders	0.2773	0.0311	0.5623	0.0910	0.0383
Escalating experimenters	0.0259	0.1027	0.0982	0.6097	0.1635
Consistent current users	0.0443	0.0779	0.0000	0.2766	0.6013

Descriptive statistics for baseline characteristics of students in the identified trajectory groups at baseline can be found in Supplementary Table 30-Supplementary Table 35. Table 17 presents the multinomial logistic regression model results comparing the characteristics at baseline of *non-susceptible non-users* against other trajectory groups for each of the six products. Results from these analyses indicate that across all products and controlling for all other characteristics, having friends that smoked cigarettes was associated with higher odds of being in any other trajectory group at baseline relative to *non-susceptible non-users*, with the highest odds of being a *consistent current user* (OR 7.15-15.50). A higher school connectedness score was associated with lower odds of being in any other trajectory group at baseline relative to *non-susceptible non-users* (OR 0.85-0.94). Students that reported using another tobacco product, ever binge drinking, and ever using marijuana also had higher odds of being in any other trajectory group at baseline relative to *non-susceptible non-users*; of note, ever using marijuana was associated with the highest odds of being a *consistent current user* (OR 9.89-16.47) and a *non-susceptible puffer* (OR 7.42-10.21), while ever binge drinking was associated with the highest odds of being a *consistent current user* (OR 3.13-4.59) and an *escalating experimenter* (OR 3.81-4.18). Students that reported skipping classes in the last 4 weeks had higher odds of being in any other trajectory group at baseline relative to *non-susceptible non-users* (OR 1.59-4.47). Finally, students that reported eating breakfast every day in a usual school week had lower odds of being in any other trajectory group at baseline relative to *non-susceptible non-users* (OR 0.41-0.82).

Table 17. Baseline characteristics associated with trajectory group membership at baseline for each tobacco product and e-cigarette, 2013-14 COMPASS study

	GROUP 2 Non-susceptible puffers	**GROUP 3** Stable low intenders	**GROUP 4** Escalating experimenters	**GROUP 5** Consistent current users
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Cigarette use (Models 1-4)				
Any friends that smoke cigarettes	2.83 (1.95, 4.13)***	1.99 (1.63, 2.43)***	4.33 (3.16, 5.95)***	15.50 (8.27, 29.03)***
Each unit increase in school connectedness score	0.94 (0.88, 1.01)	0.87 (0.85, 0.90)***	0.85 (0.80, 0.89)***	0.86 (0.79, 0.93)***
Any other tobacco product or e-cigarette use	3.08 (1.73, 5.49)***	1.82 (1.19, 2.79)**	2.75 (1.60, 4.72)***	9.52 (4.98, 18.19)***
Ever binge drank	2.35 (1.58, 3.50)***	2.59 (2.12, 3.15)***	3.97 (2.85, 5.52)***	4.59 (2.56, 8.25)***
Ever used marijuana	10.21 (6.43, 16.22)***	1.75 (1.21, 2.53)**	5.72 (3.70, 8.83)***	16.47 (8.90, 30.46)***
Skipped any classes in the last 4 weeks	1.45 (0.86, 2.43)	1.75 (1.32, 2.32)***	2.84 (1.91, 4.21)***	3.77 (2.11, 6.72)***
Ate breakfast every school day (5 days)	0.60 (0.41, 0.87)**	0.80 (0.68, 0.95)*	0.53 (0.38, 0.75)***	0.54 (0.29, 0.99)*
Met Canadian physical activity recommendations	0.87 (0.60, 1.24)	0.86, (0.73, 1.02)	0.76 (0.56, 1.03)	0.74 (0.44, 1.25)
E-cigarette use (Models 5-8)				
Any friends that smoke cigarettes	2.51 (1.78, 3.52)***	1.87 (1.51, 2.33)***	4.10 (3.13, 5.37)***	7.36 (4.66, 11.63)***
Each unit increase in school connectedness score	0.94 (0.88, 0.99)*	0.88 (0.85, 0.91)***	0.86 (0.82, 0.90)***	0.85 (0.79, 0.91)***
Any other tobacco product or e-cigarette use	3.32 (1.75, 6.30)***	1.45 (0.77, 2.70)	4.05 (2.29, 7.17)***	18.30 (8.94, 34.39)***
Ever binge drank	2.75 (1.95, 3.90)***	2.18 (1.76, 2.71)***	3.95 (2.99, 5.22)***	3.62 (2.26, 5.81)***
Ever used marijuana	7.53 (4.85, 11.71)***	1.57 (1.03, 2.40)*	4.84 (3.23, 7.25)***	9.98 (5.84, 17.07)***
Skipped any classes in the last 4 weeks	1.85 (1.17, 2.93)**	1.64 (1.21, 2.24)**	3.00 (2.12, 4.25)***	4.47 (2.74, 7.30)***
Ate breakfast every school day (5 days)	0.65 (0.47, 0.91)*	0.81 (0.68, 0.97)*	0.63 (0.48, 0.83)***	0.44 (0.26, 0.73)**
Met Canadian physical activity recommendations	0.85 (0.62, 1.17)	0.89 (0.74, 1.06)	0.79 (0.61, 1.02)	0.77 (0.50, 1.18)
Cigarillo or little cigar use (Models 9-12)				
Any friends that smoke cigarettes	2.37 (1.67, 3.36)***	1.91 (1.53, 2.37)***	3.63 (2.77, 4.75)***	7.27 (4.68, 11.29)***
Each unit increase in school connectedness score	0.94 (0.89, 1.00)*	0.88 (0.85, 0.89)***	0.85 (0.81, 0.89)***	0.87 (0.81, 0.93)***
Any other tobacco product or e-cigarette use	3.70 (2.12, 6.45)***	1.34 (0.78, 2.30)	4.10 (2.52, 6.68)***	15.46 (8.86, 26.98)***
Ever binge drank	2.98 (2.09, 4.24)***	2.23 (1.79, 2.77)***	3.90 (2.97, 5.14)***	4.28 (2.71, 6.75)***
Ever used marijuana	7.95 (5.09, 12.42)***	1.50 (0.97, 2.31)	4.57 (3.04, 6.87)***	11.33 (6.75, 19.02)***
Skipped any classes in the last 4 weeks	1.84 (1.15, 2.93)*	1.64 (1.20, 2.24)**	2.78 (1.96, 3.95)***	4.11 (2.55, 6.64)***
Ate breakfast every school day (5 days)	0.66 (0.47, 0.92)*	0.82 (0.69, 0.99)*	0.65 (0.50, 0.85)**	0.53 (0.33, 0.85)**
Met Canadian physical activity recommendations	0.91 (0.66, 1.26)	0.85 (0.71, 1.02)	0.88 (0.68, 1.13)	0.82 (0.54, 1.24)

	GROUP 2 Non-susceptible puffers	**GROUP 3** Stable low intenders	**GROUP 4** Escalating experimenters	**GROUP 5** Consistent current users
Cigar use (Models 13-16)				
Any friends that smoke cigarettes	2.91 (2.01, 4.21)***	2.04 (1.67, 2.49)***	4.08 (2.99, 5.57)***	9.57 (5.49, 16.66)***
Each unit increase in school connectedness score	0.94 (0.89, 1.01)	0.87 (0.85, 0.90)***	0.85 (0.81, 0.89)***	0.86 (0.79, 0.93)***
Any other tobacco product or e-cigarette use	2.97 (1.67, 5.28)***	1.62 (1.04, 2.52)*	4.63 (2.83, 7.59)***	13.90 (7.57, 25.53)***
Ever binge drank	2.40 (1.62, 3.55)***	2.55 (2.09, 3.11)***	3.81 (2.75, 5.27)***	3.13 (1.80, 5.45)***
Ever used marijuana	8.99 (5.65, 14.32)***	1.78 (1.22, 2.59)**	5.14 (3.34, 7.92)***	13.48 (7.41, 24.53)***
Skipped any classes in the last 4 weeks	1.55 (0.93, 2.60)	1.79 (1.35, 2.38)***	2.69 (1.82, 3.98)***	4.32 (2.51, 7.45)***
Ate breakfast every school day (5 days)	0.65 (0.45, 0.94)*	0.78 (0.66, 0.93)**	0.60 (0.43, 0.83)**	0.41 (0.22, 0.75)**
Met Canadian physical activity recommendations	0.90 (0.63, 1.28)	0.86 (0.73, 1.02)	0.84 (0.62, 1.13)	0.63 (0.38, 1.03)
Hookah use (Models 17-20)				
Any friends that smoke cigarettes	2.77 (1.93, 3.96)***	1.88 (1.52, 2.33)***	3.75 (2.85, 4.91)***	7.18 (4.53, 11.36)***
Each unit increase in school connectedness score	0.95 (0.90, 1.01)	0.88 (0.85, 0.90)***	0.86 (0.82, 0.90)***	0.85 (0.79, 0.91)***
Any other tobacco product or e-cigarette use	3.09 (1.74, 5.51)***	1.48 (0.90, 2.44)	3.80 (2.35, 6.15)***	15.20 (8.67, 26.66)***
Ever binge drank	2.48 (1.70, 3.61)***	2.21 (1.79, 2.74)***	4.01 (3.04, 5.30)***	3.56 (2.21, 5.74)***
Ever used marijuana	8.81 (5.59, 13.90)***	1.58 (1.05, 2.39)*	4.65 (3.11, 6.95)***	10.74 (6.32, 18.26)***
Skipped any classes in the last 4 weeks	1.59 (0.97, 2.62)	1.59 (1.17, 2.16)**	2.78 (1.96, 3.94)***	3.81 (2.33, 6.22)***
Ate breakfast every school day (5 days)	0.63 (0.44, 0.90)*	0.82 (0.69, 0.98)*	0.63 (0.48, 0.83)**	0.45 (0.27, 0.75)**
Met Canadian physical activity recommendations	0.88 (0.63, 1.24)	0.88 (0.74, 1.05)	0.81 (0.63, 1.05)	0.68 (0.44, 1.05)
Smokeless tobacco use				
Any friends that smoke cigarettes	2.10 (1.51, 2.91)***	1.88 (1.51, 2.34)***	3.64 (2.78, 4.77)***	7.15 (4.57, 11.19)***
Each unit increase in school connectedness score	0.94 (0.89, 1.00)*	0.88 (0.85, 0.91)***	0.85 (0.81, 0.89)***	0.85 (0.80, 0.91)***
Any other tobacco product or e-cigarette use	2.80 (1.54, 5.10)***	1.63 (0.94, 2.83)	4.41 (2.64, 7.34)***	16.31 (9.14, 29.11)***
Ever binge drank	3.23 (2.34, 4.47)***	2.24 (1.80, 2.79)***	4.18 (3.18, 5.50)***	4.44 (2.80, 7.04)***
Ever used marijuana	7.42 (4.81, 11.44)***	1.61 (1.04, 2.49)*	4.69 (3.11, 7.08)***	9.89 (5.81, 16.85)***
Skipped any classes in the last 4 weeks	1.85 (1.19, 2.86)**	1.64 (1.19, 2.24)**	2.76 (1.94, 3.92)***	3.91 (2.41, 6.34)***
Ate breakfast every school day (5 days)	0.74 (0.55, 1.01)	0.81 (0.68, 0.98)*	0.61 (0.46, 0.79)***	0.56 (0.34, 0.90)*
Met Canadian physical activity recommendations	0.90 (0.67, 1.21)	0.87 (0.73, 1.04)	0.83 (0.65, 1.07)	0.81 (0.53, 1.24)

* p<0.05 ** p<0.01 *** p<0.001

All models controlled for student reported gender, ethnicity, and baseline spending money, and student-level clustering within schools (n=70)

Cigarette use Model 1: Group 2 (n=146) versus Group 1 (n=2990); Model 2: Group 3 (n=850) versus Group 1 (n=2990); Model 3: Group 4 (n=225) versus Group 1 (n=2990); Model 5: Group 5 (n=103) versus Group 1 (n=2990)

E-cigarette use Model 5: Group 2 (n=189) versus Group 1 (n=2957); Model 6: Group 3 (n=683) versus Group 1 (n=2957); Model 7: Group 4 (n=340) versus Group 1 (n=2957); Model 8: Group 5 (n=145) versus Group 1 (n=2957)

Cigarillo or little cigar use Model 9: Group 2 (n=181) versus Group 1 (n=2959); Model 10: Group 3 (n=669) versus Group 1 (n=2959); Model 11: Group 4 (n=344) versus Group 1 (n=2959); Model 12: Group 5 (n=161) versus Group 1 (n=2959)
Cigar use Model 13: Group 2 (n=149) versus Group 1 (n=2981); Model 14: Group 3 (n=835) versus Group 1 (n=2981); Model 15: Group 4 (n=241) versus Group 1 (n=2981); Model 16: Group 5 (n=108) versus Group 1 (n=2981)
Hookah use Model 17: Group 2 (n=162) versus Group 1 (n=2969); Model 18: Group 3 (n=703) versus Group 1 (n=2969); Model 19: Group 4 (n=338) versus Group 1 (n=2969); Model 20: Group 5 (n=142) versus Group 1 (n=2969)
Smokeless tobacco use Model 21: Group 2 (n=217) versus Group 1 (n=2927); Model 22: Group 3 (n=666) versus Group 1 (n=2927); Model 23: Group 4 (n=352) versus Group 1 (n=2927); Model 24: Group 5 (n=152) versus Group 1 (n=2927)

8.6 Discussion

A major contribution of the present study was in identifying latent trajectory groups for five tobacco products in addition to cigarettes. Interestingly, we identified five latent trajectories for the use of each product, suggesting that youth tobacco product users share many characteristics regardless of the type of product they use. Consistent with previous research, a non-user group was present [i.e., *non-susceptible non-users* (Bernat et al., 2008; Colder et al., 2001; Orpinas et al., 2015; Pollard et al., 2010; Soldz & Cui, 2002)], with the lowest probability of using any product over the study period, and a current user group was also present [i.e., *consistent current users* (Audrain-McGovern et al., 2004; Colder et al., 2001; Orpinas et al., 2015; Pollard et al., 2010; Soldz & Cui, 2002)], with the highest probability of using any product over the study period. We did not identify a group of students that reduced or stopped product use; however, this was likely due to the short time period of the study and may be visible in later years. Interestingly, a *non-susceptible puffers* group was identified when we included measures of susceptibility when identifying latent trajectories. Although this group had a high probability of ever using cigarettes, these students reported low intentions to smoke in the future. It is possible that these students tried cigarette smoking and did not enjoy it, or they were able to stop smoking early on without intervention (Wellman, DiFranza, Savageau, & Dussault, 2004). From a prevention standpoint, there could be a lot to learn from this group of students about why they first tried cigarette smoking and why they did not continue, which could be useful for prevention programming.

Although many students remained in the same trajectory group over the study period, some students transitioned to a different group. Evidence illustrates that smoking behaviour is fluid and always changing during adolescence (Bernat et al., 2008; Wellman et al., 2004). The most stable group across all products was *non-susceptible non-users*. Although this was an encouraging finding, some students in this group transitioned to a higher risk group. Given that the students included in this study were in secondary school and some transitioned into and out of different trajectory groups, consistent prevention programming is needed throughout adolescence to discourage the initiation and escalation of tobacco products. Future research should identify predictors of transitioning to a higher or lower risk group and contextual factors that increase or decrease the risk of transitioning to a different group to improve current prevention and cessation programming.

Given evidence of a “risk behaviour syndrome”, where risk behaviours tend to cluster together (Jessor, 1991), we included a variety of established risk factors for tobacco use to explore

whether certain characteristics could differentiate baseline membership in different trajectory groups. Although others have suggested that tobacco use may be a warning sign of other risk behaviours and a health-risk pathway (Orpinas et al., 2015), the current results suggest that alcohol and marijuana use may be earlier signs of potential risk of using tobacco products, and the variable odds ratios across trajectory groups may help identify students who may follow a particular use pathway. For example, students that reported ever binge drinking had similar odds of being in different trajectory groups at baseline; identifying those that binge drink may not be useful for predicting students that follow particular product use pathways. In contrast, students that reported ever using marijuana had much higher odds of being *consistent current users* at baseline relative to *escalating experimenters*. Therefore, marijuana use may be a more useful identifier of students at risk for different tobacco product use pathways. Given the pending legalization of marijuana in Canada (Canada & Health Canada, 2016), future studies should continue to monitor the usefulness of such an approach.

Similar to previous research (Audrain-McGovern et al., 2004; Bernat et al., 2008; Karp et al., 2005; Pollard et al., 2010; Rosendahl et al., 2008; Stanton et al., 2004), we also identified that students that reported having friends that smoked cigarettes were more likely to be in a product use trajectory group at baseline. It is well-established that peer groups are a strong influence of tobacco product use (Forrester, Biglan, Severson, & Smolkowski, 2007; Kobus, 2003; Leatherdale, McDonald, Cameron, & Brown, 2005) and many youth obtain tobacco products from friends (Meyers, Delucchi, & Halpern-Felsher, 2017). However, it was surprising that students with friends that smoke had high odds of being in groups at *lower* risk of tobacco product use at baseline (i.e., *stable low intenders* and *non-susceptible puffers*). Future studies should identify other characteristics of students in these trajectory groups to explore why they do not progress to become tobacco users. Such information could be valuable for prevention programming. It is also worth noting that students had a moderate risk of transitioning from *non-susceptible puffers* to *escalating experimenters*, which may be a result of changes to peer group membership. Given that some predictors included in the current study are likely to change over time, additional evidence is needed to examine the relationship between changes to risk factors and trajectory membership. Our results also show that students that reported skipping classes in the last 4 weeks were more likely to be in any other trajectory group, while students with higher feelings of connection to school were less likely to be in any other trajectory group. Previous studies have identified that students in use trajectories are more likely to have lower academic performance (Karp et al., 2005) and drop out of school (Orpinas et al., 2015), and lower feelings of connection to school and skipping classes could be early indicators of students

at risk for dropping out of school. Given that there are long-term health risks associated with dropping out of school (Freudenberg & Ruglis, 2007), school-based tobacco prevention programs should attempt to foster community-building to maximize positive health outcomes and school policies could discourage students from leaving school property during school hours.

8.6.1 Strengths & limitations

This study provides important information to fill a research gap with respect to patterns and trajectories of tobacco product use. This study took a novel approach and included measures of susceptibility to future smoking when identifying latent trajectories of tobacco product use to further explore the progression from non-susceptible never-smoker to tobacco product user. The large sample size and longitudinal design of this study are unique given that longitudinal data for the use of other tobacco products are lacking. The Cq includes measures for multiple tobacco products which allowed us to identify latent class trajectories for multiple products and compare the results. Additionally, the inclusion of multiple environmental influences and behavioural factors allowed us to explore determinants of latent trajectory membership.

This study was also subject to some limitations. The largest limitation rests with the measure of other tobacco product use, which only assessed use within the last 30 days; as a result, we were not able to assess frequency of use of these products when identifying trajectories of product use. Such information would be valuable for future studies in order to provide more detailed trajectory groups. Yearly data collections may have missed important transitions in tobacco product use (Wellman et al., 2004), and future studies should explore including multiple data collections throughout the school year. This study relied on self-reported use of tobacco products; however, students were ensured that their responses were confidential and self-reported measures of smoking have previously been demonstrated to be reliable and valid (Fendrich et al., 2005; Wong et al., 2012). LTA is a relatively new technique and strict model selection criteria have not been defined, however we used procedures that were consistent with previous studies. Additionally, LTA assumes the number of groups and their characterization is the same across time, which may not be the case. Finally, the COMPASS study used a convenience, school-based sample and the results may not be generalizable to all youth in Ontario or Canada.

8.6.2 Conclusions

We identified five trajectories that described patterns of six tobacco products: *non-susceptible non-users*, *non-susceptible puffers*, *stable low intenders*, *escalating experimenters*, and *consistent current users*. Although most students remained in the same trajectory group over time, some students transitioned to a more or less risky trajectory group. Consistent prevention programming is needed throughout adolescence to discourage the initiation and escalation of tobacco product use. Having friends that smoked cigarettes, use of another tobacco product, binge drinking, marijuana use, and skipping classes were factors associated with trajectory group membership. These results have important implications for school- and community-based interventions.

Chapter 9
General Discussion

9.1 Overview

Although there have been significant reductions in harms due to smoking, many youth continue to experiment with other tobacco and nicotine products, such as e-cigarettes, cigarillos or little cigars, cigars, smokeless tobacco, and hookah. Past research has focused on tobacco cigarette smoking behaviours and has neglected investigating the use of other tobacco and nicotine products. Overall, this dissertation (1) examined the ability of current susceptibility measures to predict the use of other tobacco and nicotine products, (2) identified latent classes of tobacco and nicotine product use, and (3) identified latent trajectory groups for the use of each product. The following sections present key findings of this research, implications for practice, and directions for future research.

9.2 Summary of key findings

Chapter 5 assessed the predictive validity (including the sensitivity, specificity, PPV and NPV) of the susceptibility to smoking construct for the use of tobacco and nicotine products. Results indicated that the sensitivity of the construct was moderate (ranging from 43.2% [SLT] to 59.9% [tobacco cigarettes]) while the specificity was high (ranging from 70.9% [SLT] to 75.9% [tobacco cigarettes]). The PPV was variable, depending on the prevalence of the product (ranging from 2.6% [SLT] to 32.2% [tobacco cigarettes]), while the NPV was generally high for all products (ranging from 88.8% [tobacco cigarettes] to 99.2% [SLT]). Although similar values were calculated for each measure of the susceptibility construct, the sensitivity of S1-Try was always highest and the sensitivity of S3-Smoke was always lowest across products. These results indicated that the predictive validity of the susceptibility to future smoking construct was high, and more importantly, that the construct could be used to predict the use of ATNPs among youth populations. As a result, it may not be necessary to create additional susceptibility measures that are specific to each tobacco and nicotine product. Researchers have recently begun to alter measures of susceptibility to smoking to be specific to other tobacco and nicotine products (e.g., e-cigarettes: Bold, Kong, Cavallo, Camenga, & Krishnan-Sarin, 2017; Krishnan-Sarin et al., 2015; Saddleson et al., 2015; SLT and cigars: Portnoy et al., 2014); however, validation of these measures using a longitudinal sample is generally lacking. This study was the first to validate the susceptibility construct within the Canadian context and the

first to explore the predictive validity of the original tobacco cigarette susceptibility construct for ATNPs.

The results also indicated that each measure of the susceptibility to smoking construct was predictive of later tobacco and nicotine product use, although to a slightly different degree. Previous studies (e.g., Aslam, Zaheer, Rao, & Shafique, 2014; Dube, Arrazola, Lee, Engstrom, & Malarcher, 2013; Forrester et al., 2007; Nodora et al., 2014) have used between one and three variables to measure susceptibility to smoking, despite a lack of evidence for the validity of variations to the susceptibility construct. These results suggest that although each measure of susceptibility presents different situations where students may be interested in experimenting with a tobacco or nicotine product, each question measures a student's underlying intention to smoke in the future. As a result, researchers could continue to use all three measures of susceptibility or only a single measure when identifying students susceptible to future tobacco and nicotine product use. Using a single measure could reduce the burden on those participating in population-health surveys assessing tobacco use while still accurately identifying students at risk of future tobacco and nicotine product use.

Chapter 6 characterized non-smoking youth at baseline that used tobacco and nicotine products one- and two-years later. Given that the previous Chapter provided evidence for the predictive validity of the susceptibility construct, this manuscript included susceptibility to future smoking as a predictor in the models. Consistent with previous research (Choi et al., 2001; Huang et al., 2005; Pierce et al., 1996, 2005; Prokhorov et al., 2002), baseline susceptibility to future smoking was strongly associated with the use of each tobacco and nicotine product at one- and two-year follow-up. The results of this study provided further support for the use of measures of susceptibility to future smoking for identifying those at risk of using a variety of tobacco and nicotine products who may benefit the most from tobacco prevention programs. Consistent with PBT, this study identified that those with friends that smoked cigarettes or who reported binge drinking at baseline had higher odds of reporting the use of each tobacco and nicotine product at follow-up.

Chapter 7 identified tobacco and nicotine product use clusters for three consecutive years using LCA. Approximately one in four students reported currently using a tobacco or nicotine product at some point over the three year study period, and the prevalence of current use of most products almost doubled between baseline and the first follow-up wave, and almost tripled between baseline and the second follow-up wave. Additionally, over time more students reported using one or more products within the last 30 days. At baseline, a three-class model best fit the data based on model fit statistics and mode interpretability [(1) *non-current users*; (2) *current tobacco cigarette, CLC, and e-*

cigarette users; (3) *current polyproduct users*], while a four-class model best fit the data at the first follow-up wave [(1) *non-current users*; (2) *current e-cigarette users*; (3) *current dual tobacco cigarette and CLC users*; (4) *current polyproduct users*] and at the second follow-up wave [(1) *non-current users*; (2) *current dual tobacco cigarette and e-cigarette users*; (3) *current tobacco cigarette, CLC, cigar, and e-cigarette users*; (4) *current polyproduct users*]. Although a non-current use and a polyproduct use class were consistent across all years, the other classes differed for each data collection year. Most notably, an exclusive e-cigarette use class was first apparent in the first follow-up wave, but did not remain in the second follow-up wave. Future research should continue to monitor youth use of e-cigarettes as these products continue to evolve. Given the different classes of products used by students at each year as they progressed through secondary school, tailored prevention programming may be necessary for each grade to address the use of popular products, such as e-cigarettes. In particular, it may be prudent to include messages that address the use of multiple tobacco and nicotine products given that tobacco cigarette smoking was more often grouped with the use of other products than on its own. Furthermore, it is apparent that consistent prevention messaging may be important throughout secondary school to discourage the initiation and escalation of tobacco and nicotine product use. This study represented the first to explore latent classes of tobacco and nicotine product use among youth in Canada.

Finally, Chapter 8 identified latent trajectory groups for the use of tobacco and nicotine products using LTA. Given the results of the first two Chapters, measures of susceptibility to future smoking were included when identifying trajectory groups. Across all products, five groups of users were identified: (1) *non-susceptible non-users*, (2) *non-susceptible puffers*, (3) *stable low intenders*, (4) *escalating experimenters*, and (5) *consistent current users*. Across all products, students had the highest probability of remaining in the same group over time, although some transitions in group membership were evident. Smoking behaviour is dynamic during adolescence (Bernat et al., 2008; Wellman et al., 2004), and early, consistent intervention may be required to prevent initiation and encourage cessation. Interestingly, a *non-susceptible puffers* group was identified; students in this group reported ever using tobacco cigarettes but had low intentions to smoke in the future. It is possible that these students tried tobacco cigarette smoking and were able to stop smoking early without intervention. From a prevention standpoint, there could be a lot to learn from this group of students about why they first tried tobacco cigarette smoking and why they did not continue. Such information could be useful for developing novel prevention and cessation programs. A major contribution of this study was the identification of latent trajectory groups for ATNPs in addition to

tobacco cigarettes. Identifying the same five latent trajectory groups across tobacco and nicotine products provides additional evidence that youth tobacco product users share many characteristics, regardless of the type of product they use.

Across all studies and consistent with previous findings (e.g., Gilreath et al., 2016; Huh & Leventhal, 2016; Morean et al., 2016), we identified that youth reported using multiple tobacco and nicotine products. Based on data from Chapter 7, almost half of tobacco and nicotine product users reported using two or more products. The results of this dissertation provide further support for prevention and cessation activities that address the use of multiple tobacco and nicotine products, and not just tobacco cigarettes. Polyproduct use is concerning since these youth may be at higher risk of nicotine dependence (Harrell et al., 2017; Timberlake, 2008) given their potentially higher exposure to nicotine-containing products. Since nicotine can affect brain development in adolescents (U.S. Department of Health and Human Services, 2014) and nicotine addiction can develop quickly, additional prevention approaches may be necessary. For example, one Canadian study identified that 6% of e-cigarette products were mislabelled with respect to whether or not they contained nicotine and 15% of products were mislabelled with respect to the nicotine concentration (Czoli et al., 2018). Standard product labels and regulation of nicotine concentrations could help to prevent product mislabelling and ensure that consumers are aware of nicotine concentrations. The results of this dissertation also highlight the fact that students transition into and out of tobacco and nicotine product use throughout secondary school. As a result, consistent prevention programming may be needed throughout adolescence to discourage the initiation and escalation of tobacco and nicotine product use.

Across all studies and consistent with PBT (Jessor, 1991), peers were a common correlate of tobacco and nicotine product use. In Chapter 6, having friends that smoked cigarettes was predictive of later use of tobacco and nicotine products, while in Chapter 7, students with friends that smoked cigarettes were more likely to use multiple tobacco and nicotine products. Peers may influence tobacco and nicotine product use through various mechanisms, including by providing access and opportunities to try products in social situations (Hammal et al., 2016; Richter et al., 2008) and through modelling behaviours. Future research should identify where tobacco and nicotine products are obtained and when these products are commonly used in order to develop targeted programs and policies. Peer crowds, groups of adolescents that share common beliefs, interests, and appearances (Mackey, Greca, & M, 2007; Sussman, Pokhrel, Ashmore, & Brown, 2007), can also influence behaviour. Peer crowds can provide youth with a sense of identity and belonging and opportunities to

interact with like-minded individuals (Mackey et al., 2007). According to a systematic review, there are five common types of peer crowds: (1) students who are popular and socially oriented, (2) students who are academic, (3) students who are deviant, (4) students who are athletes, and (5) others (Sussman et al., 2007). Evidence indicates that substance use behaviours, including tobacco use, vary according to the peer crowd to which a youth belongs, where students who are deviant have the highest likelihood of smoking (Sussman et al., 2007). Knowledge of peer crowds can help with the development of targeted messaging that would be most effective for a particular group of students based on their beliefs, attitudes, and behaviours (Moran, Murphy, & Sussman, 2012; Moran & Sussman, 2015). For example, an evaluation of the truth® campaign in the United States, which targets rebellious or nonmainstream youth that are at higher risk to smoke, identified that adolescents that reported belonging to either of these crowds were more likely to believe that cigarette companies lie compared to those that belonged to other peer crowds after seeing the campaign messages (Moran et al., 2012).

Finally, the results of this dissertation also indicate that binge drinking and marijuana use were common correlates of tobacco and nicotine product use, highlighting the need for multi-substance use prevention and cessation programs. In Chapter 6, binge drinking was predictive of later use of tobacco and nicotine products, while in Chapter 7 and Chapter 8, both binge drinking and marijuana use were predictive of tobacco and nicotine product use. According to PBT (Jessor, 1991) as well as cross-sectional (Leatherdale & Burkhalter, 2012; Morean et al., 2016) and longitudinal evidence (Jackson, Sher, Cooper, & Wood, 2002; Nelson et al., 2015), risk behaviours tend to cluster together. As a result, comprehensive approaches to addressing risk behaviours that address underlying risk factors (e.g., positive coping skills) may be more effective than approaches that are restricted to specific risk behaviours (Jessor, 1991; Soldz & Cui, 2002). Such approaches may become increasingly important following the pending legalization of marijuana in Canada (Canada & Health Canada, 2016), especially considering that tobacco may be mixed with marijuana when it is smoked or nicotine could be added to cannabis oil when it is vaped, which can assist in the development of nicotine addiction (Humfleet & Haas, 2004). Such approaches would need to be evaluated to identify any indirect impacts on other risk behaviours.

9.3 Overall strengths

This dissertation project has several strengths. First, it provided important information to fill a research gap in Canada and internationally. There is a lack of longitudinal tobacco use data among

youth populations in Canada, as evidenced by the few referenced studies that used Canadian populations in the literature review. Furthermore, many longitudinal studies occurred in the mid- to late-90s, where the tobacco use landscape was markedly different from today. This research was the first to validate the susceptibility construct in a Canadian youth population, the first to validate the susceptibility construct for the use of ATNPs, the first to identify latent classes of tobacco and nicotine product use in Canada, and the first to identify latent trajectory groups of ATNP use.

Secondly, the COMPASS questionnaire collected data on a range of tobacco and nicotine products, producing the most comprehensive picture of tobacco and nicotine product use among youth in Ontario. These data allowed for the investigation of youth susceptibility to various tobacco and nicotine products, latent classes of tobacco and nicotine product use, and latent trajectory groups for tobacco and nicotine products. In addition, the COMPASS questionnaire collected data on a range of other health risk behaviours (e.g., skipping classes, binge drinking, marijuana use, etc.) and health protective behaviours (e.g., school connectedness, eating breakfast, physical activity, etc.) that influence tobacco and nicotine product use. These data allowed us to explore correlates of tobacco and nicotine product use.

Thirdly, the longitudinal design of the COMPASS study provided a unique opportunity to answer the research questions. A strength of this study design was the inclusion of three waves of data from the COMPASS study. At least three waves of data are generally needed to describe the process of change and distinguish between actual change and measurement error (Singer & Willett, 2003). Within the Canadian context, the school environment represents an ideal location for data collection since the vast majority of school-aged children and youth attend school, and will usually attend the same school for an extended period of time (e.g., four years in secondary school). The use of passive consent procedures maximized the number of students that participated from each school, increasing the sample size that was available for analysis.

Finally, this dissertation employed complex and novel analytic techniques to increase our knowledge of tobacco and nicotine product use among youth. LCA is a relatively new technique that has gained popularity in the tobacco control and youth health behaviour literature; similarly, LTA has identified patterns in tobacco cigarette smoking and other substance use behaviours, but has not identified patterns of ATNP use.

9.4 Overall limitations

Although there are many strengths with this project, there are also some limitations. The largest limitation rests with the measures themselves. Most notably, the ATNP use questions used throughout this dissertation only considered use within the last 30 days, did not ask about ever use, and did not ask about the frequency of use. Responses to this question may not have represented usual use of these ATNPs by respondents and did not allow for the identification of usual smoking patterns. There is also the potential for recall bias where students that use products infrequently do not remember using them within the last 30 days. Additionally, the COMPASS questionnaire did not collect any information about whether products were used individually or in combination with other substances, or when these products were typically used. The question that measured e-cigarette use did not identify whether nicotine was present in the e-cigarette. Although nicotine-containing e-cigarettes were not legally available at the time of the study, evidence illustrates that nicotine-containing products are available in Ontario (Czoli et al., 2018) and could be purchased by youth. Furthermore, the question that measured CLC use did not differentiate between the two products. Although there is evidence that surveillance tools that measure cigar, cigarillo, and little cigar use in a single measure may underestimate the actual prevalence of use of these products relative to more specific measures (Delnevo, Bover-Manderski, & Hrywna, 2011; Terchek, Larkin, Male, & Frank, 2009), additional evidence is necessary to identify whether separate measures are needed in the Canadian context. This study also relied on self-reported smoking behaviours, which may be subject to recall and social desirability bias. However, self-reported tobacco use measures have previously been demonstrated to be reliable and valid (Fendrich et al., 2005; Wong et al., 2012) and students were ensured that their responses were confidential.

The COMPASS study was primarily designed to evaluate the impact of changes in school-based programs, policies, and the built environment for a variety of health behaviours and not strictly to measure tobacco and nicotine product use behaviours. Given the use of a convenience sample of schools (and therefore students), the results may not be generalizable to all youth in Ontario or Canada. However, given lack of adolescent ATNP use data in Canada, the longitudinal nature of the study, and the large sample size, the results have important implications for research and practice. Additionally, in view of the primary purpose of the COMPASS study, there are also limitations with other measures found in the questionnaire. For example, the Cq did not include other measures that are known to be associated with tobacco and nicotine product use such as measures of nicotine

dependence, exposure to tobacco and nicotine product use at home, attitudes and beliefs about tobacco and nicotine products, or exposure to tobacco and nicotine product advertising and marketing. We were unable to explore the association of these attitudes and behaviours to susceptibility to, latent classes of, and latent trajectories of tobacco and nicotine product use. Furthermore, measures of peer smoking were limited to tobacco cigarette smoking, which may not have represented exposure to all types of tobacco and nicotine products and provided an imperfect estimate of ATNP use by close friends.

Limitations in the study design included that data collections only occurred once annually. Although annual data collections reduce the burden on the school and study participants, they may miss critical developmental periods or life events that lead to smoking initiation and contribute to smoking progression (Wellman et al., 2004). This could have affected the validation of the susceptibility construct and the types of latent trajectory groups that were identified. The use of a single question to identify the use of each ATNP within the past 30 days may have resulted in some misclassification. A respondent that used an ATNP for the first time or only once within the last 30 days was classified as a current user, even though they are not a regular user. The use of longitudinal data helped to mitigate some of this misclassification by identifying consistent users of tobacco and nicotine products over the course of the study. Another limitation associated with longitudinal study designs is participant drop-out. It is common for tobacco and nicotine product users to drop out of longitudinal studies (Qian et al., 2015; Siddiqui et al., 1996). As a result, the results reported here may underestimate the predictive validity of the susceptibility construct and the estimated use of tobacco and nicotine products.

Finally, there were limitations with the analytic methods that were used. LCA and LTA are relatively new analytic procedures and there are no standard criteria for model selection; however, our approach and procedures were consistent with previous studies that have used both LCA and LTA. Additionally, LTA assumes the number of groups and their characterization is the same across time, which may not be the case (as suggested in Chapter 7). This statistical modelling limitation was beyond the scope of the current project, but could be explored and addressed in future work.

9.5 Implications for practice

The results of this dissertation present implications and directions for future practice and policy. Recommended actions are outlined below.

1. *Continue to develop and implement inclusive tobacco surveillance tools*. It is clear that surveillance data on multiple tobacco and nicotine products are needed. Such data could provide accurate information about the rates of use of all tobacco and nicotine products when usual tobacco surveillance reports, which only report rates of tobacco cigarette smoking, may underestimate tobacco use by excluding those that only use ATNPs (Leatherdale et al., 2011). The results of this dissertation indicate that current measures of susceptibility to future smoking can be used to identify students at risk of using ATNPs in addition to tobacco cigarettes. Measures of susceptibility to smoking should continue to be included on youth tobacco surveillance tools. E-cigarettes have gained recent attention due to the increasing prevalence of use, particularly among youth populations. However, data from this dissertation indicate that the prevalence of use of CLCs is similar to that of both tobacco cigarettes and e-cigarettes, but CLCs have received less consideration in the literature. Additional attention is warranted to monitor and describe use of ATNPs such as CLCs. Furthermore, given the high rates of polyproduct use identified here, and the subsequent risks of nicotine addiction and negative health outcomes, tools that measure polyproduct use are needed to more fully understand use patterns among youth populations.
2. *Ensure that tobacco programs and policies are inclusive of all tobacco and nicotine products*. It is clear that additional approaches are necessary to reduce the risk of and use of multiple tobacco and nicotine products. Results of this dissertation indicate that one quarter of youth reported using a tobacco or nicotine product at some point over three consecutive years and many reported using more than one product. Given these findings, tobacco prevention and cessation programs should address the use of multiple tobacco and nicotine products and not just tobacco cigarettes. Given common misperceptions about the harms associated with other tobacco products (Chapman & Wu, 2014; Choi et al., 2012; Smith et al., 2011; Wray et al., 2012), prevention programs should draw awareness to the harms associated with any tobacco use and the risks of nicotine addiction from all tobacco and nicotine products. Polyproduct use is common and may make it more difficult for youth to quit smoking tobacco cigarettes. Therefore, cessation programs should encourage stopping or reducing the use of all tobacco products for maximum health benefits. Given the influence of the school environment to youth substance use (Baillie, Lovato, Taylor, Rutherford, & Smith, 2007; Cole & Leatherdale,

2014; Lovato, Sabiston, Hadd, Nykiforuk, & Campbell, 2006), school-level tobacco control policies should explicitly address the use of all tobacco and nicotine products and not just tobacco cigarettes. At a provincial level, tobacco control policies should be designed to impact the range of tobacco and nicotine products available. For example, tobacco cigarettes have historically been taxed at a higher rate than loose tobacco for RYO cigarettes, and tobacco taxes have more consistently increased for tobacco cigarettes relative to other tobacco products (Ontario Tobacco Research Unit, 2010).

3. *Provide consistent, multi-substance use programming throughout adolescence*. The results of this dissertation clearly provide support for a "risk behaviour syndrome" where risk behaviours tend to cluster together (Jessor, 1991). Therefore, it is evident that multi-substance use programming is important. Based on the results of this dissertation, such programming should address the use and co-use of multiple products, such as tobacco and nicotine product use, alcohol use, and marijuana use. Tailored programming may be necessary given that evidence suggests that participation in risk behaviours varies by peer group and youth in different peer crowds identify with different messages (Moran et al., 2012; Moran & Sussman, 2015). Furthermore, given the rapid increase in the prevalence of tobacco and nicotine product use over three years, consistent school-level programming throughout adolescence is warranted. Within Ontario, tobacco prevention programming is only mandated as a part of the physical health and education curriculum and students are only required to take one physical health and education course during their high school years. To prevent the initiation and escalation of substance use behaviours, programming should be provided every year to all students.

9.6 Implications for future research

The results of this dissertation also present implications and directions for future research. Recommended actions are outlined below.

1. *Develop more robust measures of other tobacco and nicotine product use*. A major limitation of the current work was with respect to the measures of tobacco and nicotine product use. Although convenient to use and popular within the literature, measures that ask about use within the past 30 days do not indicate any level of frequency of use within the past 30 days or about the usual frequency of use of the product. More robust measures of use would allow researchers to more accurately identify and classify tobacco and

nicotine product users based on the frequency of use. Additionally, although this dissertation validated measures of susceptibility to future smoking for the use of ATNPs, these measures were only able to identify approximately 50% of students that later used a tobacco or nicotine product (i.e., the sensitivity). Evidently, there are additional, unmeasured factors that may improve our ability to identify those at risk of using tobacco and nicotine products that remain unexplored.

2. *Identify how tobacco and nicotine products are obtained and when and where they are typically used*. There is a lack of knowledge of how tobacco and nicotine products are obtained, whether they are usually used individually or in combination with other substances, and when and where they are typically used. Knowledge of where ATNPs are obtained (e.g., family, friends, retailers) could inform the development of school policies that prohibit possession of tobacco and nicotine products on campus grounds, zoning policies that restrict selling tobacco and nicotine products close to schools, or closed campus policies that prohibit students from leaving the campus during school hours. Knowledge of common combinations of tobacco, nicotine, alcohol, and cannabis products, and when and where these products are typically used could aid in the development of targeted messaging.
3. *Identify school- and community-level factors that influence tobacco and nicotine product use*. This dissertation focused on identifying student-level sociodemographic and modifiable factors associated with susceptibility to, use of, and trajectories of tobacco and nicotine product use. Although some cross-sectional studies have explored school- and community-level factors associated with tobacco cigarette (e.g., Lovato, Pullman, et al., 2010; Lovato, Zeisser, et al., 2010; Lovato, Hsu, Sabiston, Hadd, & Nykiforuk, 2007) and ATNP use (e.g., Cole & Leatherdale, 2014), studies that explore changes that occur to these school- and community-level factors over time and the longitudinal impact of these factors on tobacco and nicotine product use are lacking. Knowledge of school- and community-level factors that reduce tobacco and nicotine product use among youth could encourage health-promoting policies.
4. *Evaluate the effect of programs and policies on co-occurring substance use*. Changes to tobacco control programming and policies can impact more than tobacco cigarette smoking. Youth may substitute tobacco cigarette smoking for other behaviours (e.g., ATNP, alcohol, or marijuana use) that are more cost effective, more accessible, and/or

more available. It is important to identify unintended consequences (both positive and negative) of programs and policies that target a particular behaviour. For example, the pending marijuana legalization in Canada may have unintended positive or negative effects on youth tobacco and nicotine product use. Additionally, school-based interventions that target a particular behaviour may also influence tobacco and nicotine product use and other substance use behaviours. Given the significant between-school variability in tobacco and nicotine product use (Cole & Leatherdale, 2014), and that schools may implement a variety of interventions, it would be prudent to evaluate the impact of such changes on tobacco and nicotine product use. The COMPASS study is well situated to evaluate such changes.

9.7 Conclusions

Many youth in Ontario report using tobacco and nicotine products, including tobacco cigarettes, e-cigarettes, CLCs, cigars, SLT, and/or hookah. This dissertation increases our knowledge of ATNP use in Canada. Identifying students at risk of using tobacco and nicotine products would be beneficial for targeted prevention programming. Measures of susceptibility to future smoking are valid and useful for identifying students at risk of using ATNPs and not only tobacco cigarettes. Tobacco and nicotine product use is common among youth in Ontario, particularly polyproduct use. Tobacco cigarette use was more often grouped with ATNP use than on its own, suggesting that additional prevention and cessation programs may be necessary to discourage use. Differences in class profiles over time suggest that there may be differences in product preferences as students age. Five trajectories that described patterns of tobacco and nicotine products were identified. Although most students remained in the same trajectory group over time, some students transitioned to another trajectory group. Given the initiation and escalation of tobacco and nicotine product use that occurs during adolescence, consistent prevention programming is needed throughout secondary school. Common factors associated with tobacco and nicotine product use included having friends that smoked cigarettes, binge drinking, marijuana use, and skipping classes. Since many youth reported using more than one product and commonly reported binge drinking and using marijuana, multi-substance use school and community programming continues to be relevant and important. Future research should continue to develop measures of ATNP use, identify longitudinal predictors of tobacco and nicotine product use, and explore contextual factors that increase or decrease the risk of tobacco and nicotine product use.

Appendix A

2013-14 COMPASS Questionnaire

Compass

- **This is NOT a test**. All of your answers will be kept **confidential**. No one, not even your parents or teachers, will ever know what you answered. So, please be honest when you answer the questions.
- Mark only **one option per question** unless the instructions tell you to do something else.
- Choose the option that is the **closest** to what you think/feel is true for you.

Please, use a pencil to complete this questionnaire

Please mark all your answers with full, dark marks like this: ○ ● ○ ○

START HERE

Please read each sentence below carefully. Write the correct letter, number, or word on the line and then fill in the corresponding circle.

The first letter of your **middle** name (if you have more than one middle name use your first middle name; if you don't have a middle name use "Z"):____	The name of the month in which you were born: ________	The **last** letter of your full **last** name: ___	The **second** letter of your full **first** name: ___	The **first** initial of your **mother's** first name (think about the mother you see the most):___
Ⓐ Ⓙ Ⓢ	① January	Ⓐ Ⓙ Ⓢ	Ⓐ Ⓙ Ⓢ	Ⓐ Ⓙ Ⓢ
Ⓑ Ⓚ Ⓣ	② February	Ⓑ Ⓚ Ⓣ	Ⓑ Ⓚ Ⓣ	Ⓑ Ⓚ Ⓣ
Ⓒ Ⓛ Ⓤ	③ March	Ⓒ Ⓛ Ⓤ	Ⓒ Ⓛ Ⓤ	Ⓒ Ⓛ Ⓤ
Ⓓ Ⓜ Ⓥ	④ April	Ⓓ Ⓜ Ⓥ	Ⓓ Ⓜ Ⓥ	Ⓓ Ⓜ Ⓥ
Ⓔ Ⓝ Ⓦ	⑤ May	Ⓔ Ⓝ Ⓦ	Ⓔ Ⓝ Ⓦ	Ⓔ Ⓝ Ⓦ
Ⓕ Ⓞ Ⓧ	⑥ June	Ⓕ Ⓞ Ⓧ	Ⓕ Ⓞ Ⓧ	Ⓕ Ⓞ Ⓧ
Ⓖ Ⓟ Ⓨ	⑦ July	Ⓖ Ⓟ Ⓨ	Ⓖ Ⓟ Ⓨ	Ⓖ Ⓟ Ⓨ
Ⓗ Ⓠ Ⓩ	⑧ August	Ⓗ Ⓠ Ⓩ	Ⓗ Ⓠ Ⓩ	Ⓗ Ⓠ Ⓩ
Ⓘ Ⓡ	⑨ September	Ⓘ Ⓡ	Ⓘ Ⓡ	Ⓘ Ⓡ
	⑩ October			
	⑪ November			
	⑫ December			

○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

About You

1. What grade are you in?

- ○ Grade 9
- ○ Grade 10
- ○ Grade 11
- ○ Grade 12

2. How old are you today?

- ○ 13 years or younger
- ○ 14 years
- ○ 15 years
- ○ 16 years
- ○ 17 years
- ○ 18 years or older

3. Are you female or male?

- ○ Female
- ○ Male

4. How would you describe yourself? *(Mark all that apply)*

- ○ White
- ○ Black
- ○ Asian
- ○ Aboriginal (First Nations, Métis, Inuit)
- ○ Latin American/Hispanic
- ○ Other _____

5. About how much money do you usually get <u>each week</u> to spend on yourself or to save?
(Remember to include all money from allowances and jobs like baby-sitting, delivering papers, etc.)

- ○ Zero
- ○ $1 to $5
- ○ $6 to $10
- ○ $11 to $20
- ○ $21 to $40
- ○ $41 to $100
- ○ More than $100
- ○ I do not know how much money I get each week

6. How do you <u>usually</u> travel to and from school? *(If you use two or more modes of travel, choose the one that you spend most <u>time</u> doing)*

To school	From school
○ By car (as a passenger)	○ By car (as a passenger)
○ By car (as a driver)	○ By car (as a driver)
○ By school bus	○ By school bus
○ By public bus, subway, or streetcar	○ By public bus, subway, or streetcar
○ By walking	○ By walking
○ By bicycling	○ By bicycling
○ Other_____	○ Other_____

7. Did you attend <u>this</u> school last year?

- ○ Yes, I attended the same school last year
- ○ No, I was at another school last year

8. How tall are you without your shoes on? (Please write your height in feet and inches **OR** in centimetres, and then fill in the appropriate numbers for your height.)

○ **I do not know how tall I am**

"My height is ____feet, _____inches"

OR

"My height is _____ centimetres"

Height	
Feet	Inches
0 1 2 3 4 5 6 7	0 1 2 3 4 5 6 7 8 9

OR

Height
Centimetres
0 1 2 3 4 5 6 7 8 9

Example:
My height is 5 ft 7 in

Height	
Feet	Inches
0 1 2 3 ● 6 7	● 1 2 3 4 5 6 ● 8 9

9. How much do you weigh without your shoes on? (Please write your weight in pounds **OR** in kilograms, and then fill in the appropriate numbers for your weight.)

○ **I do not know how much I weigh**

"My weight is _____ pounds"

OR

"My weight is _____ kilograms"

Weight
Pounds
0 1 2 3 4 5 6 7 8 9

OR

Weight
Kilograms
0 1 2 3 4 5 6 7 8 9

Example:
My weight is 127 lbs

Weight
Pounds
0 ● 2 3 4 5 6 ● 8 9

10. How much time per day do you *usually* spend doing the following activities?

For example: If you spend about 3 hours watching TV each day, you will need to fill in the 3 hour circle, and the 0 minute circle as shown below:

	Hours	Minutes
a) Watching/streaming TV shows or movies	0 1 2 ● 4 5 6 7 8 9	● 15 30 45

	Hours	Minutes
a) Watching/streaming TV shows or movies	0 1 2 3 4 5 6 7 8 9	0 15 30 45
b) Playing video/computer games	0 1 2 3 4 5 6 7 8 9	0 15 30 45
c) Doing homework	0 1 2 3 4 5 6 7 8 9	0 15 30 45
d) Talking on the phone	0 1 2 3 4 5 6 7 8 9	0 15 30 45
e) Surfing the internet	0 1 2 3 4 5 6 7 8 9	0 15 30 45
f) Texting, messaging, emailing **(note: 50 texts = 30 minutes)**	0 1 2 3 4 5 6 7 8 9	0 15 30 45
g) Sleeping	0 1 2 3 4 5 6 7 8 9	0 15 30 45

○○○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

Physical Activity

HARD physical activities include jogging, team sports, fast dancing, jump-rope, and any other physical activities that increase your heart rate and make you breathe hard and sweat.

MODERATE physical activities include lower intensity activities such as walking, biking to school, and recreational swimming.

11. Mark how many minutes of HARD physical activity you did on each of the last 7 days. This includes physical activity during physical education class, lunch, after school, evenings, and spare time.

	Hours					Minutes			
Monday	0	1	2	3	4	0	15	30	45
Tuesday	0	1	2	3	4	0	15	30	45
Wednesday	0	1	2	3	4	0	15	30	45
Thursday	0	1	2	3	4	0	15	30	45
Friday	0	1	2	3	4	0	15	30	45
Saturday	0	1	2	3	4	0	15	30	45
Sunday	0	1	2	3	4	0	15	30	45

For example: If you did 45 minutes of hard physical activity on Monday, you will need to fill in the 0 hour circle and the 45 minute circle, as shown below:

	Hours					Minutes			
Monday	●	1	2	3	4	0	15	30	●

12. Mark how many minutes of MODERATE physical activity you did on each of the last 7 days. This includes physical activity during physical education class, lunch, after school, evenings, and spare time. Do not include time spent doing hard physical activities.

	Hours					Minutes			
Monday	0	1	2	3	4	0	15	30	45
Tuesday	0	1	2	3	4	0	15	30	45
Wednesday	0	1	2	3	4	0	15	30	45
Thursday	0	1	2	3	4	0	15	30	45
Friday	0	1	2	3	4	0	15	30	45
Saturday	0	1	2	3	4	0	15	30	45
Sunday	0	1	2	3	4	0	15	30	45

For example: If you did 1 hour and 30 minutes of moderate physical activity on Monday, you will need to fill in the 1 hour circle and the 30 minute circle, as shown below:

	Hours					Minutes			
Monday	0	●	2	3	4	0	15	●	45

13. Were the last 7 days a typical week in terms of the amount of physical activity that you usually do?

- ○ Yes
- ○ No, I was *more* active in the last 7 days
- ○ No, I was *less* active in the last 7 days

14. Your closest friends are the friends you like to spend the most time with. How many of your closest friends are physically active?

- ○ None
- ○ 1 friend
- ○ 2 friends
- ○ 3 friends
- ○ 4 friends
- ○ 5 or more friends

15. Are you taking a physical education class at school this year?

- ○ **Yes**, I am taking one **this term**
- ○ **Yes**, I will be taking one or have taken one this school year, **but not this term**.
- ○ **No**, I am not taking a physical education class at school this year

16. Do you participate in before-school, noon hour, or after-school physical activities organized by your school? *(e.g., intramurals, non-competitive clubs)*

- ○ Yes
- ○ No
- ○ None offered at my school

17. Do you participate in competitive school sports teams that compete against other schools? *(e.g., junior varsity or varsity sports)*

- ○ Yes
- ○ No
- ○ None offered at my school

18. Do you participate in league or team sports outside of school?

- ○ Yes
- ○ No
- ○ There are none available where I live

19. On how many days in the last 7 days did you do exercises to strengthen or tone your muscles? *(e.g., push-ups, sit-ups, or weight-training)*

- ○ 0 days
- ○ 1 day
- ○ 2 days
- ○ 3 days
- ○ 4 days
- ○ 5 days
- ○ 6 days
- ○ 7 days

20. How do <u>you</u> describe your weight?

- ○ Very underweight
- ○ Slightly underweight
- ○ About the right weight
- ○ Slightly overweight
- ○ Very overweight

21. Which of the following are you trying to do about your weight?

- ○ **Lose** weight
- ○ **Gain** weight
- ○ **Stay** the same weight
- ○ I am **not trying to do anything** about my weight

22. How much do your parents, step-parents, or guardians encourage you to be physically active?

- ○ Strongly encourage
- ○ Encourage
- ○ Do not encourage or discourage
- ○ Discourage
- ○ Strongly discourage

23. How much do your parents, step-parents, or guardians support you in being physically active? *(e.g., driving you to team games, buying you sporting equipment)*

- ○ Very supportive
- ○ Supportive
- ○ Unsupportive
- ○ Very unsupportive

○○○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

Healthy Eating

24. If you do not eat breakfast every day, why do you skip breakfast? *(Mark all that apply)*

- ○ I eat breakfast every day
- ○ I don't have time for breakfast
- ○ The bus comes too early
- ○ I sleep in
- ○ I'm not hungry in the morning
- ○ I feel sick when I eat breakfast
- ○ I'm trying to lose weight
- ○ There is nothing to eat at home
- ○ Other _____

25. In a *usual* school week *(Monday to Friday)*, on how many days do you do the following?	None	1 day	2 days	3 days	4 days	5 days
a) Eat breakfast	○	○	○	○	○	○
b) Eat breakfast provided to you **as part of a school program**	○	○	○	○	○	○
c) Eat lunch at school - lunch packed and brought from home	○	○	○	○	○	○
d) Eat lunch at school - lunch purchased in the cafeteria	○	○	○	○	○	○
e) Eat lunch purchased at a fast food place or restaurant	○	○	○	○	○	○
f) Eat snacks purchased from a vending machine **in your school**	○	○	○	○	○	○
g) Eat snacks purchased from a vending machine, corner store, snack bar, or canteen **off school property**	○	○	○	○	○	○
h) Drink sugar-sweetened beverages (soda pop, Kool-Aid, Gatorade, etc.) Do not include diet/sugar-free drinks	○	○	○	○	○	○
i) Drink high-energy drinks (Red Bull, Monster, Rock Star, etc.)	○	○	○	○	○	○
j) Drink coffee or tea **with sugar** (include cappuccino, frappuccino, iced-tea, iced-coffees, etc.)	○	○	○	○	○	○
k) Drink coffee or tea **without sugar**	○	○	○	○	○	○

26. On a *usual* weekend *(Saturday and Sunday)*, on how many days do you do the following?	None	1 day	2 days
a) Eat breakfast	○	○	○
b) Eat lunch	○	○	○
c) Eat foods purchased at a fast food place or restaurant	○	○	○
d) Eat snacks purchased from a vending machine, corner store, snack bar, or canteen	○	○	○
e) Drink sugar-sweetened beverages (soda pop, Kool-Aid, Gatorade, etc.) Do not include diet/sugar-free drinks	○	○	○
f) Drink high energy drinks (Red Bull, Monster, Rock Star, etc.)	○	○	○
g) Drink coffee or tea **with sugar** (include cappuccino, frappuccino, iced-tea, iced-coffees, etc.)	○	○	○
h) Drink coffee or tea **without sugar**	○	○	○

27. YESTERDAY, ***from the time you woke up until the time you went to bed*****, how many servings of meats and alternatives did you have?** *One 'Food Guide' serving of meat and alternatives includes cooked fish, chicken, beef, pork, or game meat, eggs, nuts or seeds, peanut butter or nut butters, legumes (beans), and tofu.*

- ○ None
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 or more servings

Canada's Food Guide **Serving Sizes of Meats and Alternatives**

28. YESTERDAY, ***from the time you woke up until the time you went to bed*****, how many servings of vegetables and fruits did you have?** *One 'Food Guide' serving of vegetables and fruit includes pieces of fresh vegetable or fruit, salad or raw leafy greens, cooked leafy green vegetables, dried or canned or frozen fruit, and 100% fruit or vegetable juice.*

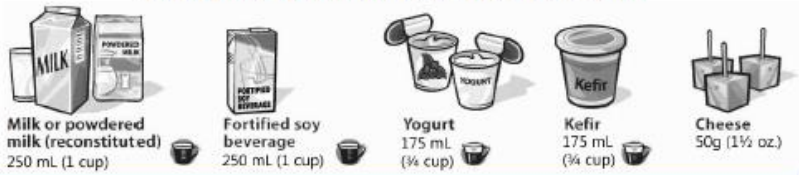
- ○ None
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 servings
- ○ 6 servings
- ○ 7 servings
- ○ 8 servings
- ○ 9 or more servings

Canada's Food Guide **Serving Sizes of Vegetables and Fruits**

29. YESTERDAY, ***from the time you woke up until the time you went to bed*****, how many servings of milk and alternatives did you have?** *One 'Food Guide' serving of milk or milk alternatives includes milk, fortified soy beverage, reconstituted powdered milk, canned (evaporated) milk, yogurt or kefir (another type of cultured milk product), and cheese.*

- ○ None
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 servings
- ○ 6 or more servings

Canada's Food Guide **Serving Sizes of Milk and Alternatives**



30. YESTERDAY, ***from the time you woke up until the time you went to bed*****, how many servings of grain products did you have?** *One 'Food Guide' serving of grain products includes bread, bagels, flatbread such as tortilla, pita, cooked rice or pasta, and cold cereal.*

- ○ None
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 servings
- ○ 6 servings
- ○ 7 servings
- ○ 8 servings
- ○ 9 or more servings

Canada's Food Guide **Serving Sizes of Grain Products**

Your Experience with Smoking

31. Have you ever tried cigarette smoking, even just a few puffs?

- ○ Yes
- ○ No

32. How old were you when you first tried smoking cigarettes, even just a few puffs?

- ○ I have never done this
- ○ I do not know

- ○ 8 years or younger
- ○ 9 years
- ○ 10 years
- ○ 11 years
- ○ 12 years
- ○ 13 years
- ○ 14 years
- ○ 15 years
- ○ 16 years
- ○ 17 years
- ○ 18 years or older

33. Do you think in the future you might try smoking cigarettes?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

34. If one of your best friends were to offer you a cigarette, would you smoke it?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

35. At any time during the next year do you think you will smoke a cigarette?

- ○ Definitely yes
- ○ Probably yes
- ○ Probably not
- ○ Definitely not

36. Do you think it would be difficult or easy for you to get cigarettes if you wanted to smoke?

- ○ Difficult
- ○ Easy
- ○ I do not know

37. Have you ever smoked a whole cigarette?

- ○ Yes
- ○ No

38. Have you ever smoked 100 or more whole cigarettes in your life?

- ○ Yes
- ○ No

○○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

39. Have you ever smoked every day for at least 7 days in a row?

- ○ Yes
- ○ No

40. On how many of the last 30 days did you smoke one or more cigarettes?

- ○ None
- ○ 1 day
- ○ 2 to 3 days
- ○ 4 to 5 days
- ○ 6 to 10 days
- ○ 11 to 20 days
- ○ 21 to 29 days
- ○ 30 days *(every day)*

41. Thinking back over the last 30 days, on the days that you smoked, how many cigarettes did you usually smoke each day?

- ○ None
- ○ A few puffs to one whole cigarette
- ○ 2 to 3 cigarettes
- ○ 4 to 5 cigarettes
- ○ 6 to 10 cigarettes
- ○ 11 to 20 cigarettes
- ○ 21 to 29 cigarettes
- ○ 30 or more cigarettes

42. Your closest friends are the friends you like to spend the most time with. How many of your closest friends smoke cigarettes?

- ○ None
- ○ 1 friend
- ○ 2 friends
- ○ 3 friends
- ○ 4 friends
- ○ 5 or more friends

43. Have you ever tried to quit smoking cigarettes?

- ○ I have never smoked
- ○ I have only smoked a few times
- ○ I have never tried to quit
- ○ I have tried to quit once
- ○ I have tried to quit 2 or 3 times
- ○ I have tried to quit 4 or 5 times
- ○ I have tried to quit 6 or more times

44. In the last 30 days, did you use any of the following? *(Mark all that apply)*

- ○ Pipe tobacco
- ○ Cigarillos or little cigars (*plain or flavoured*)
- ○ Cigars (not including cigarillos or little cigars, *plain or flavoured*)
- ○ Roll-your-own cigarettes (tobacco only)
- ○ Loose tobacco mixed with marijuana
- ○ E-cigarettes (electronic cigarettes that look like cigarettes/cigars, but produce vapour instead of smoke)
- ○ Smokeless tobacco (chewing tobacco, pinch, snuff, or snus)
- ○ Nicotine patches, nicotine gum, nicotine lozenges, or nicotine inhalers
- ○ Hookah (water-pipe) to smoke tobacco
- ○ Hookah (water-pipe) to smoke herbal sheesha/shisha
- ○ Blunt wraps (a sheet or tube made of tobacco used to roll cigarette tobacco)
- ○ I have not used any of these things in the last 30 days

Alcohol and Marijuana Use

*Please remember that we will keep your answers **completely confidential**.*

A **DRINK** means: 1 regular sized bottle, can, or draft of beer; 1 glass of wine; 1 bottle of cooler; 1 shot of liquor (rum, whiskey, etc); or 1 mixed drink (1 shot of liquor with pop, juice, energy drink).

45. In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?

- ○ I have never drunk alcohol
- ○ I did not drink alcohol in the last 12 months
- ○ I have only had a sip of alcohol
- ○ 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

46. How old were you when you first had a drink of alcohol that was more than just a sip?

- ○ I have never drunk alcohol
- ○ I have only had a sip of alcohol
- ○ I do not know

- ○ 8 years or younger
- ○ 9 years
- ○ 10 years
- ○ 11 years
- ○ 12 years
- ○ 13 years
- ○ 14 years
- ○ 15 years
- ○ 16 years
- ○ 17 years
- ○ 18 years or older

47. In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?

- ○ I have never done this
- ○ I did not have 5 or more drinks on one occasion 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

48. In the last 12 months, have you had alcohol mixed or pre-mixed with an energy drink (such as Red Bull, Rock Star, Monster, or another brand)?

- ○ I have never done this
- ○ I did not do this in the last 12 months
- ○ Yes
- ○ I do not know

49. In the last 12 months, how often did you use marijuana or cannabis? (a joint, pot, weed, hash)

- ○ I have never used marijuana
- ○ I have used marijuana but not in the last 12 months
- ○ 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

50. How old were you when you first used marijuana or cannabis?

- ○ I have never used marijuana
- ○ I do not know

- ○ 8 years or younger
- ○ 9 years
- ○ 10 years
- ○ 11 years
- ○ 12 years
- ○ 13 years
- ○ 14 years
- ○ 15 years
- ○ 16 years
- ○ 17 years
- ○ 18 years or older

51. Do you think it would be difficult or easy for you to get marijuana if you wanted some?

- ○ Difficult
- ○ Easy
- ○ I do not know

○○○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

Your School and You

52. How strongly do you agree or disagree with each of the following statements?	Strongly Agree	Agree	Disagree	Strongly Disagree
a) I feel close to people at my school.	○	○	○	○
b) I feel I am part of my school.	○	○	○	○
c) I am happy to be at my school.	○	○	○	○
d) I feel the teachers at my school treat me fairly.	○	○	○	○
e) I feel safe in my school.	○	○	○	○
f) Getting good grades is important to me.	○	○	○	○

53. In the last 30 days, in what ways were you bullied by other students? *(Mark all that apply)*

- ○ I have not been bullied in the last 30 days
- ○ Physical attacks (e.g., getting beaten up, pushed, or kicked)
- ○ Verbal attacks (e.g., getting teased, threatened, or having rumours spread about you)
- ○ Cyber-attacks (e.g., being sent mean text messages or having rumours spread about you on the internet)
- ○ Had someone steal from you or damage your things

54. In the last 30 days, how often have you been bullied by other students?

- ○ I have not been bullied by other students in the last 30 days
- ○ Less than once a week
- ○ About once a week
- ○ 2 or 3 times a week
- ○ Daily or almost daily

55. In the last 30 days, in what ways did you bully other students? *(Mark all that apply)*

- ○ I did not bully other students in the last 30 days
- ○ Physical attacks (e.g., beat up, pushed, or kicked them)
- ○ Verbal attacks (e.g., teased, threatened, or spread rumours about them)
- ○ Cyber-attacks (e.g., sent mean text messages or spread rumours about them on the internet)
- ○ Stole from them or damaged their things

56. In the last 30 days, how often have you taken part in bullying other students?

- ○ I did not bully other students in the last 30 days
- ○ Less than once a week
- ○ About once a week
- ○ 2 or 3 times a week
- ○ Daily or almost daily

57. How supportive is your school of the following?	Very supportive	Supportive	Unsupportive	Very unsupportive
a) Making sure there are opportunities for students to be physically active	○	○	○	○
b) Making sure students have access to healthy foods and drinks	○	○	○	○
c) Making sure no one is bullied at school	○	○	○	○
d) Giving students the support they need to resist or quit tobacco	○	○	○	○
e) Giving students the support they need to resist or quit drugs and/or alcohol	○	○	○	○

58. What academic level was your current or most recent Math course?

- ○ Applied
- ○ Academic
- ○ Other _____

59. In your current or most recent Math course, what is your approximate overall mark?
(Think about last year if you have not taken math this year)

- ○ 90% - 100%
- ○ 80% - 89%
- ○ 70% - 79%
- ○ 60% - 69%
- ○ 55% - 59%
- ○ 50% - 54%
- ○ Less than 50%

60. In your current or most recent English course, what is your approximate overall mark?
(Think about last year if you have not taken English this year)

- ○ 90% - 100%
- ○ 80% - 89%
- ○ 70% - 79%
- ○ 60% - 69%
- ○ 55% - 59%
- ○ 50% - 54%
- ○ Less than 50%

61. What is the highest level of education you would like to get? *(Choose only one)*

- ○ Some high school or less
- ○ High school diploma or graduation equivalency
- ○ College/trade/vocational certificate
- ○ University Bachelor's degree
- ○ University Master's / PhD / law school / medical school / teachers' college degree
- ○ I don't know

62. What is the highest level of education you think you will get? *(Choose only one)*

- ○ Some high school or less
- ○ High school diploma or graduation equivalency
- ○ College/trade/vocational certificate
- ○ University Bachelor's degree
- ○ University Master's / PhD / law school / medical school / teachers' college degree
- ○ I don't know

63. In the last 4 weeks, how many days of school did you miss because of your health?

- ○ 0 days
- ○ 1 or 2 days
- ○ 3 to 5 days
- ○ 6 to 10 days
- ○ 11 or more days

64. In the last 4 weeks, how many classes did you skip when you were not supposed to?

- ○ 0 classes
- ○ 1 or 2 classes
- ○ 3 to 5 classes
- ○ 6 to 10 classes
- ○ 11 to 20 classes
- ○ More than 20 classes

65. How often do you go to class without your homework complete?

- ○ Never
- ○ Seldom
- ○ Often
- ○ Usually

○○○○○○○○○○○○○○○○○○○○○○○○○ [serial]

Appendix B

Supplementary material from Manuscript 1

Supplementary Table 18. Comparison of demographic and behavioural characteristics of the linked sample to the unlinked sample, 2013-16 COMPASS study

Sociodemographic characteristics		Linked sample n (%)	Unlinked sample n (%)	Chi-square (df) p-value
		N=3867	N=4476	
Gender	Female	2029 (52.5)	2201 (49.2)	9.0 (1) P=0.003
	Male	1838 (47.5)	2275 (50.8)	
Ethnicity	White	3019 (78.5)	3466 (77.9)	12.6 (2) P=0.002
	Other	712 (18.5)	782 (17.6)	
	Off-reserve Aboriginal	116 (3.0)	199 (4.5)	
Spending money	Zero	907 (23.6)	929 (20.9)	33.2 (3) p<0.001
	$1-$20	1670 (43.5)	1803 (40.6)	
	More than $20	747 (19.4)	1076 (24.2)	
	I do not know how much I get each week	518 (13.5)	636 (14.3)	
Susceptibility to future cigarette smoking	Non-susceptible	2731 (70.6)	2956 (66.0)	20.1 (1) p<0.001
	Susceptible	1136 (29.4)	1520 (34.0)	
Number of friends that smoke cigarettes	None	3242 (83.9)	3583 (80.2)	19.3 (1) p<0.001
	Any	621 (16.1)	884 (19.8)	

Supplementary Table 19. Sensitivity, specificity, positive predictive value, and negative predictive value of the susceptibility construct (overall) and each susceptibility measure at Follow-up Year 1 and Follow-up Year 2 for different measures of tobacco cigarette smoking, 2013-16 COMPASS study

	Sensitivity (%)		Specificity (%)		PPV (%)		NPV (%)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Ever tried cigarettes[1]								
Overall	59.5	54.6	73.5	75.9	17.7	32.2	95.0	88.8

	Sensitivity (%)		Specificity (%)		PPV (%)		NPV (%)	
	Year 1	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**
S1-Try	52.7	47.7	78.6	80.8	19.0	34.3	94.6	88.1
S2-Offer	47.2	40.6	83.7	85.6	21.7	37.2	94.3	87.3
S3-Smoke	41.8	34.7	86.6	88.0	23.0	37.8	94.0	86.5
Smoked cigarettes in the last 30 days[2]								
Overall	56.0	57.9	71.2	72.3	4.1	11.0	98.6	96.7
S1-Try	50.6	50.7	76.5	77.5	4.5	11.7	98.6	96.4
S2-Offer	48.8	45.4	81.7	82.6	5.6	13.4	98.6	96.2
S3-Smoke	36.1	38.1	84.5	85.4	4.9	13.4	98.4	95.9
Smoked 100 whole cigarettes in life[3]								
Overall	32.1	59.8	70.6	71.3	0.8	4.6	99.3	98.7
S1-Try	28.6	50.6	75.9	76.5	0.9	4.7	99.3	98.5
S2-Offer	32.1	44.8	81.1	81.6	1.2	5.3	99.4	98.5
S3-Smoke	25.0	39.1	84.2	84.7	1.1	5.6	99.4	98.4

[1] Have you ever tried cigarette smoking, even just a few puffs?
[2] On how many of the last 30 days did you smoke one or more cigarettes?
[3] Have you ever smoked 100 or more whole cigarettes in your life?
S1-Try: "Do you think in the future you might try smoking cigarettes?"
S2-Offer: "If one of your best friends was to offer you a cigarette, would you smoke it?"
S3-Smoke: "At any time during the next year do you think you will smoke a cigarette?

Appendix C

Supplementary material from Manuscript 3

Supplementary Table 20. Fit statistics from latent class models at Baseline, Follow-up Year 1, and Follow-up Year 2, 2013-16 COMPASS study

Number of Latent Classes	Log-likelihood	BIC
Baseline		
1	-2555.77	1277.49
2	-2052.60	338.71
3	**-1994.14**	**289.35**
4	-1986.65	341.92
5*	-1986.30	408.79
Follow-up Year 1		
1	-5160.37	2562.26
2	-4070.64	450.34
3	-3987.03	350.68
4	**-3964.42**	**373.02**
5	-3950.91	413.56
6	-3945.34	469.99
Follow-up Year 2		
1	-6748.77	3228.82
2	-5364.53	527.90
3	-5259.99	386.37
4	**-5231.69**	**397.32**
5	-5220.83	443.18
6	-5215.86	500.79

* NOTE: the model did not converge in 10,000 iterations. Standard errors could not be computed for this model.
Bolded line represents the selected model.

Supplementary Table 21. Characteristics of students in the identified latent classes at Baseline, 2013-14 COMPASS study

		CLASS 1 Non-current users n (%)	**CLASS 2** Current cigarette, CLC, and e-cigarette users n (%)	**CLASS 3** Current multiple product users n (%)	X2 (df) p-value
		4461 (95.91)	175 (3.76)	15 (0.32)	
Environmental variables					
Number of friends that smoke cigarettes	None	3595 (81.22)	60 (34.29)	5 (33.33)	245.22 (2) P<0.001
	Any	831 (18.78)	115 (65.71)	10 (66.67)	
School connectedness score	Mean (stdev)	19.14 (2.71)	17.17 (3.72)	16.93 (4.70)	F=45.73 (2) P<0.001
Behavioural factors (substance use)					
Binge drinking status	Never binged	3616 (81.19)	50 (28.74)	6 (40.00)	292.43 (2) P<0.001
	Ever binged	838 (18.81)	124 (71.26)	9 (60.00)	
Marijuana use status	Never used marijuana	4151 (94.30)	61 (35.67)	6 (42.86)	810.56 (2) P<0.001
	Ever used marijuana	251 (5.70)	110 (64.33)	8 (57.14)	
Behavioural factors (non-substance use)					
Number of classes skipped in the last 4 weeks	None	4041 (91.97)	105 (61.05)	6 (42.86)	224.66 (2) P<0.001
	Any	353 (8.03)	67 (38.95)	8 (57.14)	
Number of school days ate breakfast	Less than 5 days	2169 (49.19)	124 (72.09)	10 (71.43)	37.27 (2) P<0.001
	Everyday (5 days)	2240 (50.81)	48 (27.91)	4 (28.57)	
Meets Canadian physical activity recommendations	No	2191 (50.28)	81 (48.80)	10 (66.67)	1.756 (2) P=0.415
	Yes	2167 (49.72)	85 (51.20)	5 (33.33)	
Sociodemographic characteristics					
Gender	Female	2301 (51.68)	91 (52.00)	7 (46.67)	0.16 (2) P=0.924
	Male	2151 (48.32)	84 (48.00)	8 (53.33)	
Ethnicity	White	3445 (77.66)	127 (72.57)	7 (46.67)	10.59 (2) P=0.005
	Other	991 (22.34)	48 (27.43)	8 (53.33)	
Spending money	Zero / I Don’t Know	1600 (36.11)	46 (26.59)	2 (14.29)	24.57 (4) P<0.001
	$1-$20	1933 (43.62)	67 (38.73)	8 (57.14)	
	More than $20	898 (20.27)	60 (34.68)	4 (28.57)	

Supplementary Table 22. Characteristics of students in the identified latent classes at Follow-up Year 1, 2014-15 COMPASS study

		CLASS 1 Non-current users n (%)	**CLASS 2** Current e-cigarette users n (%)	**CLASS 3** Current cigarette and CLC users n (%)	**CLASS 4** Current multiple product users n (%)	X2 (df) p-value
		4183 (89.94)	272 (5.85)	163 (3.50)	33 (0.71)	
Environmental variables						
Number of friends that smoke cigarettes	None	3202 (77.32)	149 (54.78)	46 (28.40)	7 (21.21)	297.93 (3) P<0.0001
	Any	939 (22.68)	123 (45.22)	116 (71.60)	26 (78.79)	
School connectedness score	Mean (stdev)	18.69 (2.97)	17.62 (3.17)	17.75 (3.80)	15.90 (5.95)	F=22.93 (3) P<0.001
Behavioural factors (substance use)						
Binge drinking status	Never binged	2791 (66.82)	67 (24.63)	15 (9.32)	3 (9.09)	430.99 (3) P<0.001
	Ever binged	1386 (33.18)	205 (75.37)	146 (90.68)	30 (90.91)	
Marijuana use status	Never used marijuana	3486 (84.43)	106 (39.70)	44 (27.67)	2 (6.06)	687.04 (3) P<0.001
	Ever used marijuana	643 (15.57)	161 (60.30)	115 (72.33)	31 (93.94)	
Behavioural factors (non-substance use)						
Number of classes skipped in the last 4 weeks	None	3478 (84.34)	171 (63.81)	91 (57.23)	14 (43.75)	172.46 (3) P<0.001
	Any	646 (15.66)	97 (36.19)	68 (42.77)	18 (56.25)	
Number of school days ate breakfast	Less than 5 days	2102 (50.75)	169 (62.59)	95 (58.28)	20 (60.61)	18.20 (3) P=0.004
	Everyday (5 days)	2040 (49.25)	101 (37.41)	68 (41.72)	13 (39.39)	
Meets Canadian physical activity recommendations	No	2244 (54.96)	128 (48.30)	48 (30.00)	9 (27.27)	51.02 (3) P<0.001
	Yes	1839 (45.04)	137 (51.70)	112 (70.00)	24 (72.73)	
Sociodemographic characteristics						
Gender	Female	2232 (53.47)	128 (47.06)	36 (22.09)	3 (9.09)	88.84 (3) P<0.001
	Male	1942 (46.53)	144 (52.94)	127 (77.19)	30 (90.91)	
Ethnicity	White	3201 (76.97)	209 (77.12)	139 (85.28)	30 (90.91)	9.67 (3) P=0.022
	Other	958 (23.03)	62 (22.88)	24 (14.72)	3 (9.09)	
Spending money	Zero / IDK	1344 (32.25)	51 (18.96)	27 (16.67)	6 (18.18)	81.85 (6) P<0.001
	$1-$20	1494 (35.84)	109 (40.52)	41 (25.31)	6 (18.18)	
	More than $20	1330 (31.91)	109 (40.52)	94 (58.02)	21 (63.64)	

Supplementary Table 23. Characteristics of students in the identified latent classes at Follow-up Year 2, 2015-16 COMPASS study

		CLASS 1 Non-current users n (%)	**CLASS 2** Current cigarette and e-cigarette users n (%)	**CLASS 3** Current cigarette, CLC, cigar, and e-cigarette users n (%)	**CLASS 4** Current multiple product users n (%)	X2 (df) p-value
		4180 (89.87)	301 (6.47)	124 (2.67)	46 (0.99)	
Environmental variables						
Number of friends that smoke cigarettes	None	3090 (74.55)	90 (29.90)	34 (27.64)	10 (22.22)	424.25 (3) P<0.001
	Any	1055 (25.45)	211 (70.10)	89 (72.36)	35 (77.78)	
School connectedness score	Mean (stdev)	18.47 (3.11)	17.24 (3.75)	18.50 (3.81)	16.65 (6.05)	F=17.80 (3) P<0.001
Behavioural factors (substance use)						
Binge drinking status	Never binged	2184 (52.36)	19 (6.35)	7 (5.69)	7 (15.22)	347.61 (3) P<0.001
	Ever binged	1987 (47.64)	280 (93.65)	116 (94.31)	39 (84.78)	
Marijuana use status	Never used marijuana	3043 (73.73)	45 (15.00)	18 (14.52)	5 (11.90)	670.29 (3) P<0.001
	Ever used marijuana	1084 (26.27)	255 (85.00)	106 (85.48)	37 (88.10)	
Behavioural factors (non-substance use)						
Number of classes skipped in the last 4 weeks	None	3085 (74.50)	105 (35.35)	56 (45.53)	11 (26.83)	284.10 (3) P<0.001
	Any	1056 (25.50)	192 (64.65)	67 (54.47)	30 (73.17)	
Number of school days ate breakfast	Less than 5 days	2219 (53.70)	216 (72.24)	77 (62.10)	28 (63.64)	42.51 (3) P<0.001
	Everyday (5 days)	1913 (46.30)	83 (27.76)	47 (37.90)	16 (36.36)	
Meets Canadian physical activity recommendations	No	2209 (53.94)	128 (43.24)	38 (31.67)	17 (38.64)	37.87 (3) P<0.001
	Yes	1886 (46.06)	168 (56.76)	82 (68.33)	27 (61.36)	
Sociodemographic characteristics						
Gender	Female	2242 (53.74)	134 (44.52)	18 (14.63)	5 (10.87)	111.55 (3) P<0.001
	Male	1930 (46.26)	167 (55.48)	105 (85.37)	41 (89.13)	
Ethnicity	White	3204 (77.07)	235 (78.60)	107 (86.29)	33 (71.74)	6.93 (3) P=0.074
	Other	953 (22.93)	64 (21.40)	17 (13.71)	13 (28.26)	
Spending money	Zero / IDK	1088 (26.12)	47 (15.67)	13 (10.48)	6 (13.04)	88.24 (6) P<0.001
	$1-$20	997 (23.94)	55 (16.67)	12 (9.68)	4 (8.70)	
	More than $20	2080 (49.94)	203 (67.67)	99 (79.84)	36 (78.26)	

Appendix D

Supplementary material from Manuscript 4

Supplementary Table 24. Item-response probabilities for the 5-group model of cigarette use at each time point, 2013-16 COMPASS study

	GROUP 1 Non-susceptible non-users			**GROUP 2** Non-susceptible puffers			**GROUP 3** Stable low intenders			**GROUP 4** Escalating experimenters			**Group 5** Consistent current users		
	Baseline	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**
S1-Try															
1 (Definitely yes)	0.0010	0.0014	0.0004	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0014	0.0000	0.0082	0.0136	0.0194	0.0261
2 (Probably yes)	0.0000	0.0000	0.0021	0.0000	0.0069	0.0000	0.0584	0.0731	0.0608	0.4384	0.2068	0.0886	0.0000	0.0000	0.0000
3 (Probably not)	0.0406	0.0354	0.0404	0.0860	0.0165	0.0092	0.8005	0.7521	0.6213	0.1569	0.0074	0.0000	0.0000	0.0000	0.0000
4 (Definitely not)	0.9539	0.9606	0.9497	0.0590	0.1675	0.0261	0.1321	0.1173	0.1126	0.0000	0.0102	0.0012	0.0000	0.0000	0.0000
5 (Ever tried)	0.0046	0.0027	0.0073	0.8550	0.8091	0.9647	0.0080	0.0575	0.2052	0.4033	0.7757	0.9020	0.9864	0.9806	0.9739
S2-Offer															
1 (Definitely yes)	0.0000	0.0005	0.0005	0.0032	0.0030	0.0044	0.0000	0.0017	0.0038	0.0160	0.0096	0.0181	0.2243	0.4619	0.7544
2 (Probably yes)	0.0003	0.0000	0.0003	0.0000	0.0050	0.0277	0.0124	0.0417	0.0557	0.3384	0.4785	0.5802	0.6364	0.5039	0.2456
3 (Probably not)	0.0277	0.0270	0.0240	0.3043	0.2539	0.1405	0.6608	0.7647	0.8172	0.6456	0.5119	0.3882	0.1393	0.0342	0.0000
4 (Definitely not)	0.9721	0.9725	0.9753	0.6924	0.7381	0.8275	0.3267	0.1918	0.1233	0.0000	0.0000	0.0136	0.0000	0.0000	0.0000
S3-Smoke															
1 (Definitely yes)	0.0006	0.0007	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0018	0.0000	0.0000	0.0073	0.2328	0.5768	0.8150
2 (Probably yes)	0.0000	0.0000	0.0003	0.0230	0.0099	0.0138	0.0000	0.0065	0.0100	0.2791	0.4541	0.6969	0.6037	0.4114	0.1730
3 (Probably not)	0.0055	0.0039	0.0024	0.2269	0.1462	0.1308	0.6187	0.7188	0.8042	0.6857	0.5459	0.2958	0.1151	0.0000	0.0000
4 (Definitely not)	0.9938	0.9955	0.9973	0.7501	0.8438	0.8554	0.3802	0.2747	0.1840	0.0352	0.0000	0.0000	0.0485	0.0118	0.0120
Current cigarette use															
1 (Yes)	0.0000	0.0000	0.0000	0.0410	0.0172	0.0261	0.0000	0.0000	0.0000	0.0000	0.1212	0.4417	0.7527	0.8579	0.8859
2 (No)	1.0000	1.0000	1.0000	0.9590	0.9828	0.9739	1.0000	1.0000	1.0000	1.0000	0.8788	0.5583	0.2473	0.1421	0.1141

S1-Try: “Do you think in the future you might try smoking cigarettes?”
S2-Offer: “If one of your best friends was to offer you a cigarette, would you smoke it?”
S3-Smoke: “At any time during the next year do you think you will smoke a cigarette?

Supplementary Table 25. Item-response probabilities for the 5-group model of e-cigarette use at each time point, 2013-16 COMPASS study

	GROUP 1 Non-susceptible non-users			**GROUP 2** Non-susceptible puffers			**GROUP 3** Stable low intenders			**GROUP 4** Escalating experimenters			**Group 5** Consistent current users		
	Baseline	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**
S1-Try															
1 (Definitely yes)	0.0009	0.0014	0.0004	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0059	0.0127	0.0238	0.0297
2 (Probably yes)	0.0000	0.0000	0.0022	0.0000	0.0054	0.0000	0.0502	0.0769	0.0548	0.2930	0.1712	0.0935	0.1477	0.0088	0.0000
3 (Probably not)	0.0323	0.0339	0.0390	0.1726	0.0201	0.0161	0.7902	0.7613	0.6486	0.3816	0.0498	0.0105	0.0000	0.0000	0.0000
4 (Definitely not)	0.9626	0.9629	0.9459	0.2864	0.2432	0.1129	0.1537	0.1211	0.1185	0.0000	0.0084	0.0024	0.0000	0.0000	0.0043
5 (Ever tried)	0.0041	0.0018	0.0126	0.5410	0.7312	0.8710	0.0042	0.0406	0.1781	0.3255	0.7706	0.8877	0.8396	0.9674	0.9660
S2-Offer															
1 (Definitely yes)	0.0000	0.0000	0.0005	0.0000	0.0069	0.0000	0.0000	0.0026	0.0028	0.0042	0.0041	0.0205	0.1969	0.5721	0.7642
2 (Probably yes)	0.0003	0.0000	0.0000	0.0000	0.0151	0.0112	0.0085	0.0300	0.0461	0.1805	0.4963	0.5554	0.6872	0.4279	0.2358
3 (Probably not)	0.0243	0.0254	0.0221	0.2440	0.2367	0.1398	0.6121	0.7693	0.8220	0.7879	0.4989	0.4135	0.1159	0.0000	0.0000
4 (Definitely not)	0.9754	0.9746	0.9774	0.7560	0.7413	0.8490	0.3794	0.1981	0.1290	0.0274	0.0007	0.0107	0.0000	0.0000	0.0000
S3-Smoke															
1 (Definitely yes)	0.0006	0.0007	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0035	0.0098	0.1830	0.6969	0.8262
2 (Probably yes)	0.0000	0.0000	0.0003	0.0120	0.0081	0.0174	0.0000	0.0057	0.0036	0.0943	0.4633	0.6433	0.7368	0.3031	0.1547
3 (Probably not)	0.0046	0.0038	0.0019	0.1346	0.1369	0.1332	0.5604	0.7063	0.8011	0.8609	0.5332	0.3319	0.0371	0.0000	0.0000
4 (Definitely not)	0.9948	0.9956	0.9978	0.8534	0.8550	0.8493	0.4381	0.2879	0.1952	0.0448	0.0000	0.0149	0.0432	0.0000	0.0190
Current e-cigarette use															
1 (Yes)	0.0076	0.0236	0.0266	0.0683	0.1597	0.1431	0.0236	0.0728	0.0720	0.1033	0.2486	0.2638	0.2545	0.3975	0.4460
2 (No)	0.9924	0.9764	0.9734	0.9317	0.8403	0.8569	0.9764	0.9272	0.9280	0.8967	0.7514	0.7362	0.7455	0.6025	0.5540

S1-Try: “Do you think in the future you might try smoking cigarettes?”
S2-Offer: “If one of your best friends was to offer you a cigarette, would you smoke it?”
S3-Smoke: “At any time during the next year do you think you will smoke a cigarette?

Supplementary Table 26. Item-response probabilities for the 5-group model of cigarillo or little cigar use at each time point, 2013-16 COMPASS study

	GROUP 1 Non-susceptible non-users			**GROUP 2** Non-susceptible puffers			**GROUP 3** Stable low intenders			**GROUP 4** Escalating experimenters			**Group 5** Consistent current users		
	Baseline	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**
S1-Try															
1 (Definitely yes)	0.0008	0.0014	0.0004	0.0000	0.0000	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0061	0.0117	0.0229	0.0290
2 (Probably yes)	0.0000	0.0000	0.0022	0.0060	0.0062	0.0000	0.0441	0.0754	0.0552	0.2807	0.1744	0.0936	0.1558	0.0096	0.0000
3 (Probably not)	0.0299	0.0333	0.0387	0.1758	0.0344	0.0180	0.7844	0.7677	0.6496	0.4399	0.0548	0.0108	0.0000	0.0000	0.0000
4 (Definitely not)	0.9655	0.9638	0.9423	0.2581	0.2536	0.0765	0.1695	0.1222	0.1202	0.0000	0.0103	0.0025	0.0000	0.0000	0.0045
5 (Ever tried)	0.0038	0.0015	0.0165	0.5601	0.7058	0.9055	0.0000	0.0348	0.1750	0.2794	0.7605	0.8871	0.8324	0.9674	0.9666
S2-Offer															
1 (Definitely yes)	0.0000	0.0000	0.0005	0.0000	0.0068	0.0000	0.0000	0.0025	0.0031	0.0028	0.0038	0.0229	0.1840	0.5524	0.7485
2 (Probably yes)	0.0003	0.0000	0.0000	0.0000	0.0132	0.0132	0.0063	0.0307	0.0459	0.1600	0.4809	0.5528	0.6694	0.4476	0.2448
3 (Probably not)	0.0238	0.0250	0.0223	0.2520	0.2391	0.1502	0.5882	0.7683	0.8219	0.8126	0.5152	0.4132	0.1466	0.0000	0.0067
4 (Definitely not)	0.9760	0.9750	0.9772	0.7480	0.7409	0.8366	0.4055	0.1985	0.1291	0.0245	0.0000	0.0111	0.0000	0.0000	0.0000
S3-Smoke															
1 (Definitely yes)	0.0006	0.0007	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0035	0.0026	0.1687	0.6719	0.8316
2 (Probably yes)	0.0000	0.0000	0.0004	0.0135	0.0083	0.0169	0.0000	0.0046	0.0034	0.0708	0.4493	0.6491	0.7192	0.3281	0.1492
3 (Probably not)	0.0038	0.0037	0.0020	0.1495	0.1358	0.1489	0.5385	0.7069	0.7991	0.8766	0.5472	0.3363	0.0657	0.0000	0.0000
4 (Definitely not)	0.9956	0.9956	0.9977	0.8370	0.8560	0.8342	0.4599	0.2885	0.1975	0.0526	0.0000	0.0120	0.0464	0.0000	0.0192
Current cigarillo or little cigar use															
1 (Yes)	0.0035	0.0068	0.0140	0.0491	0.0877	0.0981	0.0002	0.0207	0.0458	0.0508	0.1452	0.1958	0.1909	0.5031	0.4575
2 (No)	0.9965	0.9932	0.9860	0.9509	0.9123	0.9019	0.9998	0.9793	0.9542	0.9492	0.8548	0.8042	0.8091	0.4969	0.5425

S1-Try: “Do you think in the future you might try smoking cigarettes?”
S2-Offer: “If one of your best friends was to offer you a cigarette, would you smoke it?”
S3-Smoke: “At any time during the next year do you think you will smoke a cigarette?

Supplementary Table 27. Item-response probabilities for the 5-group model of cigar use at each time point, 2013-16 COMPASS study

	GROUP 1 Non-susceptible non-users			**GROUP 2** Non-susceptible puffers			**GROUP 3** Stable low intenders			**GROUP 4** Escalating experimenters			**Group 5** Consistent current users		
	Baseline	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**
S1-Try															
1 (Definitely yes)	0.0010	0.0014	0.0004	0.0000	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0067	0.0180	0.0262	0.0279
2 (Probably yes)	0.0000	0.0000	0.0021	0.0001	0.0072	0.0000	0.0631	0.0745	0.0533	0.3600	0.1757	0.0964	0.0579	0.0000	0.0000
3 (Probably not)	0.0390	0.0349	0.0384	0.1394	0.0223	0.0187	0.8025	0.7586	0.6393	0.1749	0.0360	0.0108	0.0000	0.0000	0.0000
4 (Definitely not)	0.9567	0.9616	0.9431	0.1222	0.2073	0.0309	0.1333	0.1204	0.1205	0.0000	0.0087	0.0026	0.0000	0.0000	0.0045
5 (Ever tried)	0.0033	0.0021	0.0160	0.7383	0.7632	0.9505	0.0000	0.0465	0.1869	0.4650	0.7796	0.8835	0.9241	0.9738	0.9676
S2-Offer															
1 (Definitely yes)	0.0000	0.0004	0.0005	0.0000	0.0045	0.0000	0.0000	0.0017	0.0030	0.0100	0.0092	0.0227	0.2700	0.6163	0.7514
2 (Probably yes)	0.0003	0.0000	0.0000	0.0000	0.0145	0.0143	0.0128	0.0334	0.0451	0.2972	0.5159	0.5627	0.7300	0.3837	0.2402
3 (Probably not)	0.0270	0.0259	0.0226	0.2556	0.2513	0.1404	0.6630	0.7705	0.8199	0.6928	0.4750	0.4058	0.0000	0.0000	0.0084
4 (Definitely not)	0.9728	0.9737	0.9769	0.7444	0.7297	0.8454	0.3242	0.1944	0.1319	0.0000	0.0000	0.0088	0.0000	0.0000	0.0000
S3-Smoke															
1 (Definitely yes)	0.0006	0.0007	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	0.0000	0.0043	0.0013	0.2630	0.7655	0.8365
2 (Probably yes)	0.0000	0.0000	0.0004	0.0156	0.0090	0.0219	0.0000	0.0060	0.0035	0.2516	0.4919	0.6590	0.6798	0.2345	0.1433
3 (Probably not)	0.0054	0.0038	0.0020	0.1880	0.1494	0.1397	0.6167	0.7124	0.7984	0.7161	0.5038	0.3285	0.0085	0.0000	0.0000
4 (Definitely not)	0.9940	0.9955	0.9976	0.7964	0.8416	0.8384	0.3820	0.2816	0.1981	0.0322	0.0000	0.0111	0.0487	0.0000	0.0202
Current cigar use															
1 (Yes)	0.0021	0.0053	0.0079	0.0229	0.0465	0.0729	0.0044	0.0166	0.0307	0.0329	0.0996	0.1207	0.1789	0.3782	0.3486
2 (No)	0.9979	0.9947	0.9921	0.9771	0.9535	0.9271	0.9956	0.9834	0.9693	0.9671	0.9004	0.8793	0.8211	0.6218	0.6514

S1-Try: “Do you think in the future you might try smoking cigarettes?”
S2-Offer: “If one of your best friends was to offer you a cigarette, would you smoke it?”
S3-Smoke: “At any time during the next year do you think you will smoke a cigarette?

Supplementary Table 28. Item-response probabilities for the 5-group model of hookah use at each time point, 2013-16 COMPASS study

	GROUP 1 Non-susceptible non-users			**GROUP 2** Non-susceptible puffers			**GROUP 3** Stable low intenders			**GROUP 4** Escalating experimenters			**Group 5** Consistent current users		
	Baseline	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**
S1-Try															
1 (Definitely yes)	0.0009	0.0014	0.0004	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0060	0.0129	0.0258	0.0308
2 (Probably yes)	0.0000	0.0000	0.0022	0.0000	0.0055	0.0000	0.0509	0.0746	0.0520	0.2989	0.1724	0.0972	0.1432	0.0100	0.0000
3 (Probably not)	0.0334	0.0341	0.0393	0.1511	0.0159	0.0131	0.7916	0.7507	0.6313	0.3671	0.0348	0.0112	0.0000	0.0000	0.0000
4 (Definitely not)	0.9616	0.9631	0.9414	0.2659	0.2234	0.1349	0.1520	0.1194	0.1124	0.0000	0.0099	0.0038	0.0000	0.0000	0.0043
5 (Ever tried)	0.0042	0.0014	0.0168	0.5830	0.7551	0.8520	0.0039	0.0553	0.2043	0.3340	0.7829	0.8818	0.8439	0.9642	0.9648
S2-Offer															
1 (Definitely yes)	0.0009	0.0000	0.0005	0.0000	0.0077	0.0000	0.0000	0.0024	0.0024	0.0048	0.0044	0.0307	0.0129	0.6193	0.7722
2 (Probably yes)	0.0003	0.0000	0.0000	0.0000	0.0143	0.0191	0.0075	0.0326	0.0421	0.1926	0.5208	0.5723	0.6838	0.3807	0.2278
3 (Probably not)	0.0249	0.0259	0.0226	0.2392	0.2285	0.1274	0.6154	0.7675	0.8257	0.7815	0.4748	0.3869	0.1173	0.0000	0.0000
4 (Definitely not)	0.9748	0.9741	0.9769	0.7608	0.7495	0.8535	0.3772	0.1976	0.1298	0.0211	0.0000	0.0101	0.0000	0.0000	0.0000
S3-Smoke															
1 (Definitely yes)	0.0006	0.0007	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0041	0.0104	0.1858	0.7541	0.8576
2 (Probably yes)	0.0000	0.0000	0.0004	0.0128	0.0091	0.0183	0.0000	0.0051	0.0031	0.0986	0.4936	0.6708	0.7434	0.2459	0.1216
3 (Probably not)	0.0045	0.0037	0.0019	0.1392	0.1261	0.1216	0.5642	0.7107	0.8040	0.8582	0.5023	0.3086	0.0249	0.0000	0.0000
4 (Definitely not)	0.9949	0.9956	0.9978	0.8480	0.8648	0.8601	0.4343	0.2843	0.1929	0.0433	0.0000	0.0102	0.0459	0.0000	0.0208
Current hookah use															
1 (Yes)	0.0030	0.0062	0.0131	0.0256	0.0950	0.0642	0.0016	0.0157	0.0248	0.0476	0.0920	0.1094	0.1353	0.2799	0.2912
2 (No)	0.9970	0.9938	0.9869	0.9744	0.9050	0.9358	0.9984	0.9843	0.9752	0.9524	0.9080	0.8906	0.8647	0.7201	0.7088

S1-Try: “Do you think in the future you might try smoking cigarettes?”
S2-Offer: “If one of your best friends was to offer you a cigarette, would you smoke it?”
S3-Smoke: “At any time during the next year do you think you will smoke a cigarette?

Supplementary Table 29. Item-response probabilities for the 5-group model of smokeless tobacco use at each time point, 2013-16 COMPASS study

	GROUP 1 Non-susceptible non-users			**GROUP 2** Non-susceptible puffers			**GROUP 3** Stable low intenders			**GROUP 4** Escalating experimenters			**Group 5** Consistent current users		
	Baseline	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**	**Baseline**	**FY1**	**FY2**
S1-Try															
1 (Definitely yes)	0.0008	0.0014	0.0004	0.0000	0.0000	0.0000	0.0019	0.0000	0.0000	0.0000	0.0000	0.0056	0.0121	0.0269	0.0298
2 (Probably yes)	0.0000	0.0000	0.0022	0.0000	0.0062	0.0000	0.0468	0.0752	0.0537	0.2728	0.1732	0.0963	0.1587	0.0000	0.0000
3 (Probably not)	0.0311	0.0339	0.0385	0.1651	0.0272	0.0204	0.7958	0.7552	0.6431	0.4154	0.0317	0.0123	0.0000	0.0000	0.0000
4 (Definitely not)	0.9640	0.9629	0.9479	0.3447	0.2252	0.0596	0.1544	0.1204	0.1202	0.0104	0.0095	0.0026	0.0000	0.0000	0.0045
5 (Ever tried)	0.0040	0.0018	0.0111	0.4903	0.7414	0.9200	0.0010	0.0493	0.1830	0.3014	0.7856	0.8831	0.8292	0.9731	0.9656
S2-Offer															
1 (Definitely yes)	0.0000	0.0000	0.0005	0.0000	0.0073	0.0000	0.0000	0.0024	0.0030	0.0030	0.0087	0.0244	0.1891	0.6243	0.7380
2 (Probably yes)	0.0003	0.0000	0.0000	0.0000	0.0138	0.0152	0.0072	0.0337	0.0442	0.1622	0.5202	0.5556	0.6707	0.3699	0.2530
3 (Probably not)	0.0245	0.0256	0.0223	0.2172	0.2395	0.1363	0.5964	0.7682	0.8224	0.7990	0.4711	0.4101	0.1402	0.0000	0.0091
4 (Definitely not)	0.9752	0.9744	0.9772	0.7828	0.7395	0.8485	0.3964	0.1958	0.1303	0.0357	0.0000	0.0100	0.0000	0.0058	0.0000
S3-Smoke															
1 (Definitely yes)	0.0006	0.0007	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0000	0.0040	0.0006	0.1740	0.7759	0.8272
2 (Probably yes)	0.0000	0.0000	0.0003	0.0102	0.0053	0.0188	0.0000	0.0057	0.0030	0.0729	0.4980	0.6550	0.7355	0.2241	0.1521
3 (Probably not)	0.0044	0.0037	0.0019	0.1131	0.1357	0.1316	0.5479	0.7115	0.8002	0.8688	0.4979	0.3337	0.0450	0.0000	0.0000
4 (Definitely not)	0.9950	0.9956	0.9977	0.8768	0.8590	0.8496	0.4505	0.2828	0.1967	0.0583	0.0000	0.0107	0.0454	0.0000	0.0207
Current smokeless tobacco use															
1 (Yes)	0.0048	0.0024	0.0043	0.0518	0.0478	0.0494	0.0000	0.0124	0.0242	0.0630	0.0694	0.0690	0.1031	0.2870	0.2988
2 (No)	0.9952	0.9976	0.9957	0.9482	0.9522	0.9506	1.0000	0.9876	0.9758	0.9370	0.9306	0.9310	0.8969	0.7130	0.7012

S1-Try: “Do you think in the future you might try smoking cigarettes?”
S2-Offer: “If one of your best friends was to offer you a cigarette, would you smoke it?”
S3-Smoke: “At any time during the next year do you think you will smoke a cigarette?

Supplementary Table 30. Baseline characteristics of students in the cigarette use trajectory groups at baseline, 2013-14 COMPASS study

		GROUP 1 Non-susceptible non-users n (%)	**GROUP 2** Non-susceptible puffers n (%)	**GROUP 3** Stable low intenders n (%)	**GROUP 4** Escalating experimenters n (%)	**GROUP 5** Consistent users n (%)	X2 (df) p-value
		3213 (69.08)	163 (3.50)	912 (19.61)	243 (5.22)	120 (2.58)	
Gender	Female	1612 (50.23)	72 (44.44)	490 (53.96)	147 (60.49)	78 (65.00)	24.07 (4) P<0.001
	Male	1597 (49.77)	90 (55.56)	418 (46.04)	96 (39.51)	42 (35.00)	
Ethnicity	White	2468 (77.32)	109 (67.28)	724 (79.65)	189 (77.78)	89 (74.17)	12.84 (4) P=0.012
	Other	724 (22.68)	53 (32.72)	185 (20.35)	54 (22.22)	31 (25.83)	
Spending money	Zero / I don't know	1190 (37.35)	41 (25.31)	300 (33.00)	84 (34.57)	33 (27.97)	34.60 (8) P<0.001
	$1-$20	1376 (43.19)	76 (46.91)	416 (45.76)	95 (39.09)	45 (38.14)	
	More than $20	620 (19.46)	45 (27.78)	193 (21.23)	64 (26.34)	40 (33.90)	
Number of friends that smoke cigarettes	None	2782 (87.16)	95 (58.28)	652 (72.44)	113 (46.89)	18 (15.00)	645.86 (4) P<0.001
	Any	410 (12.84)	68 (41.72)	248 (27.56)	128 (53.11)	102 (85.00)	
School connectedness score†	Mean (stdev)	19.50 (2.62)c	18.61 (2.97)[a]	18.29 (2.70)[a]	17.42 (2.93)[b]	16.89 (3.66)[b]	F=82.14 P<0.001
Current use of any other tobacco product or e-cigarette	No	3149 (98.01)	136 (83.44)	858 (94.08)	203 (83.54)	54 (45.00)	749.85 (4) P<0.0001
	Yes	64 (1.99)	27 (16.56)	54 (5.92)	40 (16.46)	66 (55.00)	
Binge drinking status	Never binge drank	2834 (88.23)	91 (56.52)	611 (67.29)	105 (43.21)	31 (26.05)	679.85 (4) P<0.001
	Ever binge drank	378 (11.77)	70 (43.48)	297 (32.71)	138 (56.79)	88 (73.95)	
Marijuana use status	Never used marijuana	3095 (97.73)	101 (62.35)	824 (91.56)	164 (68.05)	34 (29.06)	1146.65 (4) 0<0.001
	Ever used marijuana	72 (2.27)	61 (37.65)	76 (8.44)	77 (31.95)	83 (70.94)	
Number of classes skipped in the last 4 weeks	None	3006 (94.98)	135 (84.38)	781 (86.87)	173 (72.08)	57 (49.14)	426.11 (4) P<0.001
	Any	159 (5.02)	25 (15.63)	118 (13.13)	67 (27.92)	59 (50.86)	
Number of school days ate breakfast	Less than 5 days	1422 (44.69)	102 (64.97)	511 (56.78)	173 (72.38)	95 (81.20)	159.94 (4) P<0.001
	Everyday (5 days)	1760 (55.31)	55 (35.03)	389 (43.22)	66 (27.62)	22 (18.80)	
Meets Canadian physical activity recommendations	No	1584 (50.49)	80 (50.31)	431 (48.10)	109 (46.78)	53 (46.49)	2.99 (4) P=0.559
	Yes	1553 (49.51)	79 (49.69)	465 (51.90)	124 (53.22)	61 (53.51)	

† comparisons with the same letter are not statistically significant (p>0.05).

Supplementary Table 31. Baseline characteristics of students in the e-cigarette use trajectory groups at baseline, 2013-14 COMPASS study

		GROUP 1 Non-susceptible non-users n (%)	**GROUP 2** Non-susceptible puffers n (%)	**GROUP 3** Stable low intenders n (%)	**GROUP 4** Escalating experimenters n (%)	**GROUP 5** Consistent users n (%)	X2 (df) p-value
		3178 (68.33)	203 (4.36)	738 (15.87)	370 (7.96)	162 (3.48)	
Gender	Female	1602 (50.47)	86 (42.57)	387 (52.65)	219 (59.35)	105 (64.81)	28.72 (4) P<0.001
	Male	1572 (49.53)	116 (57.43)	348 (47.35)	150 (40.65)	57 (35.19)	
Ethnicity	White	2438 (77.23)	148 (73.27)	584 (79.46)	293 (79.19)	116 (71.60)	7.58 (4) P=0.108
	Other	719 (22.77)	54 (26.73)	151 (20.54)	77 (20.81)	46 (28.40)	
Spending money	Zero / I don't know	1179 (37.42)	54 (26.73)	251 (34.15)	117 (31.71)	47 (29.19)	36.89 (8) P<0.001
	$1-$20	1359 (43.13)	95 (47.03)	338 (45.99)	155 (42.01)	61 (37.89)	
	More than $20	613 (19.45)	53 (26.24)	146 (19.86)	97 (26.29)	53 (32.92)	
Number of friends that smoke cigarettes	None	2758 (87.36)	131 (64.53)	548 (75.27)	184 (50.00)	39 (24.38)	645.40 (4) P<0.001
	Any	399 (12.64)	72 (35.47)	180 (24.73)	184 (50.00)	121 (75.63)	
School connectedness score†	Mean (stdev)	19.51 (2.61)[b]	18.73 (2.97)[a]	18.38 (2.67)[a]	17.70 (2.96)[c]	16.76 (3.31)[d]	F=86.09 (4) P<0.001
Current use of any other tobacco product	No	3140 (98.80)	180 (88.67)	719 (97.43)	316 (85.41)	75 (46.30)	1052.87 (4) P<0.0001
	Yes	38 (1.20)	23 (11.33)	19 (2.57)	54 (14.59)	87 (53.70)	
Binge drinking status	Never binge drank	2806 (88.32)	116 (57.43)	531 (72.24)	168 (45.65)	51 (31.68)	709.46 (4) P<0.001
	Ever binge drank	371 (11.68)	86 (42.57)	204 (27.76)	200 (54.35)	110 (68.32)	
Marijuana use status	Never used marijuana	3066 (97.86)	140 (69.65)	684 (93.83)	265 (72.40)	63 (39.87)	1054.85 (4) P<0.001
	Ever used marijuana	67 (2.14)	61 (30.35)	45 (6.17)	101 (27.60)	95 (60.13)	
Number of classes skipped in the last 4 weeks	None	2979 (95.15)	170 (84.58)	649 (89.27)	270 (74.38)	84 (53.16)	460.56 (4) P<0.001
	Any	152 (4.85)	31 (15.42)	78 (10.73)	93 (25.62)	74 (46.84)	
Number of school days ate breakfast	Less than 5 days	1403 (44.58)	122 (61.62)	402 (55.22)	246 (67.77)	130 (81.76)	165.55 (4) P<0.001
	Everyday (5 days)	1744 (55.42)	76 (38.38)	326 (44.78)	117 (32.23)	29 (18.24)	
Meets Canadian physical activity recommendations	No	1563 (50.39)	104 (51.74)	348 (48.07)	170 (48.02)	72 (45.57)	3.17 (4) P=0.530
	Yes	1539 (49.61)	97 (48.26)	376 (51.93)	184 (51.98)	86 (54.43)	

† comparisons with the same letter are not statistically significant (p>0.05).

Supplementary Table 32. Baseline characteristics of students in the cigarillo or little cigar use trajectory groups at baseline, 2013-14 COMPASS study

		GROUP 1 Non-susceptible non-users n (%)	**GROUP 2** Non-susceptible puffers n (%)	**GROUP 3** Stable low intenders n (%)	**GROUP 4** Escalating experimenters n (%)	**GROUP 5** Consistent users n (%)	X2 (df) p-value
		3180 (68.37)	196 (4.21)	719 (15.46)	377 (8.11)	179 (3.85)	
Gender	Female	1601 (50.41)	79 (40.51)	385 (53.77)	218 (57.98)	116 (64.80)	31.37 (4) P<0.001
	Male	1575 (49.59)	116 (59.49)	331 (46.23)	158 (42.02)	63 (35.20)	
Ethnicity	White	2439 (77.21)	141 (72.31)	566 (79.05)	304 (80.64)	129 (72.07)	9.23 (4) P=0.056
	Other	720 (22.79)	54 (27.69)	150 (20.95)	73 (19.36)	50 (27.93)	
Spending money	Zero / I don't know	1181 (37.46)	51 (26.15)	243 (33.94)	121 (32.18)	52 (29.21)	39.04 (8) P<0.001
	$1-$20	1362 (43.20)	92 (47.18)	330 (46.09)	156 (41.49)	68 (38.20)	
	More than $20	610 (19.35)	52 (26.67)	143 (19.97)	99 (26.33)	58 (32.58)	
Number of friends that smoke cigarettes	None	2759 (87.34)	127 (64.80)	532 (74.93)	198 (52.94)	44 (24.86)	635.35 (4) P<0.001
	Any	400 (12.66)	69 (35.20)	178 (25.07)	176 (47.06)	133 (75.14)	
School connectedness score†	Mean (stdev)	19.50 (2.61)[b]	18.74 (2.95)[a]	18.41 (2.68)[a]	17.65 (2.91)[c]	16.93 (3.28)[d]	F=85.48 (4) P<0.001
Current use of any other tobacco product or e-cigarette	No	3128 (98.36)	163 (83.16)	696 (96.80)	312 (82.76)	75 (41.90)	1111.88 (4) P<0.001
	Yes	52 (1.64)	33 (16.84)	23 (3.20)	65 (17.24)	104 (58.10)	
Binge drinking status	Never binge drank	2813 (88.46)	108 (55.67)	518 (72.35)	178 (47.47)	55 (30.90)	729.47 (4) P<0.001
	Ever binge drank	367 (11.54)	86 (44.33)	198 (27.65)	197 (52.53)	123 (69.10)	
Marijuana use status	Never used marijuana	3071 (97.93)	131 (67.88)	669 (94.23)	277 (74.26)	70 (40.00)	1103.85 (4) P<0.001
	Ever used marijuana	65 (2.07)	62 (32.12)	41 (5.77)	96 (25.74)	105 (60.00)	
Number of classes skipped in the last 4 weeks	None	2982 (95.18)	162 (83.94)	634 (89.42)	279 (75.41)	95 (54.29)	462.09 (4) P<0.001
	Any	151 (4.82)	31 (16.06)	75 (10.58)	91 (24.59)	80 (45.71)	
Number of school days ate breakfast	Less than 5 days	1406 (44.65)	117 (61.26)	393 (55.20)	246 (67.03)	141 (80.11)	159.83 (4) P<0.001
	Everyday (5 days)	1743 (55.35)	74 (38.74)	319 (44.80)	121 (32.97)	35 (19.89)	
Meets Canadian physical activity recommendations	No	1563 (50.35)	103 (53.09)	331 (46.88)	179 (49.58)	81 (46.55)	4.355 (4) P=0.360
	Yes	1541 (49.65)	91 (46.91)	375 (53.12)	182 (50.42)	93 (53.45)	

† comparisons with the same letter are not statistically significant (p>0.05).

Supplementary Table 33. Baseline characteristics of students in the cigar use trajectory groups at baseline, 2013-14 COMPASS study

		GROUP 1 Non-susceptible non-users n (%)	**GROUP 2** Non-susceptible puffers n (%)	**GROUP 3** Stable low intenders n (%)	**GROUP 4** Escalating experimenters n (%)	**GROUP 5** Consistent users n (%)	X2 (df) p-value
		3203 (68.87)	163 (3.50)	897 (19.29)	264 (5.68)	124 (2.67)	
Gender	Female	1609 (50.30)	65 (40.12)	488 (54.65)	155 (58.71)	82 (66.13)	29.86 (4) P<0.001
	Male	1590 (49.70)	97 (59.88)	405 (45.35)	109 (41.29)	42 (33.87)	
Ethnicity	White	2460 (77.31)	114 (70.37)	712 (79.64)	206 (78.03)	87 (70.16)	10.92 (4) P=0.028
	Other	722 (22.69)	48 (29.63)	182 (20.36)	58 (21.97)	37 (29.84)	
Spending money	Zero / I don't know	1186 (37.34)	40 (24.69)	299 (33.45)	86 (32.70)	37 (30.08)	34.38 (8) P<0.001
	$1-$20	1374 (43.26)	75 (46.30)	405 (45.30)	109 (41.44)	45 (36.59)	
	More than $20	616 (19.40)	47 (29.01)	190 (21.25)	68 (25.86)	41 (33.33)	
Number of friends that smoke cigarettes	None	2776 (87.24)	98 (60.12)	640 (72.32)	124 (46.97)	22 (18.03)	631.89 (4) P<0.001
	Any	406 (12.76)	65 (39.88)	245 (27.68)	140 (53.03)	100 (81.97)	
School connectedness score†	Mean (stdev)	19.50 (2.62)[b]	18.76 (2.89)[a]	18.30 (2.71)[a]	17.51 (2.97)[c]	16.63 (1.52)[d]	F=86.00 (4) P<0.001
Current use of any other tobacco product or e-cigarette	No	3142 (98.10)	135 (82.82)	849 (94.65)	198 (75.00)	43 (34.68)	1057.14 (4) P<0.001
	Yes	61 (1.90)	28 (17.18)	48 (5.35)	66 (25.00)	81 (65.32)	
Binge drinking status	Never binge drank	2826 (88.23)	92 (57.14)	604 (67.64)	112 (42.59)	38 (30.89)	664.12 (4) P<0.001
	Ever binge drank	377 (11.77)	69 (42.86)	289 (32.36)	151 (57.41)	85 (69.11)	
Marijuana use status	Never used marijuana	3087 (97.75)	104 (64.60)	812 (91.75)	177 (67.30)	38 (31.67)	1112.14 (4) P<0.001
	Ever used marijuana	71 (2.25)	57 (35.40)	73 (8.25)	86 (32.70)	82 (68.33)	
Number of classes skipped in the last 4 weeks	None	3000 (95.06)	136 (85.00)	770 (87.10)	189 (72.69)	57 (47.50)	454.21 (4) P<0.001
	Any	156 (4.94)	24 (15.00)	114 (12.90)	71 (27.31)	63 (52.50)	
Number of school days ate breakfast	Less than 5 days	1416 (44.64)	97 (61.39)	507 (57.29)	180 (69.77)	103 (84.43)	161.59 (4) P<0.001
	Everyday (5 days)	1756 (55.36)	61 (38.61)	378 (42.71)	78 (30.23)	19 (15.57)	
Meets Canadian physical activity recommendations	No	1577 (50.43)	86 (53.42)	421 (47.79)	121 (48.40)	52 (43.33)	4.97 (4) P=0.291
	Yes	1550 (49.57)	75 (46.58)	460 (52.21)	129 (51.60)	68 (56.67)	

† comparisons with the same letter are not statistically significant (p>0.05).

Supplementary Table 34. Baseline characteristics of students in the hookah use trajectory groups at baseline, 2013-14 COMPASS study

		GROUP 1 Non-susceptible non-users n (%)	**GROUP 2** Non-susceptible puffers n (%)	**GROUP 3** Stable low intenders n (%)	**GROUP 4** Escalating experimenters n (%)	**GROUP 5** Consistent users n (%)	X2 (df) p-value
		3192 (68.63)	175 (3.76)	759 (16.32)	366 (7.87)	159 (3.42)	
Gender	Female	1605 (50.35)	72 (41.38)	397 (52.58)	221 (60.38)	104 (65.41)	33.02 (4) P<0.001
	Male	1583 (49.65)	102 (58.62)	358 (47.42)	145 (39.62)	55 (34.59)	
Ethnicity	White	2451 (77.29)	122 (70.11)	603 (79.76)	289 (78.96)	114 (71.70)	11.16 (4) P=0.025
	Other	720 (22.71)	52 (29.89)	153 (20.24)	77 (21.04)	45 (28.30)	
Spending money	Zero / I don't know	1184 (37.41)	42 (24.14)	257 (33.99)	118 (32.33)	47 (29.75)	38.81 (8) P<0.001
	$1-$20	1366 (43.16)	83 (47.70)	347 (45.90)	153 (41.92)	59 (37.34)	
	More than $20	615 (19.43)	49 (28.16)	152 (20.11)	94 (25.75)	52 (32.91)	
Number of friends that smoke cigarettes	None	2769 (87.32)	107 (61.14)	559 (74.63)	187 (51.37)	38 (24.20)	632.45 (4) P<0.001
	Any	402 (12.68)	68 (38.86)	190 (25.37)	177 (48.63)	119 (75.80)	
School connectedness score†	Mean (stdev)	19.51 (2.61)[b]	18.82 (2.91)[a]	18.36 (2.69)[a]	17.69 (2.93)[c]	16.78 (3.38)[d]	F=85.91 (4) P<0.001
Current use of any other tobacco product or e-cigarette	No	3134 (98.18)	148 (84.57)	728 (95.92)	300 (81.97)	66 (41.51)	1016.05 (4) P<0.001
	Yes	58 (1.82)	27 (15.43)	31 (4.08)	66 (18.03)	93 (58.49)	
Binge drinking status	Never binge drank	2816 (88.25)	100 (57.47)	541 (71.66)	165 (45.21)	50 (31.65)	704.63 (4) P<0.001
	Ever binge drank	375 (11.75)	74 (42.53)	214 (28.34)	200 (54.79)	108 (68.35)	
Marijuana use status	Never used marijuana	3078 (97.84)	115 (66.09)	701 (93.47)	263 (72.65)	61 (39.35)	1068.95 (4) P<0.001
	Ever used marijuana	68 (2.16)	59 (33.91)	49 (6.53)	99 (27.35)	94 (60.65)	
Number of classes skipped in the last 4 weeks	None	2989 (95.07)	147 (84.97)	668 (89.19)	265 (73.82)	83 (53.55)	452.92 (4) P<0.001
	Any	155 (4.93)	26 (15.03)	81 (10.81)	94 (26.18)	72 (46.45)	
Number of school days ate breakfast	Less than 5 days	1411 (44.64)	106 (62.35)	415 (55.41)	243 (67.69)	128 (82.05)	164.50 (4) P<0.001
	Everyday (5 days)	1750 (55.36)	64 (37.65)	334 (44.59)	116 (32.31)	28 (17.95)	
Meets Canadian physical activity recommendations	No	1571 (50.42)	91 (52.60)	359 (48.19)	167 (47.71)	69 (44.52)	4.12 (4) P=0.390
	Yes	1545 (49.58)	82 (47.40)	386 (51.81)	183 (52.29)	86 (55.48)	

† comparisons with the same letter are not statistically significant (p>0.05).

Supplementary Table 35. Baseline characteristics of students in the smokeless tobacco use trajectory groups, 2013-14 COMPASS study

		GROUP 1 Non-susceptible non-users n (%)	**GROUP 2** Non-susceptible puffers n (%)	**GROUP 3** Stable low intenders n (%)	**GROUP 4** Escalating experimenters n (%)	**GROUP 5** Consistent users n (%)	X2 (df) p-value
		3149 (67.71)	231 (4.97)	720 (15.48)	382 (8.21)	169 (3.63)	
Gender	Female	1583 (50.33)	103 (44.78)	382 (53.28)	222 (58.27)	109 (64.50)	25.14 (4) P<0.001
	Male	1562 (49.67)	127 (55.22)	335 (46.72)	159 (41.73)	60 (35.50)	
Ethnicity	White	2416 (77.24)	168 (73.04)	568 (79.22)	303 (79.32)	124 (73.37)	6.26 (4) P=0.181
	Other	712 (22.76)	62 (26.96)	149 (20.78)	79 (20.68)	45 (26.63)	
Spending money	Zero / I don't know	1173 (37.57)	63 (27.39)	242 (33.75)	121 (31.76)	49 (29.17)	41.10 (8) P<0.001
	$1-$20	1344 (43.05)	111 (48.26)	333 (46.44)	157 (41.21)	63 (37.50)	
	More than $20	605 (19.38)	56 (24.35)	142 (19.80)	103 (27.03)	56 (33.33)	
Number of friends that smoke cigarettes	None	2732 (87.34)	157 (67.97)	533 (75.07)	197 (51.84)	41 (24.55)	628.24 (4) P<0.001
	Any	396 (12.66)	74 (32.03)	177 (24.93)	183 (48.16)	126 (75.45)	
School connectedness score†	Mean (stdev)	19.51 (2.62)[b]	18.81 (2.86)[a]	18.42 (2.69)[a]	17.65 (2.92)[c]	16.86 (3.26)[d]	F=85.91 (4) P<0.001
Current use of any other tobacco product or e-cigarette	No	3103 (98.54)	206 (89.18)	694 (96.39)	313 (81.94)	72 (42.60)	1079.35 (4) P<0.001
	Yes	46 (1.46)	25 (10.82)	26 (3.61)	69 (18.06)	97 (57.40)	
Binge drinking status	Never binge drank	2793 (88.72)	131 (56.96)	520 (72.52)	176 (46.32)	52 (30.95)	745.59 (4) P<0.001
	Ever binge drank	355 (11.28)	99 (43.04)	197 (27.48)	204 (53.68)	116 (69.05)	
Marijuana use status	Never used marijuana	3041 (98.00)	165 (71.74)	668 (93.95)	277 (73.28)	67 (40.61)	1050.62 (4) P<0.001
	Ever used marijuana	62 (2.00)	65 (28.26)	43 (6.05)	101 (26.72)	98 (59.39)	
Number of classes skipped in the last 4 weeks	None	2953 (95.23)	194 (84.72)	635 (89.44)	281 (74.93)	89 (53.94)	459.27 (4) P<0.001
	Any	148 (4.77)	35 (15.28)	75 (10.56)	94 (25.07)	76 (46.06)	
Number of school days ate breakfast	Less than 5 days	1389 (44.55)	132 (58.41)	393 (55.35)	257 (68.53)	132 (79.52)	160.95 (4) P<0.001
	Everyday (5 days)	1729 (55.45)	94 (41.59)	317 (44.65)	118 (31.47)	34 (20.48)	
Meets Canadian physical activity recommendations	No	1548 (50.36)	118 (51.75)	335 (47.45)	178 (48.63)	78 (47.27)	2.90 (4) P=0.575
	Yes	1526 (49.64)	110 (48.25)	371 (52.55)	188 (51.37)	87 (52.73)	

† comparisons with the same letter are not statistically significant (p>0.05).

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