Exploration of youth knowledge and perceptions of individual-level climate mitigation action

Gary J Pickering1,2,4, Kaylee Schoen2, Marta Bott4 and Xavier Fazio3,4

1 Department of Biological Sciences, Brock University 1812 Sir Isaak Brock Way, St. Catharines ON L2S 3A1, Canada
2 Department of Psychology, Brock University 1812 Sir Isaak Brock Way, St. Catharines ON L2S 3A1, Canada
3 Department of Education, Brock University 1812 Sir Isaak Brock Way, St. Catharines ON L2S 3A1, Canada
4 Environmental Sustainability Research Centre, Brock University, 1812 Sir Isaak Brock Way, St. Catharines ON L2S 3A1, Canada
5 Sustainability Research Centre, University of the Sunshine Coast, Sippy Downs, Queensland, Australia

E-mail: gpickering@brocku.ca

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Abstract
The current climate crisis necessitates effective mitigation action across all scales, including behaviours and lifestyle decisions at the individual level. Youth need to align lifestyle with the 2.1 tonnes of CO2 emissions per person per year required by 2050 to prevent the worse impacts of climate change (CC), yet little is known regarding their preparedness to act nor knowledge of the efficacy of the personal actions available to them. The main objectives of this study were to determine in a representative sample of 17–18 year old Canadians (n = 487) their: (1) beliefs around whether their activities or lifestyle choices can help to lessen CC, and (2) knowledge of the efficacy of individual-level behaviours in reducing greenhouse gas emissions (GGE). Results from the online survey (Likert scale) show that youth have limited confidence in how well their schooling has prepared them for CC and mitigation. However, the majority (88%) believe that their activities and lifestyle choices can help in mitigating CC. Knowledge of the relative efficacy of GGE-reducing actions was generally poor (Wilcoxon signed rank tests and open-ended responses) with, for instance, recycling overestimated and having one fewer child underestimated, suggesting that youth are not well equipped with the requisite knowledge to maximise CC mitigation through their personal choices. Our findings inform high school curricula and CC education and policy more broadly.

1. Introduction

1.1. Context
Anthropogenic climate change (CC) is widely acknowledged and generally understood, but the global response to climate mitigation has remained wholly inadequate. The IPCC’s most recent special report estimates that human activities have caused 1 °C of warming above pre-industrial levels (Masson-Delmotte et al 2018) and at the current rate of greenhouse gas emissions (GGE) this is expected to reach 1.5 °C between 2030 and 2052. The impact to natural and human systems are projected to be catastrophic should warming continue to rise to 2 °C above pre-industrial levels, leaving a relatively narrow window for the transformative societal changes needed to limit global warming to around 1.5 °C. While businesses, governments, and non-governmental organisations clearly must play their part (Pedersen and Lam 2018), an important component of the transformation from the current ‘business as usual’ state will depend on the extent to which individuals adopt meaningful and sustained reductions in their GGE, given the significant proportion of emissions in developed countries that are directly attributable to individual actions and lifestyle decisions (Pacala and Socolow 2004, Dietz et al 2009, Baiocchi et al 2010, Masson-Delmotte et al 2018, Van De Ven et al 2018, Moran et al 2018). This requires a deeper understanding of the barriers to effective change that operate at the individual level.

1.2. Climate mitigation behaviour
A simple lack of knowledge may represent one important obstacle to effective climate mitigation
behaviour. For instance, policy makers often execute a ‘top-down’ model of communication, assuming that a general lack of knowledge among the public is the main contributor to a lack of pro-environmental action (Burgess et al 1998). Indeed, some studies have shown that accurate knowledge about CC associates with climate mitigation behaviours and intention to behave pro-environmentally more broadly (e.g. Bord et al 2000, Frick et al 2004, Pickering et al 2020). While this information-deficit model (Bulkeley 2000)—which assumes that the link between knowledge and behaviour is linear and causal—can explain some climate mitigation action/inaction, it is not sufficient to bridge the attitude-behaviour gap, as public action is mediated by other factors including social contexts and perceptions of responsibility (Barr and Gilg 2007). While education is important in providing accurate information to individuals about their GGE, the information should be provided by credible sources at points of decision and be presented so as to minimize the cognitive effort needed to make informed choices (Stern and Wolske 2017). There are also additional barriers to transitioning from knowledge to action that must be acknowledged and addressed. For instance, social norms, ideologies, sunk costs and perceived risk can all contribute to behavioural inaction regardless of CC knowledge (Gifford et al 2011). Current strategies to encourage climate mitigation action typically aim at small and relatively easy behaviours such as turning off the lights when leaving a room, in the hopes that a spillover-effect will lead to further change. However, some evidence suggests that this approach can lead to a negative spillover-effect, where change in one area can lead to inaction in another (Gifford et al 2011). To be most effective, interventions need to target the more difficult but more impactful mitigation behaviours.

While previous research has identified some of the most effective actions that individuals and households can take to reduce energy consumption and mitigate CC (Gardner and Stern 2008, Girod et al 2014, Lacroix 2018), Wynes and Nicholas (2017) have recently evaluated a wide range of individual lifestyle choices and calculated their potential to reduce GGE in developed countries, based on data from 39 sources and 148 scenarios. Of the actions assessed in their study, seven were characterised as high impact (>0.8 tonnes CO₂-equivalent (tCO₂e) emission reductions per year), specifically (in descending order of most impactful): have one fewer child, live car free, avoid one transatlantic flight, buy green energy, buy more efficient car, switch electric car to car free, and eat a plant-based diet. In contrast, five actions were classified as moderate (replace gasoline with hybrid car, wash clothes in cold water, recycle, hang dry clothes) or low (upgrade light bulbs) impact. The difference in emissions savings between many of these discrete behaviours is large, with for instance, having one fewer child up to 1000 times more impactful that upgrading light bulbs. Attari et al (2010) concluded that individuals generally have very little understanding of the relative energy consumption and savings of different behaviours, and that knowledge of the relative savings could help them make more informed decisions. While it has been argued that it may be better to encourage actions with smaller emissions reductions but adopted by a larger population (Stern and Wolske 2017), these findings taken overall highlight the need for public education focused on high impact GGE-reducing behaviours rather than the relative tokenism of others.

1.3. Youth: behavioural barriers and opportunities

Engaging youth to adopt and adapt to a low carbon lifestyle is critical if the GGE reduction targets needed to avoid the worst impacts of CC are to be achieved. Correspondingly, they must become accustomed to a lifestyle of 2.1 tonnes of CO₂ emissions per person per year by 2050 (Girod et al 2014), despite their minimal role in contributing to the climate crisis and the generally lower income, higher costs, less time and deteriorating environment within which they find themselves (Kershaw et al 2018). Youth, and particularly late adolescents, are at a stage in development where academic and social learning are being processed and integrated into worldviews that will influence attitudes, values and lifestyles for a lifetime. This is particularly salient in the context of GGE, as the impact of their decisions accumulates across a longer time period than for older individuals, and thus has the potential to contribute more to achieving emissions reduction targets. Also, critically, this is a period where behavioural habits—both pro- and counter-environmental—are being formed. Encouragingly, many of the lifestyle decisions that are most impactful in reducing GGE, such as habitual dietary choices (CDC 1996), are forming during these years. This extends to the decision to acquire a driver’s licence and purchase their first car, as well as becoming sexually active and considering the impact of childbearing. Accurate knowledge of the relative efficacy of these actions is needed to assist them in making informed lifestyle decisions that will support the GGE reduction targets.

Generally, youth hold more favourable environmental attitudes than older generations, but they are often reluctant to participate in CC mitigation behaviours (de Leeuw et al 2015). Part of this reluctance is associated with believing that they have relatively little control; that the important decisions are taken above their heads, leaving them as spectators (Robitaille 2018). From a theoretical framework, perceived control is a key element in influencing behaviour. For instance, under the Theory of Planned Behaviour, which has been successfully applied to understanding pro-environmental actions (e.g. Tonglet et al 2004), behavioural intention is determined by three factors:
an individual’s control over an action, normative beliefs or social pressures, and behavioural beliefs or attitudes (Ajzen 1991, 2002). If an individual has control over a specific action, feels socially pressured to carry out the action, and has a generally positive attitude towards it, they are more likely to have the intent to carry out that behaviour. The Theory of Planned Behaviour has been applied to understanding pro-environmental behaviour in high-school students (de Leeuw et al 2015), with the authors concluding that it is particularly important that students have perceived control over the action and that they see significant others such as family, friends and celebrities performing the behaviour. Other scholars have noted that youth with a greater internal locus of control and higher environmental knowledge report stronger pro-environmental behaviour and intentions (Fielding and Head 2012). Perceived intractability of CC has also been linked to climate mitigation in youth, and students with more individualist (as opposed to collectivist) orientation view CC as more intractable and are less likely to take climate-mitigating action (Xiang et al 2019). McNeill and Vaughn (2012) have reported that students are more likely to engage in climate action if they both understand the causes of CC and have knowledge of specific action strategies. Understanding the current knowledge deficits around GGE-reducing behaviour and other barriers to effective youth participation in mitigation efforts is critical and can inform wider societal initiatives, including development and implementation of youth-informed and youth-targeted policy that can facilitate and support these goals (Shazeeen 2018).

1.4. Current study
The primary aim of this study is to explore the level of awareness and accuracy of knowledge among Canadian youth on how individual lifestyle choices affect CC mitigation. Our expectation is that the accuracy of knowledge among youth regarding individual lifestyle choices and GGE is low. This expectation is informed by the findings of Wynes and Nicholas (2017), who examined high school textbook content for GGE reduction behaviours from seven Canadian provinces. They concluded that the textbooks largely fail to mention high-impact actions, which accounted for just 4% of recommended actions, and instead focused on incremental changes that would yield much smaller potential emissions reductions. In addition to building on these findings, we also selected Canada for this case study as it has a very high level of carbon emissions in both absolute and per capita terms, is among the world’s major oil producers, and in recent history has avoided participation in global GGE mitigation initiatives, ‘despite (its) carbon intensity and relative stage of wealth and development’ (Brown 2012, p 325). It is rated 54th out of 60 countries on the Climate Change Performance Index (CCPI 2019), contributing to a moral imperative to participate in GGE reduction initiatives with much greater intensity and urgency than is currently the case (Pickering 2015).

1.4.1. Specific objectives and hypotheses.
The main objectives of this study were to explore in 17–18 year old Canadians:

1. Beliefs around whether their activities or lifestyle choices can help to lessen CC, and (2) Knowledge of the efficacy of individual-level behaviours in reducing GGE. Secondary objectives were to assess where respondents sourced their CC information from, and how well informed and confident they felt about CC and mitigation options. Given recent and extensive media coverage in 2019 on CC and youth activism, we hypothesized that respondents would show a high level of belief that their actions can help to lessen CC (H1). However, given the findings of Wynes and Nicholas (2017) on the shortcomings of Canadian high school textbook content, we hypothesised that low-impact behaviours would have higher saliency than high-impact behaviours (H2).

If youth are not aware of the relative contribution of their personal choices, they are not able to make the informed decisions needed to align lifestyle with the 2.1 annual tonnes of emissions per person per year required by 2050 to prevent the worse impacts of CC (Girod et al 2014). Determining this information is needed to inform secondary school curricula and CC education and policy more broadly. Education has an essential role to play—presenting a ‘pedagogy of hope’; demonstrating the existence of solutions which can be instigated in the short term that youth can participate in (Robitaille 2018), and providing accurate information about the efficacy of actions that reduce GGE, thereby contributing to a more sustainable world.

2. Materials and methods

2.1. Study design and recruitment
Individuals were recruited through the online data collection company Dynata® in November 2018. To be eligible, participants had to be 17 or 18 years of age and Canadian citizens or permanent residents. This age range was selected as in Canada youth are typically completing their secondary school education then, and thus questions around their perceptions of how well their schooling had prepared them with respect to CC and mitigation action could be answered while their experiences were ‘fresh’. It is also an age when youth are forming their own beliefs, identities and habitual behaviours that impact climate and environmental sustainability more broadly (such as dietary choices). A further criterion was that respondents aged 17 had to obtain parental permission prior to completing the survey. Participants completed the online survey on the Qualtrics® platform and ethics clearance was granted through the
Brock University Research Ethics Board (#17-360). Completed responses retained for analysis purposes varied between n = 425 and 487, depending on the question.

2.2. Belief in lifestyle choices
Participants were initially asked Do you believe that your activities or lifestyle choices can help to lessen climate change?, with a yes or no response option. Individuals who answered yes are hereafter referred to as ‘positive responders’ and those who answered no as ‘negative responders’. Negative responders were then asked Why do you believe that your activities or lifestyle choices cannot help to lessen climate change? (open-ended response, no word limit). These qualitative responses were subsequently compiled and summarised.

2.3. Knowledge of climate mitigation behaviours
Knowledge of individual-level CC mitigation behaviours was assessed using a mixed-methods approach. Firstly, positive responders were asked In your opinion, what are the most effective actions that you could take to help lessen climate change in your life? (list up to 3 items) (open-ended response, no word limit). Later, all participants were asked to read a short statement before continuing: Greenhouse gas emissions are the main cause of climate change, and carbon dioxide is the main greenhouse gas. They were then asked to rank six behaviours by how much they could reduce GGE: live car free; have one fewer child; eat a plant-based diet; switch electric car to car free; recycle; and upgrade lightbulbs. With respect to GGE reductions, these lifestyle choices represent four high impact (the first four listed above), one moderate impact (recycle) and one low impact (upgrade lightbulbs) behaviours, as calculated by Wynes and Nicholas (2017). Order of presentation of behaviours was randomised across the study, and a rank of one indicated the most reduction in emissions and six the least reduction.

2.4. Other measures
Basic demographic variables were also assessed, including age, gender, and school type (Public, Catholic, Other). Sources of CC information were determined (check-all-that-apply, with the 11 response options based on Morris and Pickering 2019), as well as confidence and trust in their CC knowledge and education. The latter were assessed prior to the GGE ranking task via responses on individual five-point Likert scales (strongly disagree to strongly agree) to the following five questions (with order of presentation randomised): I feel as though my school has taught me enough about climate change; I feel as though my school has taught me enough about how to reduce greenhouse gas emissions; I feel as though my school has taught me about the impact of animal agriculture on the environment; I have confidence in my knowledge about climate change in general; I have confidence in my knowledge about which behaviours to change to best reduce greenhouse gas emissions.

2.5. Data treatment and analysis
Our data were predominantly descriptive in nature and were compiled in Excel (Microsoft Excel® for Mac version 16.31). XLSTAT (version 2017.1.1, New York) was used for summary statistics and Chi-squared tests which were used to determine if responder status (positive or negative) was associated with demographic variables. NVivo (v12, QSR International, Chadstone, Victoria, 3148, Australia) was used to create a visual representation of the citation frequencies of words used by positive responders for the open-ended mitigation question. Wilcoxon signed rank test (SPSS, v20, SPSS Inc. Chicago, IL) was used to determine differences in rankings of GGE reducing behaviours and those calculated by Wynes and Nicholas (2017).

3. Results
3.1. Sample characteristics
The demographics of our sample are shown in table 1. Our sample is similar to the wider Canadian population for gender and geography, although Ontario is somewhat over-represented (38% of population) and Quebec somewhat under-represented (23% of population) (Statistics Canada 2016).

3.1.1. Sources of CC information and beliefs
Participants were asked from which sources they receive their CC information from. The Internet, School/Education and Social Media were the predominant sources reported and were all identified by over 50% of respondents (figure 1). In the Canadian adult population television is the most cited source (approx. 77%; Morris and Pickering 2019), whereas for our sample it ranked as only the 6th at 45%. Similarly, while Non-governmental organisations are an important source of CC information for Canadian adults (45%), they account for only 18% in our sample. Interestingly, in the Morris and Pickering study—which used a very similar check-all-that-apply list—four sources were identified by a third or more of respondents, whereas seven sources were acknowledged by a third or more of our respondents, suggesting that youth are accessing a wider and perhaps richer pool of resources for their CC information than is the case for adults. The distribution of the number of information sources used by youth is given in the Supplementary Materials (supplementary figure 1 (https://stacks.iop.org/ERL/15/104080/))

Perceptions of CC knowledge and mitigation were assessed with five questions on how confident participants were in their knowledge of the topic and how well they felt their school had taught them about it.
Table 1. Sample characteristics.

|                | Number | Proportion of sample |
|----------------|--------|----------------------|
| **Age**        |        |                      |
| 17 years.      | 190    | 39%                  |
| 18 years.      | 297    | 61%                  |
| **Gender**     |        |                      |
| Male           | 213    | 44%                  |
| Female         | 271    | 56%                  |
| Other          | 3      | 0.7%                 |
| **Location**   |        |                      |
| Ontario        | 227    | 47%                  |
| Quebec         | 77     | 16%                  |
| Alberta        | 57     | 12%                  |
| British Columbia| 57   | 12%                  |
| Manitoba       | 18     | 4%                   |
| Nova Scotia    | 15     | 3%                   |
| Saskatchewan   | 15     | 3%                   |
| Newfoundland and Labrador | 10 | 2% |
| New Brunswick  | 10     | 2%                   |
| Other          | 1      | 0.2%                 |
| **High school**|       |                      |
| Public         | 355    | 73%                  |
| Catholic       | 78     | 16%                  |
| Other          | 54     | 11%                  |

As shown in figure 2, confidence was not high for any of the measures, with the average response for all questions lying between neither agree nor disagree and somewhat agree.
3.2. Mitigation through lifestyle

In response to the question ‘Do you believe that your activities or lifestyle choices can help to lessen climate change?’ 88% responded yes and 12% responded no. 89% of females, 87% of males and 100% of ‘other’ responded in the positive. A Chi-square test of independence showed that males and females did not differ in their response type ($\chi^2 (1 \text{ df}) = 0.60, p = 0.44$). Similarly, belief in personal actions lessening CC did not vary with school type ($\chi^2 (2 \text{ df}) = 0.40, p = 0.82$) nor age ($\chi^2 (1 \text{ df}) = 3.25, p = 0.07$), although the latter approached significance with 92% of 17 year olds and 86% of 18 year olds responding with yes. A higher proportion of negative responders (22%) was evident for Central Canada (Alberta and Saskatchewan) than for either Eastern (10%) or Western (8%) Canada ($\chi^2 (2 \text{ df}) = 8.9, p = 0.01$).

3.2.1. Negative responders

Participants who did not believe that their actions could help mitigate CC were asked to elaborate why in free text. Representative answers included ‘I have too little impact’, ‘My current activities do not affect the climate in a major way positively or negatively’, and ‘Because I am only one person among billions—my actions alone cannot lessen climate change’; overall suggestive of a sense of helplessness and perhaps reluctance to take responsibility. Other responses focused on assignment of blame, such as ‘Mass production companies produce more emissions than the single person’, ‘Corporations and large companies are main and major polluters’, and ‘It is up to the market, not me as a consumer’. Some replies indicated a lack of awareness of CC or its anthropogenic origins, such as ‘Climate change is natural and the effects by humans is so small that all this hype is useless’, ‘Mother nature does whatever, we cannot control the weather’, and ‘There is No Climate Change or Global Warming’. In general, responses indicated that participants could be conceptualised as belonging to one of two groups—those with a very negative/sceptical view of CC and those who generally demonstrated low perceived self-efficacy with respect to their actions making a difference. These groupings are illustrated in figure 3.

3.3. Knowledge of mitigation actions

Participants who answered yes to the question ‘Do you believe that your activities or lifestyle choices can help to lessen climate change?’ (‘positive responders’) were asked what they believed are the most effective actions that they could take personally to help lessen CC and were prompted to list up to three items. All respondents were later asked to rank six behaviours by how much they think they can reduce GGE.

3.3.1. CC mitigation—open-ended responses

Interpretable responses to the open-ended question are summarised in table 2. Two independent
assessors reclassified responses into the action categories shown; the interclass correlation was then calculated as 0.992, indicating excellent reliability.

Actions related to recycling were the clearly dominant theme, while conserving energy and reducing waste were also listed by more than 20% of respondents. With respect to the most impactful actions in reducing GGE from the literature, having fewer children or flying less were not mentioned by anyone. Eating a plant-based diet was the 11th most frequently cited action with 10% of participants. While recognition of the impact of vehicles on GGE was relatively high (‘drive less’ was mentioned by one in four, and ‘take public transportation’ by 16%), buying a more efficient car had low saliency. Finally, buying or using green energy was very seldom cited. Specifically, the word ‘renewable’ was only mentioned six times (and not always clearly in the context of energy), ‘solar’ was used once, and other specific words signifying green or renewable energy including ‘wind’, ‘hydroelectric’, ‘geothermal’ and their synonyms were never used. Littering less and electing to quit or not take up smoking were curious actions reported by 4%–8% of participants as the most effective in lessening CC.

Figure 3. MindMap of Negative Responders and representative comments (n = 57).

3.3.2. Greenhouse gas emissions reduction—ranking
Participants assigned ranks to six behaviours based on how much they believed each could reduce GGE, with ‘1’ indicating the most reduction and ‘6’ the least. We hypothesized that rankings of the efficacy of actions would not match those derived from Wynes and Nicholas (2017) (‘calculated ranks’); specifically, respondents would overestimate the least impactful behaviours (upgrade lightbulbs and recycle). Wilcoxon signed rank tests showed significant differences between the youth and calculated rankings for have one fewer child (Z = −17.30, p < .0001), live car free (Z = − 6.58, p < .0001), recycle (Z = − 16.7, p < .0001) and upgrade lightbulbs (Z = − 16.26, p < .0001). Have one fewer child (4.5) and live car free (2.6) were rated as less impactful than the calculated rank, whereas upgrade lightbulbs (4) and recycle (2.7) were rated as more impactful (figure 4).

We also assessed whether knowledge of behaviours that can reduce GGE was associated with select independent variables by first calculating an ‘efficacy knowledge score’ (EKS). This was done by taking the absolute value of the difference between a respondent's ranking of each action and the ‘true’ rank from Wynes and Nicholas (2017), and then calculating the mean of these differences for each respondent. Under this scheme, a score of zero represents perfect alignment with the ‘true’ ranks (high knowledge), and three represents the maximum discordance in ranks (low knowledge). Distribution of EKSs is shown in Supplementary Materials figure 2.

With regard to demographic factors, EKS did not vary with gender (male: mean 2.0, n = 195; Female: mean 2.0, n = 252) (p(t) = 0.52) nor school type attended (mean: public 2.0, n = 330; catholic 1.9, n = 71; other 2.1, n = 49) (p(F) = 0.49). However, youth aged 18 years had a lower EKS (mean 1.9, n = 277) than those aged 17 years (mean 2.1, n = 182) (t = 2.8; p = 0.006), indicating greater knowledge of
Table 2. The most effective actions youth\(^\dagger\) believe they can take to lessen CC.

| Actions\(^\ddagger\) | Frequency cited (% respondents) | Representative examples cited |
|---------------------|---------------------------------|------------------------------|
| Recycle            | 44.3                            | recycle, recycle more, recycle clothes |
| Conserve energy    | 24.9                            | use less electricity, turn off lights, use energy wisely, saving energy, energy efficient lightbulbs, heat less |
| Drive less         | 23.8                            | less cars, avoid driving, carpool, take my car less, drive less |
| Reduce waste       | 20.0                            | reduce trash, reduce waste, consume less, use hand dryers instead of paper, not wasting food |
| Take public transportation | 15.7                          | using bus, use public transport, use bus more |
| Reduce plastic     | 15.7                            | not use plastic straws, use less plastic, less plastic bottles, do not use plastic bags, reusable bottles |
| Conserve water     | 14.6                            | close faucet, save water, taking shorter showers |
| Reduce emissions   | 13.8                            | stricter pollution controls, less emissions, reduce carbon footprint, stop pollution, less fossil fuel burning |
| Walk more          | 10.5                            | walk instead of driving, walking to destination, walking to work |
| Re-use             | 10.0                            | re-use, use things more than once, reusable products, shop at thrift stores |
| Eat plant-based diet | 10.0                        | become vegetarian, lower meat consumption, not buying as much meat, vegan lifestyle, stay vegetarian, eat less beef |
| Litter less        | 8.1                             | Do not litter, stop littering, pick up other people’s litter |
| Ride bike          | 8.1                             | Riding bikes to school/work, use a bike for closer distances, using a bicycle more often |
| Spread awareness   | 6.2                             | holding events to spread awareness of its effects, volunteer, informing others, spread awareness, advocate for the environment through social media, start a petition |
| Use electric car   | 5.9                             | electric cars, using environmentally friendly cars, drive electric, stop using gas powered car, hybrid car |
| Compost            | 5.7                             | use green bin, compost, have a compost bin |
| Plant trees        | 4.9                             | more green areas, plant trees, plant crops, plant more trees, grow trees, stop cutting trees without replanting them |
| Do not smoke       | 3.8                             | Do not smoke, quit smoking |
| Support environmental organizations greener businesses | 2.4                         | help ocean organisation, donate to proactive causes, support environmental friendly companies, buy from companies that do not pollute, donate to charity regarding climate change |
| Purchase locally   | 2.4                             | Eat more food produced buy my country, eat local, buy local |
| Eat clean food     | 1.9                             | Buy sustainable food, eat better, cleaner food production, eat organic |
| Vote               | 1.6                             | Vote for leaders who will do something, voting for proactive political parties, elect government officials that support green programs |

\(^\dagger\)Only youth who answered ‘yes’ to Do you believe that your activities or lifestyle choices can help to lessen climate change? (‘positive responders’) were asked this question (n = 428); \(^\ddagger\) Actions lists are those with > 5 responses.

The relative efficacy of GGE reducing actions. A series of one-way ANOVAs assessed whether any specific information source for CC identified by respondents associated with EKS; all tests were non-significant (p(t) > 0.05). To examine the hypothesis that diversity of information sources might associate with EKS, we conducted a Pearson correlation analysis to determine the relationship between number of CC information sources used (minimum 0; maximum 12; mean 4.8 ± 2.7) and EKS. The result showed no association (r = −0.03, p = 0.46).

With respect to beliefs, EKS did not differ between individuals who do not believe that their activities or lifestyle choices can help to lessen CC (mean 2.0; n = 55) and those that do (mean 2.0; n = 404) (p(t) = 0.89). Interestingly, there was no relationship between EKS and agreement with the statement I have confidence in my knowledge about climate change in
general \( (r = 0.00, p = 0.96) \), even when responses were recategorized and dichotomized into Agree \( (n = 340) \) and Disagree \( (n = 47) \) with the Neither Agree nor Disagree category \( (n = 71) \) removed \( (p(t) = 0.80) \). Similarly, there was no association between EKS and agreement with I have confidence in my knowledge about which behaviours to change to best reduce greenhouse gas emissions \( (r = -0.01, p = 0.86) \), even when responses were recategorized and dichotomized into Agree \( (n = 308) \) and Disagree \( (n = 65) \) with the Neither Agree nor Disagree category \( (n = 86) \) removed \( (p(t) = 0.78) \).

4. Discussion and conclusion

4.1. Mitigation through lifestyle \( (H_1) \)

Encouragingly, the majority of youth surveyed believed that their activities or lifestyle choices can help to lessen CC, confirming \( H_1 \). Given the importance of individual agency and perceived control amongst youth with respect to acting pro-environmentally (de Leeuw et al. 2015), this is an important finding. The belief that their actions can make a difference and that they have some (assumed) control over them may anticipate corresponding intent for CC mitigation behaviour under the Theory of Planned Behaviour (Ajzen 1991, 2002). However, a limitation of our study is that we did not determine all of the salient factors associated with behaviour or intent, and in the context of youth action on climate mitigation this remains an important area for further research. One of the key themes amongst the negative responders in our study is that of the scale of the mitigation challenge and the relative ineffectiveness of individual-level actions. This survey was conducted just prior to the Greta Thunberg ‘phenomenon’ (the 16-year-old Swedish student who started a major global CC awareness movement that has mobilised many youth to action, such as through school ‘climate strikes’ (Ly 2019, Watts 2019). It remains to be determined if such awareness-raising will translate into a belief of greater agency amongst youth over CC mitigation at the individual level. Novel educational approaches may also assist with the sense of helplessness and lack of agency evident in the responses of some of the negative responders. ‘Gamification’ offers potential in this regard with, for instance, the Cyber-hero game (Klisanin 2019) raising belief in youth that they can make a real difference in mitigating CC by adopting ‘planetary stewardship’ (Klisanin 2012, 2017).

4.2. Knowledge of mitigation actions \( (H_2) \)

While the majority of youth surveyed believe their actions and lifestyle decisions can make a difference, we also assessed their knowledge around the relative impact of various behaviours. Our two measures of the accuracy of perceptions on the efficacy of CC mitigation actions have good agreement. Low impact behaviours such as recycling and reducing
waste are over-estimated, while the most impactful behaviour of choosing to have one fewer child is under-estimated, thus confirming our H$_2$. Under and over estimation of extremes by US adults in estimating the energy consumption and savings of various activities has previously been reported (Attari et al 2010). The perceived effectiveness of recycling, as captured in both of our measures, warrants further consideration. It is a behaviour for which most youth should have significant agency over, in contrast with actions for which current agency may be more limited, such as the independence and resources to purchase and eat sustainably grown food in a family household environment. Thus, it perhaps is not surprising that it topped the list of actions that individuals felt they could perform to make a difference. However, it was also judged as the most effective at reducing GGE more generally, which is consistent with the findings of Wynes and Nicholas (2017) who reported recycling as the most cited action in unique Canadian high school textbooks. Its perceived importance may also be reinforced simply by greater exposure, such as seeing and engaging with recycling bins and programs at school and elsewhere on a daily basis.

Adopting a plant-based diet and changing household lightbulbs are ranked as approximately equi-impactful at reducing GGE by youth, yet the former is eight times more effective (Wynes and Nicholas 2017). We speculate that the underestimation of plant-based diets may improve in the near future due to increased awareness of the negative environmental impacts of farmed meat (Stea and Pickering 2018) from recent and intensive marketing and advertising campaigns for new alternative-meat products such as Beyond Meat ™. Encouragingly, the opportunity to significantly reduce GGE by limiting use of fossil fueled-vehicles appears to have reasonably high awareness amongst our sample, and is noteworthy in a country where the transportation sector is the 2nd biggest contributor to GGE (Government of Canada 2017). Using public transport, reducing the effects of driving, living car free, and similar actions that would limit total GGE from vehicles are noted in the majority of Canadian high school science textbooks, and such action can have a significant impact on GGE savings (Wynes and Nicholas 2017).

The most impactful behaviour rated in our study—having one fewer child—was scored as the least effective at reducing GGE. It is possible that respondents consider this behaviour 'unfair' and that this influenced their efficacy rating. Further research is planned to assess youth perceptions of the fairness, equity and values around specific CC mitigation options, and this will provide additional context for our results and further inform policy decisions. However, taking the finding at face value, the consequences for the climate of this ignorance, if not addressed, are non-trivial. For instance, as noted by Wynes and Nicholas (2017) a US family who chooses to have one fewer child would provide the same level of emissions reductions as 684 teenagers who choose to adopt comprehensive recycling for the rest of their lives (p3). Having one fewer child is so impactful because of the cumulative effects of fewer emitting descendants calculated across full life cycles (Murtaugh and Schlax 2009), and this concept may be cognitively less intuitive for some youth than other behaviours when they were considering their responses for this exercise. Nonetheless, within the Canadian education system, addressing this knowledge deficit will be challenging given its controversial nature. Relying on governments to induce schools to promote smaller families through educational syllabi would likely be rejected by the general public as a form of social engineering unacceptable to most (voting) people (Greenwood 2019). Greater penetration may be found outside of the formal school curricula, and public educators may need to consider accessing these alternative channels.

Finally, the extent to which accuracy of knowledge around GGE reducing behaviours varies with participants’ current activity in this area remains to be determined. For instance, to what extent might individuals who currently eat a plant-based diet differ in their estimation of its relative value in mitigating CC compared with meat-eaters?

4.3. Policy and other considerations

A critical shortcoming highlighted by Wynes and Nicholas (2017, 2019), and indirectly supported by our results, is the curricula content of Canadian high schools, from which educational materials such as textbooks are developed. In preferring to promote lower-impact actions, both governments and educational institutions may have missed an opportunity to educate youth. Although some provinces (e.g. Ontario and Saskatchewan) provide a more comprehensive curriculum for CC education, the overarching focus is on the scientific (ecological) foundation of CC rather than its impacts and personal mitigation options (Wynes and Nicholas 2019). Introducing students to higher-impact actions at an early stage allows for the potential integration of those behaviours into their adult lifestyles (Greenwood 2019). As noted by Stern and Wolske (2017), having one fewer child and living car free (the actions with the greatest potential for GGE-reduction) accrue their full benefits over the course of a lifetime or beyond, and as such require long-term commitment on the part of youth compared with more immediate actions such as hanging clothes to dry, recycling, or changing lightbulbs. As such, these actions may meet with considerable resistance. Nonetheless, if presented in school curricula as viable personal and future CC mitigation actions they can serve as starting points for instruction and dialogue around how to facilitate the higher-impact changes (Stern and Wolske 2017).
A recent Canadian survey of students in Grades 7–12 (ages 12–18 years), educators, and the general public on CC knowledge and perceptions found strong support for youth-based education about CC across all respondent groups. Nevertheless, less than half of the educators surveyed reported teaching CC (Field et al 2019). Support for curriculum policy that embeds CC knowledge and its scientific consensus, and how to mitigate it through personal high impact actions, would go far to address the societal challenge of GGE reduction (Wynes and Nicholas 2019). Combining this with high quality professional resources augmented with effective professional learning (pre-service and in-service education) opportunities will help to improve teaching efficacy and competencies to address the long-term commitments to actions that have the greatest potential for meaningful GGE reduction (Stevenson et al 2016, Nicholls 2017, Dahl 2019, Field et al 2019).

While our findings, coupled with the reports of Wynes and Nicholas (2017, 2019), point to the need for development of revised and accurate educational materials for high schools on individual-level CC behaviours, these materials need to also contextualise CC mitigation within the larger context of societal responsibility. That is, they should include insights from economic and political science (e.g. the benefits of carbon pricing and political action), given that changes in individual lifestyles alone will not be sufficient to address the climate crisis (Masson-Delmotte et al 2018). Additionally, a greater emphasis on numeracy skills, including statistical reasoning, should also be part of the education focus. For instance, to understand that switching to a vegan rather than omnivorous diet is about as effective as choosing not to own a dog, yet both are much less effective than giving up a car in terms of GGE reductions requires a comprehension of differences in magnitude of discrete values (in this case 0.9, 0.8, and 2.4 tCO₂e per year, respectively; Wynes and Nicholas 2017, Supplementary Materials 4). To fully appreciate and accept the extent of GGE savings that follow from having one fewer child, an understanding of more advanced mathematical concepts is needed, including those implicit in stochastic modeling and recursive algorithms (Murtaugh and Schlax 2009). Higher levels of numeracy may not only better inform behavioural decisions regarding CC mitigation, they have also been linked to the ability to draw stronger and more precise affective meaning from numbers and numerical comparisons, and being less susceptible to framing effects (Peters et al 2006). The latter finding is an important consideration given the politicised environment of the CC debate and the ready access that youth have to misinformation. It would be informative to apply the magnitude estimation approach of Attari et al (2010) to determine more precisely the accuracy of youth perceptions of the relative efficacy of GGE reducing actions.

Civic actions such as joining organisation and spreading awareness were not assessed in the ranking exercise as their actual impact on GGE reduction has not been quantified; however, while these were noted by some respondents in the open-ended question, their saliency was very low. This finding may at face value seem at odds with the growing global youth movements nominally aimed at increasing awareness and promoting action on CC. It may be that youth view participation in these movements more in the context of protest and even assigning blame for the climate crisis, and less as an effective action for mitigation. Further research may consider looking at the interactions between beliefs and participation in such civic actions and other personal mitigation choices. For instance, does one enforce the other or does participation in climate protests result in reduced mitigation efforts in other areas of their lives (i.e. negative spillover or rebound effects; Gifford 2011, Gifford et al 2011)?

In addition to being criticized for lacking sensitivity, context and ignoring family planning as a human right (Pedersen and Lam 2018), the Wynes and Nicholas (2017) paper which formed the basis for our investigation has also been challenged because of methodological concerns. Specifically, Van Basshuysen and Brandstedt (2018) argue that the impact of having one fewer child on GGE may be overestimated as there are elements of double counting in the calculations and they do not account for the possibility that global emission trajectories become net-zero or even negative. Conversely, Greenwood (2019) has suggested that the impact of having one fewer child can be even more apparent if the Wynes and Nicholas’ data is presented in alternative ways (for instance, as a percentage of total yearly GGE). Overall, the relative efficacy of the actions considered here, including having one fewer child, are broadly supported by other scholarly work (e.g. Murtaugh and Schlax 2009, Lacroix 2018, Moran et al 2018), and can be used in future research that seeks to further advance understanding of climate mitigation knowledge and the educational and behavioural implications. We do, however, acknowledge the variability in GGE associated with various activities, and this should be considered when selecting behaviors and designing related survey questions in the future.

4.4. Conclusion
In our study of a representative sample of 17–18 year old Canadian youth, confidence in how well their schooling had prepared them for CC and mitigation was not high. However, and importantly, most believed that their activities and lifestyle choices could help in mitigating CC. We report for the first time on the knowledge of youth of the relative efficacy of individual-level actions that reduce GGE, and conclude that low-impact behaviours, particularly recycling, are over-estimated. Our findings
inform education policies, including high-school curricula development, as well as other interventions that seek to develop individual agency amongst youth to better equip them to build more sustainable futures.

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Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

ORCID iD

Gary J Pickering https://orcid.org/0000-0001-5104-4968

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