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When the labs closed: graduate students' and postdoctoral fellows' experiences of disrupted research during the COVID-19 pandemic

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Abstract

Government imposed lockdown measures in response to the COVID-19 pandemic resulted in widespread laboratory closures. This study aimed to examine the impact of this disruption on graduate students and postdoctoral fellows completing laboratory-based research in Canada. We used an anonymous online survey and semi-structured interviews to document the experiences of graduate students and postdoctoral fellows during laboratory closures and following the transition to working from home. We employed a mixed-method approach using survey and interview data to identify shared experiences, concerns, and supports. The emotions reported by respondents at different points during laboratory closures align with the Kübler-Ross model of grief following change. Respondents describe closure processes as chaotic and confusing, primarily resulting from inconsistent communication. Respondents reported increased indications of distress while working from home. Concerns about how COVID-19 might impact trainees were identified, including decreasing competitiveness of applicants while limiting future employment opportunities. Finally, we outline five types of supports that can be implemented by supervisors and administrators to support graduate students and postdoctoral fellows to return to the laboratory. Overall, we document shared experiences of respondents during the COVID-19 laboratory shutdown and identify areas of improvement in the event widespread laboratory closures occur in the future.

Key words: COVID-19, graduate students, postdoctoral fellows, higher education policy, laboratory closure

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Introduction

In spring 2020, researchers worldwide experienced an unprecedented wave of laboratory closures in response to the COVID-19 pandemic. In mere weeks, nearly all research was put on pause to prevent further spread of SARS-CoV-2 (Servick et al. 2020a).

Widespread closure of laboratories was unprecedented. Research laboratories have had emergency shutdowns following natural disasters before, such as hurricanes, floods, and earthquakes (Kohler and Gray 2014; Dalton 2001, 2005; Rodriguez et al. 2018). However, these shutdowns differ from the COVID-19 laboratory shutdown because of two key factors. First, most natural disasters are

geographically contained, as opposed to impacting a worldwide population. Second, although catastrophic, natural disasters occur over a finite amount of time. Following a hurricane or earthquake, researchers can begin to make plans for what is necessary to reopen. Closures due to COVID-19 did not come with this timescale, with many not knowing when they will be able to return to pre-COVID-19 level operating capacity.

Researchers and institutions had to react quickly to close laboratories, doing such varied tasks as freezing samples, culling animal colonies, and moving conferences online (Arnold 2020; Grimm 2020; Servick et al. 2020a, 2020b). Universities rapidly shifted course content online (Bao 2020; Iyer et al. 2020). However, the initial focus of supporting principal investigators to close their laboratories and helping undergraduates transition to online learning left many graduate students and postdoctoral fellows feeling like afterthoughts in the early days of COVID-19.

More recently, there has been increased awareness of how the COVID-19 research shutdown will impact graduate students and postdoctoral fellows (Ahmed et al. 2020; Ashton and Pintor-Escobar 2020; Leshner 2020). Most of this work has focused on using past data about this population to predict what difficulties and challenges they will experience due to laboratory closures. Some groups have asked graduate students directly what their concerns are and what supports they require, including work from Australia showing an increase in financial hardship amongst PhD students at the University of Sydney (Johnson et al. 2020).

The purpose of this study was to examine the impact of research disruption during the COVID-19 pandemic on graduate students and postdoctoral fellows completing laboratory-based research in Canada. We did this through a national online survey asking respondents about events surrounding laboratory closures, activities completed while working from home, and their concerns about how COVID-19 will impact them going forward. Our aim was to identify areas of support needed by graduate students and postdoctoral fellows during the COVID-19 pandemic as well as support that trainees feel they will need once the pandemic dissipates. We also wanted to identify best practices for widespread laboratory shutdowns that could be used if similar situations arise in the future. In addition to identifying these supports and best practices, we have documented the stages of grief experienced by graduate students and postdoctoral fellows in response to the COVID-19 laboratory closures. This is valuable as we can draw on past literature analysing grief responses following change to align potential supports with trainees processing how the pandemic has impacted them.

Methods

Ethics approval

The study protocol was approved by the Hamilton Integrated Research Ethics Board (HiREB) under project number 10832. Following the recruitment of potential interview participants, a protocol amendment was made to have an additional interviewer, as the primary interviewer had a conflict of interest with two participants. Correspondence with HiREB indicated a formal addendum was not required. Instead, a note to file was added to the study file to document this protocol modification. One key ethical concern in studying graduate students' and postdoctoral fellows' experiences is participant privacy and confidentiality. We asked respondents about experiences and feelings that they may not want their supervisors or colleagues to know about. Thus, we were intentional with our use of qualitative narrative data to ensure participant experiences were represented while maintaining anonymity. Another ethical concern when studying trainees' experience is the power structures within academia. We paid careful attention to potential power dynamics when designing our informed consent forms to prevent potential undue influence.

Study design, participants, and recruitment

We used a convergent mixed-methods research approach, integrating quantitative and qualitative responses from an anonymous online survey and qualitative responses from semi-structured interviews. Mixed-methods research involves the collection of both quantitative and qualitative data, with the aim that the integration of data will yield greater insight than each data set could provide individually (Johnson et al. 2007). We selected this method due to the emerging nature of the pandemic. As there has not been a pandemic of this scale requiring widespread laboratory closures before, there was limited past literature we could draw upon to inform a theoretic basis for this study. For this reason, a mixed-methods research approach allowed for a holistic viewpoint through the comparison of quantitative and qualitative perspectives (Teddlie and Tashakkori 2009; Creswell and Creswell 2017). The philosophical underpinning of mixed-methods research, pragmatism, also aligns with our research focus as it emphasizes the understanding problems and identifying solutions (Rossman and Wilson 1985).

Two means of data collection were used: an anonymized online survey and an optional follow-up one-on-one virtual interview. The target population for this study was all persons who: (*i*) are a graduate student or postdoctoral fellow in Canada, (*ii*) engage in laboratory-based research, and (*iii*) had their research stopped or paused by the COVID-19 pandemic. There were no inclusion or exclusion criteria based on age, ethnicity, disability, gender, or race.

The online survey was promoted via Twitter and email. For email advertisements, the investigators contacted coordinators of email subscription lists from across all Canadian provinces, including departmental administrative staff, graduate student associations, postdoctoral fellow association, and professional academic organizations. These individuals or groups were selected due to their ability to share study information widely with graduate students and postdoctoral fellows. Midway through the study period, a second set of emails were sent to regions that had a low survey response rate.

The online survey was administered through LimeSurvey, taking approximately 30–45 min to complete (**Supplementary Material 1**). Participants contacted by email received a letter of information about the study in PDF format and a link to access the survey. Participants contacted via Twitter were provided a link to access the survey, where an electronic version of the letter of information was provided prior to obtaining consent to participate. All survey questions were optional, with respondents permitted to skip any questions they preferred not to answer. The online survey was open from 27 April 2020 to 8 June 2020, with 315 respondents completing at least one section of the survey.

At the end of the survey, participants could opt-in to participate in one-on-one virtual interviews and (or) in follow-up surveys in a year or more time as the pandemic unfolds. Those interested in participating in virtual interviews were sent a separate letter of information outlining the survey protocols.

Semi-structured interviews were conducted from 11 May 2020 to 8 June 2020 with 18 participants via Zoom, a video conference software that allows for the recording of meetings. Interviews lasted between 30 min to 1 h (**Supplementary Material 2**). Participants' cameras were turned off during the interview process. Following the transcription of interviews, video recordings were deleted.

Data analysis

Following our mixed-methods research design, both qualitative and quantitative data sets were analyzed in parallel (Teddlie and Tashakkori 2009; Creswell and Creswell 2017). Survey and interview data were formatted and transferred to the qualitative data analysis software

MAXQDA (VERBI GmbH, Berlin, Germany). Descriptive statistics were generated for both data sets. Quantitative data was entered into GraphPad Prism 8 (GraphPad Software, San Diego, USA) for analysis and formatting, with additional statistical analysis completed using R (Foundation for Statistical Computing, Vienna, Austria). Two-sided Fisher's exact test with Bonferroni correction was used for contingency table statistical analysis.

A thematic analysis was conducted of the narrative feedback from the surveys (Creswell 2013). Themes were discussed and refined by two researchers. The interview transcripts were then analyzed using these same themes, as the interviews were designed to drill down into information provided on the surveys. Data from interviews were used to (*i*) confirm themes from the survey and (*ii*) to provide more specific details on individuals' experiences. Beyond information on specific lab shut down requirements (for example, differences between animal labs and labs where experiments can be more abruptly halted, such as where tissues samples can be frozen for long-term storage), no new themes emerged. Data from individual interviews did not encompass all themes, but collectively, all themes were addressed. The researchers analyzing the data debated the granularity of themes. More granular themes were more useful and provided a clearer picture of the survey data, while more general categories were more useful when considering the interview data collectively. With these caveats, there were no noteworthy discrepancies between the two data sets. These themes were given to an independent third investigator to ensure identified themes could be subsequently found by someone who had not previously seen the data. A full list of themes can be found in Supplementary **Table S3**. While the relative prevalence of themes was taken into account, code frequency was not counted due to previously documented limitations of quantizing narrative accounts of experience; implying certain lived experience hold greater significance due to magnitude, that frequency may reflect a respondent's willingness or comfortability discussing a subject rather than prevalence, and the loss of contextual nuance (Hewitt-Taylor 2001; Saldana 2012; Creswell 2013; Vaismoradi et al. 2013).

As was expected, some of the data collected in the interviews were highly specific to individual circumstances. While this did not result in additional themes, this information is important to consider. It draws attention to the fact that laboratory shutdown and reopen protocols must account for local, specific circumstances. While generalizations can be made, there is no one-size-fits-all laboratory shutdown or reopening template. All plans must account for laboratory-specific scenarios. Integration of qualitative and quantitative data sets was achieved through a side-by-side comparison approach within the results and discussion, focusing on convergent and divergent findings from these comparisons (Teddlie and Tashakkori 2009; Creswell and Plano Clark 2017).

Results

Respondent characteristics

The online survey was completed by 315 respondents (**Fig. 1**). Biology (30.2%) and Health Medical Sciences (19.4%) were the most reported respondent area of research (**Fig. 1A**). Eight provinces were represented, with the majority from Ontario (34.9%) and Quebec (17.1%) (**Fig. 1B**). Most respondents lived with at least one other person while working from home, with only 17.6% of respondents living alone (**Fig. 1C**). Slightly less than half of respondents lived with a partner or spouse (44.1%) and 23.9% reported living with parents (**Fig. 1C**). Half of the respondents were female, 18.4% male, and 1.2% were nonbinary or genderfluid (**Fig. 1D**), with just over a quarter of respondents (27.9%) not disclosing their gender. Doctoral (PhD) students made up 37.5% of respondents, with Master's students representing 21.6%, postdoctoral fellows representing 14.9%, and 26% not disclosing their position (**Fig. 1E**). There was a fairly even distribution of graduate student respondents with regards to degree progress, with fewer students in the process of defending their thesis (**Fig. 1F**). Postdoctoral

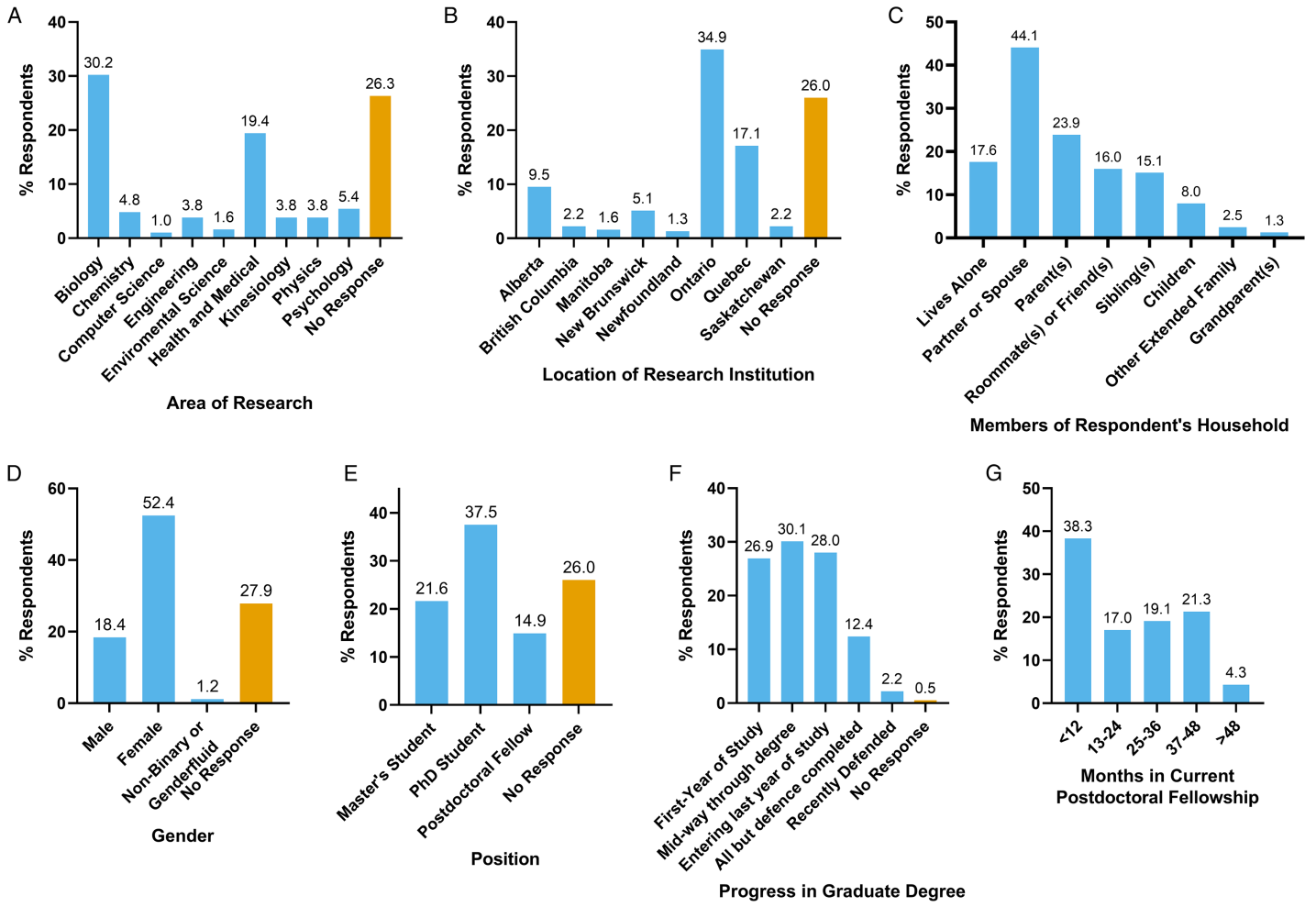

Fig. 1. Survey respondent characteristics. (A) Respondent area of research, $N = 315$. (B) Location of respondent's research institution, $N = 315$. (C) Living situation of the respondent while working from home. Percentage of respondents with listed members of the household is shown. $N = 238$. (D) Gender of respondents, $N = 315$. (E) Academic position of respondents, $N = 315$. (F) Progress in graduate degrees for Master's and PhD students, $N = 186$. (G) Months in postdoctoral fellowship position, $N = 47$.

fellow respondents ranged in experience from less than 12 months to greater than 48 months in their current position (Fig. 1G).

A slight majority of respondents (59.6%) had previously published research articles (Table S4). Postdoctoral fellows were more likely than graduate students to be looking for their next academic position, with 57% of postdoctoral fellows seeking a new position compared to 28% of Master's and 23% of PhD students (Table S4).

The 18 interview participants reflected general overall demographic characteristics of survey respondents (Table S5). Most interviewees were female (66.6%), PhD students (72.2%), and conducting either biology (38.9%) or health and medical science research (33.3%) (Table S5). Four Canadian provinces were represented, with most interviewees being from research institutions in Ontario (50.0%) or Quebec (38.9) (Table S5). Similar trends were seen in degree progress, the number of months in a postdoctoral position, and those seeking new academic positions (Table S5).

The transition from research to social distancing

We asked survey respondents who made the decision to pause experiments or close down laboratories. Seventeen percent reported they personally made the decision to stop experiments before their laboratory was closed (Fig. 2A). Twenty percent had supervisors who closed their laboratories prior to an official shutdown (Fig. 2A). Of the remaining respondents, 45.6% experienced closures decided by their department, research institute, faculty, or university (Fig. 2A). Most respondents completed their final experiments in March 2020, with 68.4% ending in between 8 March 2020 and 21 March 2020 (Fig. 2B). Only 13.4% came from laboratories with standard operating procedures (SOPs) for quickly shutting down the laboratory created prior to the COVID-19 pandemic, with an additional 18.1% laboratories creating a shutdown SOP in response to the pandemic (Fig. 2C).

Respondents noted a lack of clear and consistent communication between supervisors, administration, and trainees, leading to a chaotic and confusing shutdown experience. Changes in protocol happened quite suddenly, as two respondents explained:

> "One day, we were told that we could continue recruiting human subjects; the next, everything was to be shut down." (Survey ID 770)

> "After a week of emails saying like, 'We're open. We're open. We're open.' [. . .] And then that night around 6:30 PM, after getting an email at 3 PM saying 'We're open', we got an email saying 'Gotcha. Campus is closed'." (Interviewee 6)

There were also discrepancies among people in positions of power in how they reacted to the impending shutdown. This led to graduate students and postdoctoral fellows discussing the situation amongst themselves, increasing their anxiety as many did not have the positional power to enact change at the laboratory or institutional level:

> "Some people in charge were behaving like this was a minor inconvenience and others were behaving like this was an apocalypse, you know? So, I think having those kinds of contradictory messages from people in charge was difficult." (Interviewee 4)

> "There was discussion and there was lots and lots of uncertainty and anxiety, I would say, from myself and my peers. Looking towards our supervisor was not very helpful, as I felt that we were more informed about what other institutions were doing than they were." (Interviewee 11)

Concerning the logistics of laboratory and project shutdown, respondents reported multiple steps to pause projects including: backing up data, setting up remote servers to access data, discontinuing ongoing experiments, freezing samples for indefinite storage, culling animal colonies to reduce numbers or euthanizing animals early to obtain data, discarding samples that could not be stored long term, securing equipment and biohazards safely, rescheduling or cancelling in-person meetings with human participants, cleaning laboratory space, testing the back-up power supplies to key equipment (such as freezers), turning off nonessential equipment, and the physical locking up the laboratory. Twenty-nine percent of respondents helped shut down others' projects in addition to their own (Fig. 2D). A respondent's academic position did not significantly impact the likelihood of assisting in other shutdown activities outside of their project (Table S6, Fisher's exact test, $P > 0.9999$).

When asked if, in hindsight, they would change anything about the shutdown procedure, respondents discussed three main things they would do differently. First, they would stop experiments sooner out of their own volition rather than being abruptly cut off by the university. Second, they would want "more clear communications from everyone involved" (Survey ID 704). Third, they would have brought more things home with them from the lab, including personal belongings, data, technology,

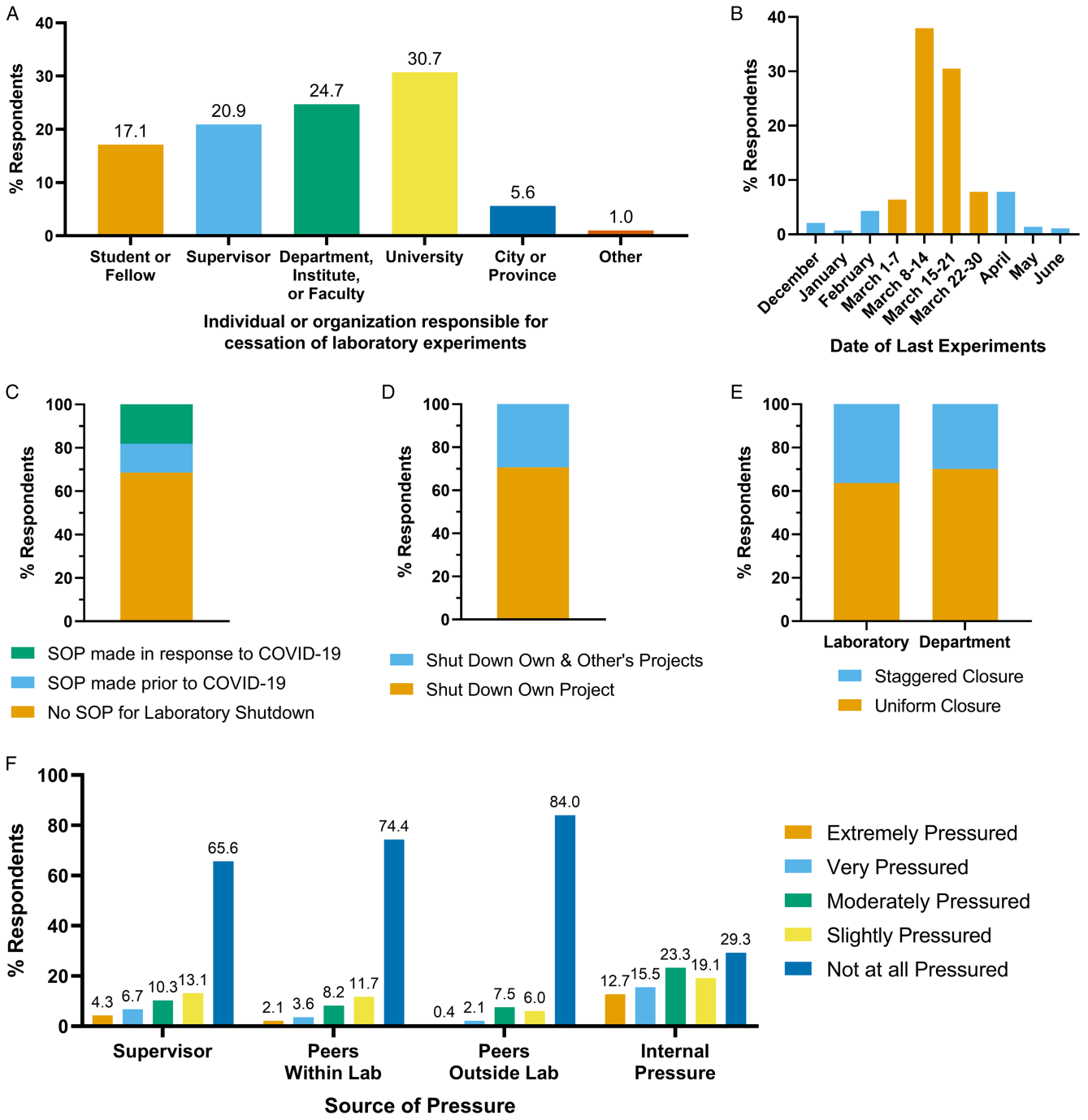

Fig. 2. Characteristics of laboratory shutdowns experienced by respondents across Canada. (A) Respondent description of the individual or organization, including the respondent themselves, that made the decision to cease laboratory experience. (B) Date of last experiments performed by respondents. (C) Prevalence of standard operating procedures (SOPs) for fast laboratory closures. (D) Project shutdown responsibilities of respondents. (E) Closure practices of respondent laboratories and departments. Uniform closure describes scenarios where all work stopped at approximately the same time. Staggered closure describes scenarios where some individuals transitioned to work from home while others continued to work in lab. (F) Prevalence of pressure to keep working during laboratory closures.

and print resources. Many did not initially take these items as they "did not think [they] would be locked out so long" (Survey ID 156). This also included setting up remote access to data and laboratory information.

A slight majority (63.7%) of laboratories had a uniform closure, meaning all students and fellows stopped experiments at approximately the same time (Fig. 2E). A similar trend was also reported at the departmental level, with most (70.1%) laboratories closing in unison (Fig. 2E). A frequent reason cited for a staggered closure of laboratory experiments was differences in ease of pausing experiments. For example, some respondents recognized that animal model research might take longer to pause:

> "Those who had to finish animal data collection went into lab while others started working at home. It made a lot of sense." (Survey ID 158)

> "My colleague was in the middle of an animal experiment and had she terminated the experiment early, she would have had to sacrifice animals without collecting any data, rendering those animals a waste. I am glad she continued the experiment until the planned end-point, thereby not having to use any additional animals." (Survey ID 188)

Overall, respondents who started to work from home while their colleagues continued working in the lab had a mix of responses to the situation. Some wished they could have continued working for longer, feeling "Frustrated and angry that [colleagues] would complete their research while I had to start over" (Survey ID 183) or that "It felt unfair and I was a little jealous" (Survey ID 253). These sentiments of jealousy and frustration were accompanied by statements of belief that they were falling behind by losing research time. Others were upset that they specifically had been asked to go home first, as this was interpreted to mean their project had "lower apparent priority" (Survey ID 117) compared to others in the laboratory. There were also feelings of concern for colleagues who continued working, as one respondent explained:

> "It was also worrying to see others still complete work and putting themselves in harm's way during a pandemic to ensure they could actively finish their experiment." (Survey ID 18)

Conversely, respondents who continued working longer than their colleagues reported feelings of anxiety and guilt. Some felt "guilty that I was putting others at risk" (Survey ID 22) by continuing to work in the lab and that the concern of their colleagues made them feel more anxious. As summarized by one respondent, "I was the one working. And felt like I was doing something wrong" (Survey ID 325).

Respondents who experienced more uniform laboratory closures had different sets of reactions to the research shutdown. Similar to those who had an uneven closure, respondents reported feeling "anxious because it was really starting to show the reality and seriousness of the situation" (Survey ID 284). This anxiety stemmed from realizations that COVID-19 was significant enough to warrant large-scale closures or generalized anxiety, rather than citing concern about their safety or the safety of colleagues as expressed by respondents who experienced staggard closures. There were also conflicting feelings of isolation and unity. On one hand, respondents reported feeling "Lonely and sad. I really miss being around my peers" (Survey ID 425). This stemmed largely from losing in-person social interactions. On the other hand, respondents said "it created a sense of solidarity for me. Everyone was working together to try and keep people safe" (Survey ID 533). Others cited a uniform closure as bringing an end to the confusion and mixed messages they experienced prior to the shutdown,

> "I think I felt a bit relieved when all the labs finally shut, and I knew that everyone was at home. It just meant that all the uncertainty of when the labs were going to close was over and everyone was now on the same page" (Survey ID 767)

We asked respondents about the prevalence of pressure they experienced from different sources to continue experiments prior to receiving an official shutdown directive from their research institution. This included external sources such as their supervisor or peers and internal sources such as themselves. Many respondents indicated that they received no pressure to continue from external sources, such as their supervisor (65.6%), peers within the laboratory (74.4%), or peers external to the laboratory (84.0%) (Fig. 2F). Those who were pressured to continue experiments were more likely to be pressured by individuals in their laboratory group, with one-third being pressured by supervisors and one-quarter pressured by peers within the laboratory (Fig. 2F).

Some respondents who experienced external pressure said their supervisor "does not believe COVID is a very serious issue and that responses have been an over-reaction" (Survey ID 265) or that they "kept saying things like 'you can't just STOP research' " (Survey ID 364). For others who had peers who "suggested that we were overreacting" (Survey ID 255) or who "felt like the pandemic wasn't super serious" (Survey ID 515), these respondents reported beginning to question whether shutting down laboratory experiments was the best decision following discussion with peers.

A much different trend emerged when respondents were asked about the pressure they put on themselves to continue research; 70.7% of respondents reported some level of internal pressure to continue working (Fig. 2F). This is consistent with known levels of stress associated with the "publish-or-perish" culture in academia (Davis et al. 2007; Miller et al. 2011; Tijdink et al. 2016; Hangel and Schmidt-Pfister 2017; Haven et al. 2019). Respondents described fear of losing research time and data, often tied to a fear of not being able to graduate or submit a manuscript:

> "My thesis is due at the end of the summer. I was scared because even if research were to have started up again, I lost my window of time where I could have continued research. At this point, I just have to write a thesis with the data I have." (Survey ID 73)
>
> "I am losing a lot of valuable data collection time and am concerned I won't finish on time to graduate." (Survey ID 417)
>
> "The days prior to the shutdown were filled with some pressure because I was trying to finish experiments that would provide data for an upcoming manuscript. My hope was that I'd get the data I needed and then go home and start writing the paper." (Survey ID 71)

Others explained they felt self-conscious stopping work when peers were working, worried that they would be perceived as less hard working or as lazy.

Following laboratory closures, most respondents (79.2%) remained in the same city in which their laboratory is located (Table 1), with the most common explanation being that it is the location of their full-time residence. Other reasons to remain included "not wanting to do unnecessary flying" (Survey

Table 1. Migration patterns of graduate students and postdoctoral fellows during the transition to working from home.

Category	*N* (%)
Remained in same city as their laboratory	224 (79.2)
Traveled to a city within the same province or territory (<1-h drive)	26 (9.2)
Traveled to a city within the same province or territory (> 1-h drive)	18 (6.4)
Traveled to another province or territory	13 (4.6)
Traveled to another country	2 (0.7)

ID 99), international flights being cancelled, and not wanting to put family or friends at risk by traveling from an area with a high incidence of COVID-19. For the fifth of respondents who relocated to another city, most cited moving to be with family as a primary factor, as they lived by themselves and did not want to be alone or because they wanted to move to "an area with fewer cases and less dense population" (Survey ID 739). Some respondents noted they otherwise may not have moved; however, they were away when their laboratory shut down and they did not return:

> "I had gone home to visit my parents for a weekend, and they live in another city, and I thought it was just going to be for a weekend, but then the conversation [concerning laboratory closures] shifted over the course of the weekend. So instead of coming back to the big city and the densely populated area, I stayed behind." (Interviewee 2)

Working from home during social distancing

Following the closure of the laboratory workspace, 48.6% of respondents had individual workspaces in their homes, 31.0% shared workspace with others in their household (Table 2), and 20.4% of respondents did not have a dedicated workspace in their home (Table 2). Additionally, 21.9% of respondents were taking one or more courses as part of planned studies, which were transitioned online (Table 2). Approximately a third of respondents had one or more projects in the process of peer review (Table 2).

Respondents completed several activities while working from home, which we classified as being directly related to COVID-19, self-care, research, or household maintenance (Fig. 3, Tables 3–6). In addition to descriptive reporting of activities by all respondents, we also stratified respondent responses by gender and academic position (Tables S7 and S8). Differences between subpopulations was determined through Fisher's exact test with Bonferroni correction (Tables S7 and S8). No

Table 2. Characteristics of working from home experiences by respondents across Canada.

Category	*N* (%)
Dedicated home workspace	
No	52 (20.4)
Yes, shared workspace	79 (31.0)
Yes, individual workspace	124 (48.6)
Participation in course(s) as part of planned studies prior to shutdown	
No	183 (71.5)
Yes, the course transitioned online during shutdown	63 (21.9)
Yes, the course ended during shutdown	4 (1.3)
Project(s) in the peer-review process	
No	164 (64.1)
Yes, recently submitted or with an editor	28 (10.9)
Yes, sent for peer review	16 (6.3)
Yes, completing revisions (major or minor)	26 (10.2)
Yes, submitted revisions	10 (3.9)
Yes, recently accepted	12 (4.7)

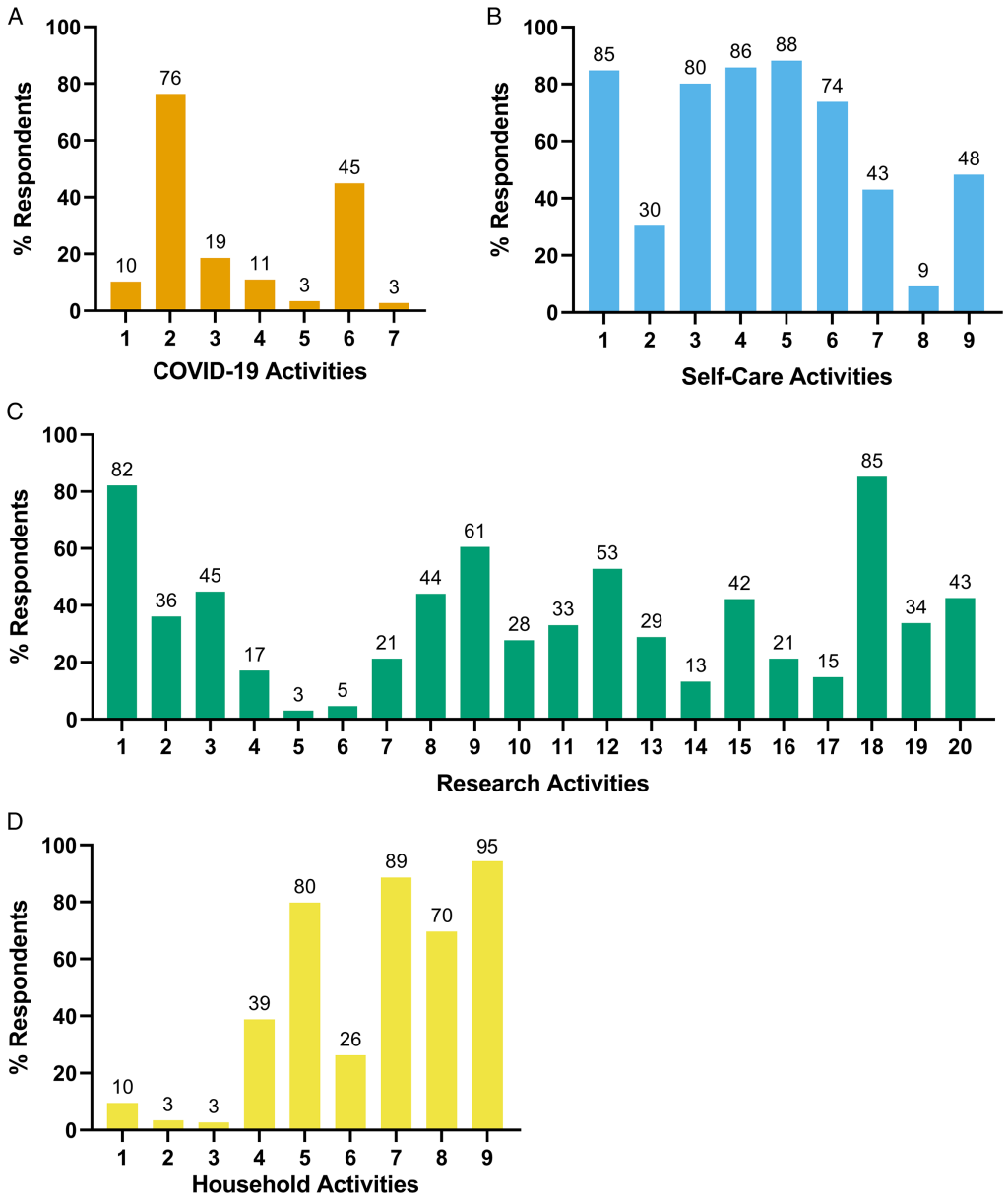

Fig. 3. Activities conducted by graduate students and postdoctoral fellows while working from home. Values are displayed in percentage of total respondents across (A) COVID-19, (B) Self-Care, (C) Research, and (D) Household-related activities. $N = 263$. Full list of activity descriptions available in Tables 3–6.

significant differences were identified between female and male respondents (Table S7). However, three significant differences in research-related activities were identified between graduate students and postdoctoral fellows.

More respondents reported participating in COVID-19-related activities that directly impacted their family or friends as opposed to the public at large. For example, 76% of respondents indicated sharing accurate information about COVID-19 with family and friends, compared to 19% sharing the same

Table 3. Descriptions of COVID-19-related activities completed by respondents while working at home. Respondent percentages can be found in Fig. 3A.

Number	Activity description
1	Collecting/donating personal protective equipment or other supplies to local hospitals
2	Sharing accurate information about COVID-19 with family and friends
3	Sharing accurate information about COVID-19 with the general public
4	Volunteering your research skills to support research on COVID-19 (in-person or remote work)
5	Volunteering your research skills to support patient testing efforts for COVID-19
6	Supporting family, friends, or others in quarantine (for example, picking up groceries)
7	Supporting health care professionals (for example, picking up groceries, providing childcare support)

Table 4. Descriptions of self-care related activities completed by respondents while working at home. Respondent percentages can be found in Fig. 3B.

Number	Activity description
1	Exercise (indoor or outdoor)
2	Meditation or mindfulness
3	Connecting with family and friends by phone
4	Connecting with family and friends by email, text, or other messaging software
5	Connecting with family and friends by video chat
6	Practicing an old hobby or skill (for example, baking, gardening, music, reading)
7	Developing a new hobby or skill (for example, baking, gardening, music, reading)
8	Attending virtual religious or spiritual services
9	Establishing and maintaining routine

information with the general public (Fig. 3A, Table 3). Other COVID-19-related activities included donation of personal protective equipment (10%), volunteering to support COVID-19 research (11%), and supporting others in quarantine (45%) (Fig. 3A, Table 3).

Respondents reported high levels of self-care activities while working from home (Fig. 3B, Table 4). Many prioritized connecting with family and friends virtually, with 84% connecting by video chat, 86% using a text-based medium such as email or texting, and 80% using phone calls (Fig. 3B, Table 4). Exercising either indoors or outdoors was also frequently reported (85%) (Fig. 3B, Table 4). While 74% respondents returned to previous hobbies or skills, 43% of respondents said they began developing a new hobby or skill while working from home (Fig. 3B, Table 4). Other self-care activities with lower levels of reporting included establishing a new routine (48%), meditation or mindfulness (30%), and attending virtual religious or spiritual services (9%) (Fig. 3B, Table 4).

Despite being away from the laboratory environment, respondents continued to participate in several research-related activities, the most common being reading the literature (85%), virtual lab meetings (82%), and analyzing data gathered prior to shutdown (61%) (Fig. 3C, Table 5). Writing-related activities such as drafting manuscripts (53%), designing scientific figures (42%), and writing thesis chapters (33%) were reported (Fig. 3C, Table 5). Slightly less than half (45%) of respondents attended

Table 5. Descriptions of research-related activities completed by respondents while working at home. Respondent percentages can be found in Fig. 3C.

Number	Activity description
1	Virtual laboratory meetings
2	Virtual journal clubs
3	Virtual scientific meetings, conferences, or seminars
4	Virtual committee meeting
5	Virtual comprehensive examination
6	Virtual thesis defense
7	Updating laboratory notebooks
8	Creating strategic plans for future experiments
9	Analysis of data gathered before laboratory closing
10	Preparing applications for awards, conferences, scholarships, etc.
11	Writing thesis chapter(s)
12	Writing draft manuscript(s)
13	Writing review article(s)
14	Writing protocols, standard operating procedures
15	Designing scientific figures
16	Working on written revisions to a paper in peer review
17	Organizing reagents and (or) data spreadsheets
18	Reading the literature
19	Completing online training or learning new skills virtually
20	Updating your CV, LinkedIn, ORCID, or similar online platform

virtual scientific meetings, conferences, or seminars from home (Fig. 3C, Table 5). Other respondents did activities to help prepare for after the pandemic, such as creating strategic plans for future experiments (44%) or updating their curriculum vitae and (or) LinkedIn profile (43%) (Fig. 3C, Table 5). All three significant differences identified between postdoctoral fellow and graduate student respondents' activities reported were research-related activities. Unsurprisingly, significantly more graduate students reported writing thesis chapters than postdoctoral fellows (Table S8, Fisher's exact test), $P = 0.0015$) Significantly more postdoctoral fellow respondents also reported writing draft manuscripts ($P = 0.045$) and working on paper revisions ($P = 0.0165$) (Table S8, Fisher's exact test).

There were high levels of reported household maintenance activities, including cleaning tasks (94%), cooking meals for self (89%), cooking for others (70%), and completing necessary excursions such as grocery shopping (80%) (Fig. 3D, Table 6). In terms of caregiving, 10% of respondents reported caring for children, while 3% reported caring for dependent adults (Fig. 3). 39% of respondents reported caring for pets (Fig. 3D, Table 6). Overall, more than half of respondents thought there was an even distribution of labour in their household (66.1%) (Table 7). These respondents described "dividing tasks so that everyone plays a role and contributes to household chores" (Survey ID 87).

Others reported one or more members of the household intentionally took on more household responsibilities from others:

Table 6. Descriptions of household-related activities completed by respondents while working at home. Respondent percentages can be found in Fig. 3D.

Number	Activity Description
1	Care and supervision of children
2	Supervising emergency remote learning/homeschooling of children
3	Care of dependent adults
4	Care of pets
5	Completing necessary excursions to support your household (for example, to obtain groceries or medication)
6	Completing necessary excursions to support others (for example, to obtain groceries or medication for family)
7	Cooking meals for myself
8	Cooking meals for others in my household
9	Domestic cleaning tasks (for example, vacuuming, washing dishes, doing laundry)

Table 7. Opinions on household distribution of labour.

Category	No – uneven distribution of labour, *N* (%)	Yes – even distribution of labour, *N* (%)	Total respondents
Female Respondents	53 (36.8%)	91 (63.2%)	144
Male Respondents	11 (23.4%)	36 (76.6%)	47
Total Population	75 (33.9%)	146 (66.1%)	221

Note: Total population includes respondents who are non-binary or genderfluid, as well as those who did not disclose their gender. Significance was determined by a two-sided Fisher's exact test with Bonferroni correction using GraphPad Prism 8 and R. ($P > 0.9999$).

> "My partner isn't employed right now so he does more than half the chores because he has more time than me." (Survey ID 29)
>
> "Some household members have chronic health issues and aren't able to do as much." (Survey ID 462)

However, some respondents had an uneven distribution of household labour that they were dissatisfied with, describing a continuation or amplification of an imbalance which existed prior to the COVID-19 pandemic:

> "Some gender roles are hard to escape and I find myself, now that I am always home, picking up even more of the slack than before." (Survey ID 248)
>
> "Though my partner and I both work from home, I still feel like a lot of home duties fall on me. I do 80% of the cleaning and cooking—though this is not much different prior to COVID." (Survey ID 741)

Respondents were asked to rank how frequently they experience, if at all, a variety of symptoms of distress while working from home (Fig. 4). We used a list of distress symptoms (Items 1–8, Table S9) previously developed by the National College Health Assessment Survey II (NCHA II)

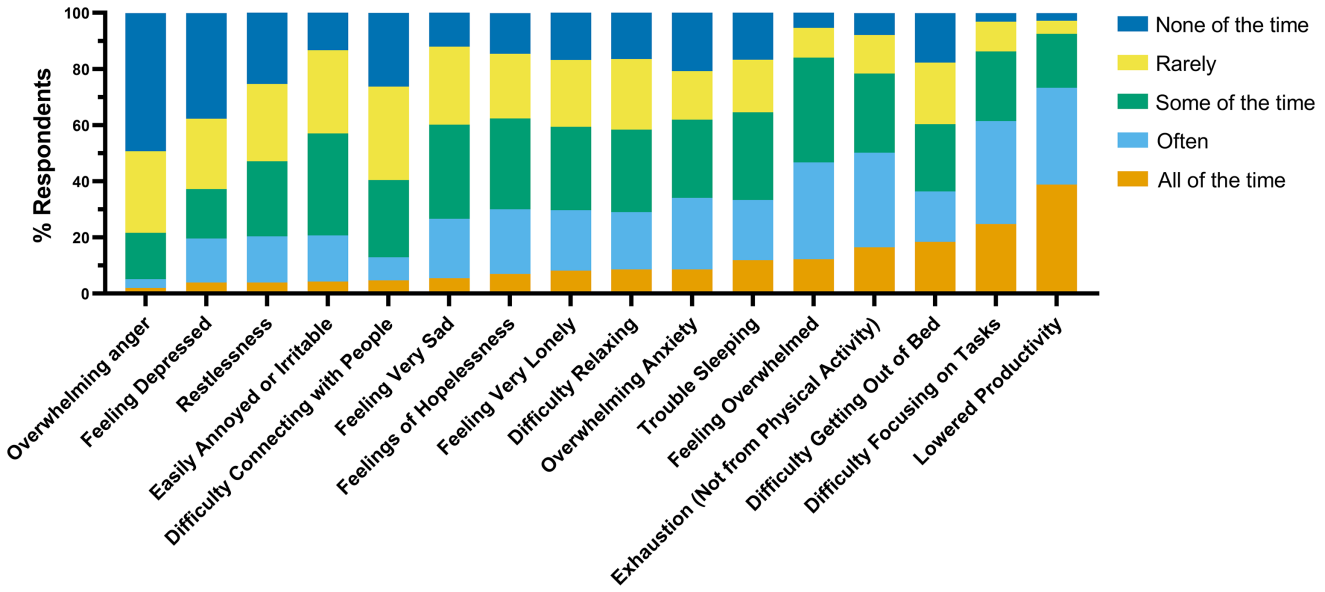

Fig. 4. Self-reported symptoms of distress while working from home during COVID-19. Values are displayed in percentage of total respondents across 16 symptoms of distress. $N = 254–256$. Items are ranked from lowest to highest percentage of respondents reporting feeling "All of the time".

(American College Health Association 2016). Additional items (Items 9–16, **Table S9**) were included as there was anecdotal reporting of these symptoms by graduate students through social media. The most reported symptoms related to attention, including lowered productivity and difficulty focusing on tasks (**Fig. 4**). Other symptoms with high incidence included difficulty getting out of bed, exhaustion not related to physical activity, and feeling overwhelmed (**Fig. 4**).

A greater proportion of female respondents reported symptoms of distress than male respondents (**Table S9**). However, only two distress items had significant differences between men and women; feeling overwhelmed (Fisher's exact test, $P = 0.0435$) and being easily annoyed or irritable (Fisher's exact test, $P = 0.0435$) (**Table S9**). This trend is consistent with past findings and literature showing women are more likely to report symptoms of distress (Mirowsky and Ross 1995; Statistics Canada 2015; Moyser 2020).

Respondents were asked to identify their three biggest barriers to getting work done at home, to which four main barriers were identified. The first barrier was technical issues, which primarily stemmed from lack of access to stable, high-speed internet. Other issues in this category included not having enough computer processing power to run analyses and access to software. The second barrier was distractions in the home, such as noise, other household members, and household chores that are not present in the laboratory:

> "So if I just get up to go grab a glass of water, then I'll see something and I'll fix it. Or oh, there's a little bit of dishes. I'll start doing them and I'll start doing other things, and I'll never go back to work. So when I work in the lab and in my office at the desk, there's nothing else." (Interviewee 14)

Respondents with children also cited childcare as another distracting factor, as one respondent put it "[My daughter] is only 15 months so she requires a lot of hands-on attention, so my husband and I take turns watching her so we only work for 2–2.5 hours/day" (Survey ID 137).

The third barrier identified was motivation, or lack thereof. Respondents had difficulty starting tasks, focusing on tasks, and finishing activities. Some attributed this to the lack of an impending deadline, as "nothing seems pressing and I sometimes genuinely do not feel like working" (Survey ID 129). Others felt that their "research is less relevant now" (Survey ID 52), and since they were unable to do experiments, they lacked motivation to do other activities.

The fourth barrier was mental health, with either new anxiety or depression developing, or previous conditions worsening with the pandemic shutdown. As one respondent explained, "managing my anxiety and depression during this uncertainty has left very little energy to focus on work" (Survey ID 311). Thus, their main activity during this period was taking care of themselves. Oftentimes, lack of motivation and mental health barriers compounded with one another, as described by one respondent:

> "My brain seems to just shut down all the time, and I have a hard time controlling and coming out of it. I just feel so overwhelmed thinking I have so much to do that I don't do anything and then I get anxious because I'm afraid that I didn't do enough work." (Survey ID 562)

We next asked respondents to list three supports they received while working at home, to which five main categories of support were identified. The first support was financial, with respondents citing the "financial security of my stipend" (Survey ID 311), the Canada Emergency Student Benefit, the Canada Emergency Response Benefit, and other sources of monetary support to cover costs and "prevent financial anxieties" (Survey ID 48). The second support was social connections, which was described as coming from several sources, including family, friends, a partner or spouse, children, laboratory peers, and pets. As summarized by one respondent, these social connections made them "feel supported and validated in my feelings, and knowing that we're all struggling. Support from friends and peers makes me feel less alone and I know I'm not the only one having trouble with this" (Survey ID 493).

The third support was establishing and maintaining routines during social distancing. Respondents said having routines, either self-imposed or from external sources such as a weekly laboratory meeting, helped with finding motivation, as well as "feeling that there is a rhythm and purpose to my daily life again" (Survey ID 133). Dog-owning respondents cited their pet, in addition to emotional support, also served as an external source to gently force them to maintain healthy routines:

> "Having a dog has helped me stay in a normal routine of getting up at a decent time to take her outside and getting out for a walk every day." (Survey ID 515)

> "My dog insists on thrice daily walks, which gets me up and moving. And I find that I get back from walks and I can focus a lot better." (Interviewee 6)

The fourth support respondents identified was relating to mental health, which mirrors the previously identified barrier. This included professional support such as counselling, therapy, and remote telemedicine services. Other supports included meditation and exercise as means to maintain mental health. As explained by one respondent, "running removes all the excess anxiety and improves my mood" (Survey ID 116).

The fifth type of support came from the respondent's supervisor or other administrative figure. This included virtual laboratory meetings to implement routine as well as keeping respondents socially "connected to my work and my co-workers" (Survey ID 255). However, most respondents identified supervisors' and administrators' understanding, transparency, and emotional support as what they valued the most:

"My supervisor is very supportive not only of my research but also my well-being. He listens and encourages me to take care of my mental health and understands that this social distancing thing is having a pretty big impact on me." (Survey ID 562)

"[My] supervisor telling the group during lab meeting to focus on health and family and not expecting any productivity at this time." (Survey ID 87)

"My department chair has been very transparent which has provided clarity and some ease of anxiety." (Survey ID 195)

"I'd say my supervisor genuinely, she has been incredibly supportive during this time of understanding what it's like to go through this, but also keeping us very aware of decisions that are being made and very realistic." (Interviewee 3)

Concerns and supports for returning to the laboratory

Respondents had a number of concerns that the COVID-19 pandemic could impact them going forward (Fig. 5). There was a high degree of similarity between quantitative and qualitative data focused on respondents' concerns. These worries tended to fall into three categories: personal, disruption of research activities, and career impacts. A minority of respondents also said they were not very worried about the impacts of COVID-19.

As personal concerns, respondents were worried friends or family members would get sick or die from COVID-19, especially those with underlying health conditions or who were essential workers. Interestingly, respondents were more worried about others contracting COVID-19 than themselves contracting it (Fig. 5).

Respondents were more concerned about "the impact COVID-19 will have on my long-term physical and mental health" (Survey ID 516). Thus, the concern came from the impact of social distancing and working from home in response to COVID-19, rather than concern of contracting the virus. Respondents cited concerns about decreased social interaction while working from home, which left

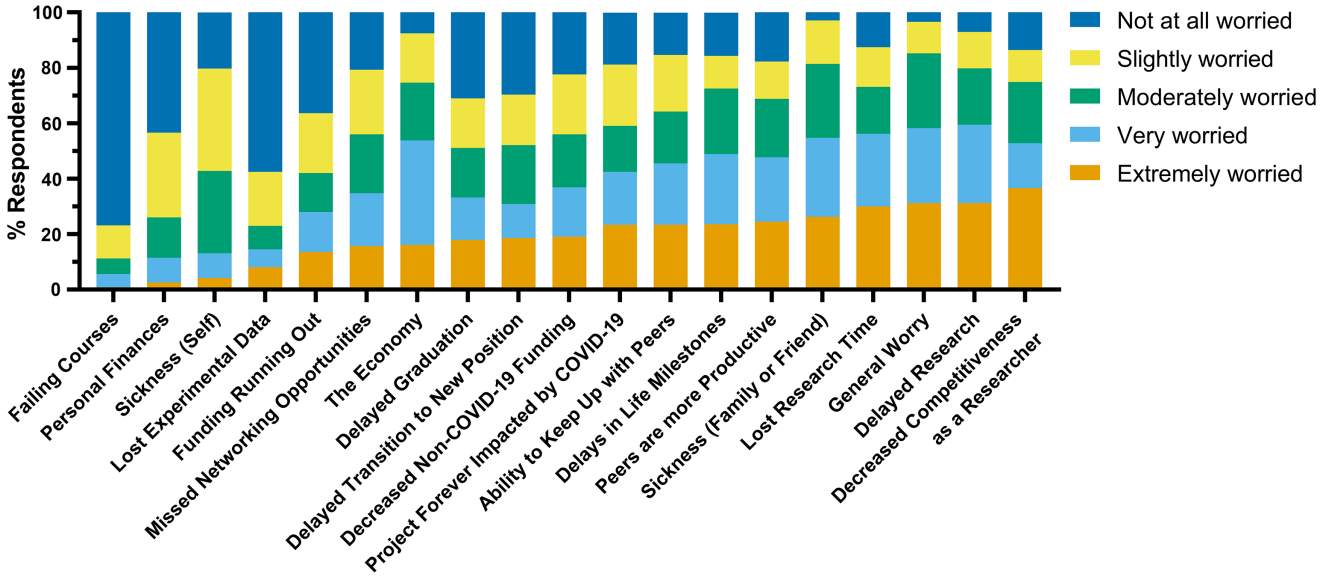

Fig. 5. Graduate students and postdoctoral fellows' concerns related to the COVID-19 pandemic. Values are displayed in percentage of total respondents across 19 potential areas of concern. $N = 234–237$. Items are ranked from lowest to highest percentage of respondents reporting feeling "Extremely Worried".

them "feeling lonely and isolated" (Survey ID 394). Some did not know when they would be able to see their family face-to-face again. Others were concerned that this would negatively impact their ability to make connections with people going forward as "spending so much time in social isolation will just exacerbate" (Survey ID 513) their natural awkwardness or introversion. Maintaining current social connections was also a challenge, as one respondent put it:

> "Not being able to physically see people makes it harder to maintain connections. I had a 'COVID' birthday and it felt like I was forgotten by most people, even though a birthday is not a priority in times like these." (Survey ID 37)

A section of respondents was concerned that they would need to delay key life milestones such as getting married, beginning a new job, or starting a family. Often these events were pushed back due to a respondents' graduation date or end of postdoctoral fellowship getting extended due to laboratory closures. One respondent summarized the impact of COVID-19 as follows:

> "This situation has screwed up my whole life plan, I just want to scream, I feel like I have no control." (Survey ID 377)

Despite financial help being identified previously as a support by some respondents, 56.6% worried that COVID-19 would impact their personal finances. Some were struggling even with governmental support, while others were worried about the security of their research funding. Increased financial uncertainty was cited as a reason some respondents were choosing to delay life milestones. Others were frustrated that they needed to continue to pay tuition fees, despite not being able to conduct research:

> "I am still paying full tuition to sit on my couch and not be allowed into my lab, when that tuition I'm paying is to be a part of a research program, a research program I currently cannot take part in." (Interviewee 17)

Respondents listed a number of concerns related to their current research activities. Some were worried "that funding for basic research will become scarce" (Survey ID 80) due to the focus on COVID-19 research and the state of the economy. Others were concerned about going overtime on their degree or fellowship due to COVID-19 would impact their eligibility for funding in the future. Traditionally, this would result in reduction or stoppage of stipend money. Although many institutions and funding agencies have announced accommodation for students and fellows for fall 2020, respondents were more concerned about the "availability of funds next year and the coming years, [as] that may actually be an issue" (Interviewee 8). This worry of going overtime or delaying graduation due to decreased research productivity was intertwined in several responses throughout the survey. Some respondents had "cancelled [their] current research topic and forced [them] to have to change it" (Survey ID 664) in response to the laboratory shutdown, modifying their thesis in a way that would forever be impacted by COVID-19. Others lamented canceled travel opportunities for networking and "missed opportunity for international collaboration" (Survey ID 742). As one respondent explained:

> "I'm in that crucial new investigator period of my career. COVID represents a year of no conferences, no networking, no data collection… it's setting everything back." (Survey ID 203)

Many concerns regarding current research activities connected with concerns about how COVID-19 might impact their careers: 86.4% of respondents were worried about their competitiveness as a researcher, with 36.6% describing themselves as extremely worried (Fig. 5). Many respondents were concerned that their lack of productivity during the laboratory closure period and decreased publications would make them less desirable candidates for future positions. As summarized by one respondent:

> "My goal is to become a tenure-track faculty member at a research-intensive university, which is a difficult enough task as is. But I worry that because of this situation, I will either not be productive enough to secure a position, or I will have to prolong my postdoc experience in order to gain enough productivity to be a viable candidate. I also worry that universities will have decreased hiring in the next few years, which coincides with my entry into the academic job market." (Survey ID 255)

Many respondents were concerned about the availability of employment both within and outside academia in the post-COVID-19 era. Some hope "there are still jobs in academia (or any kind of research) after all the economic fallout" (Survey ID 99). Postdoctoral fellows, in particular, were concerned about universities freezing hiring for faculty positions. Some respondents had already made the decision to alter their career goals in response to COVID-19:

> "I am convinced about leaving Academia." (Survey ID 113)

> "Before COVID, I was gaining momentum in my project. I was deciding between transferring from MSc to PhD, but after COVID I lost this motivation entirely. I now have decided to finish with an MSc and hopefully find a job afterwards." (Survey ID 763)

> "I feel like the time away from [the lab], whether this is good or bad has maybe made me cooled off a little bit and like feeling more, I don't know, further from science and thinking that maybe that's not bad." (Interviewee 4)

Respondents had a number of ideas when asked about what supports would help them transition back to laboratory work post COVID-19 which we categorized into five groups: personal protective equipment and protocols, understanding and empathy, guidance and direction, timeline support, and financial support.

The minimum support respondents asked from both supervisors and administration were adequate personal protective equipment and protocols on how to reopen and work in laboratory space. The emphasis was placed on clearly communicating safety procedures and protocols that are put in place, as respondents did not want a similar confusion and anxiety that took place during laboratory shutdowns to repeat themselves.

What respondents wanted most from their supervisors was the first two groupings of support: (*i*) understanding and empathy and (*ii*) guidance and direction. First, respondents wanted "understanding I won't be as productive as before COVID for a long time" (Survey ID 458), "reassurance that delays are acceptable" (Survey ID 739), and "emotional support and encouragement" (Survey ID 769). Respondents described wanting their supervisors to be explicit that they do not expect pre-COVID-19 levels of productivity and that they will not be made to feel guilty over lost time. They also wanted "moral support getting back on track with experiments" (Survey ID 123), as respondents are still reeling from the emotional and stressful toll of the shutdown experience. Respondents described hesitancy and fear at returning to a laboratory situation where this flexibility was unlikely to be found:

> "My supervisor has zero empathy or tolerance and I'm extremely worried about going back to work with him" (Survey ID 69)

Second, respondents were hoping to receive explicit guidance and direction from supervisors as to where to go with projects once they returned to work. There were frequent descriptions of wanting "clear goals for me to finish my program" (Survey ID 93), "a detailed plan of how to be most efficient with research efforts" (Survey ID 347), and "clear communication" (Survey ID 248). Respondents encouraged the development of a research plan that would limit the potential negative impacts of

the laboratory shutdown, get experiments back up and running efficiently, and keep respondents on time in their degree progression. Respondents also wanted supervisors to "acknowledge that the PhD or the master's degree that students had originally set out to accomplish may not be feasible within our current time frames" (Interviewee 11) and that adjustments would be required.

The supports requested from administration, including departments, faculties, and the university itself, focused more on structural supports including degree timeline and financial supports. Timeline support focused mainly on flexibility. Some students explicitly asked for "flexibility for certain milestones (comprehensive exams, graduation timeline, funding timeline) that allows us to get back to our research without feeling like we need to compress everything into the time that we lost" (Survey ID 92). Others wanted expectations for key requirements to change as extending time in their degree "is something I really don't want to do" (Survey ID 651) and wanted "assurance that I will graduate on time" (Survey ID 583). Respondents had a variety of suggestions for financial support, including increasing fundable periods for all students and fellows, ensuring students who go overtime due to COVID-19 are not penalized financially, lowering the cost of tuition, and increasing financial support for students to purchase software and technology to work partially from home. Respondents also asked that specific guidelines for timeline and financial support be developed for international students and fellows. This was due to international trainees having a unique set of concerns regarding these two items related to Canada's immigration and visa policies, which could potentially change in response to COVID-19.

Grief response to COVID-19 laboratory closure

There was an underlying feeling of grief that permeated throughout survey and interview responses. Respondents lamented the data that were lost, the conferences that might have been, and how this new reality of social distancing and working from home was not something they ever expected. We used the Kübler-Ross model of grief as a lens to view respondents' reactions to the laboratory closures.

The Kübler-Ross grief construct is one of the most well-known models to describe the process of grief (Craytor and Kubler-Ross 1969). Although initially developed to describe how people process the grief that results from terminal illness and death, it has also been used to describe grief from a variety of sources, including job loss, educational reforms, and organizational change (Barger et al. 2006; Amundson and Borgen 1982; Elrod and Tippett 2002; Malone 2018). The Kübler-Ross model outlines five stages of grief: denial, anger, bargaining, depression, and acceptance. The stages described by Kübler-Ross are not a linear process, but can occur simultaneously and in any order (Craytor and Kubler-Ross 1969).

Denial is the disbelief following unexpected and shocking news, which Kübler-Ross and others posit gives individuals time to process (Craytor and Kubler-Ross 1969; Schoolfield and Orduña 1994). Anger is when frustration boils over, often due to perceived unfairness of the situation (Craytor and Kubler-Ross 1969). Bargaining focuses on what could have been done differently to change what is happening, even if nothing could have been done to prevent the situation (Craytor and Kubler-Ross 1969). Kübler-Ross described bargaining as the temporary belief that "there is a slim chance that [the person experiencing the change] may be rewarded for good behavior and be granted a wish for special services", that they will be rewarded for this behaviour and the situation will be better than anticipated (Craytor and Kubler-Ross 1969). Depression is the sense of loss that occurs when the person acknowledges the situation cannot be fixed or glossed over, replaced by a sadness that is often very private (Craytor and Kubler-Ross 1969). Acceptance is learning how to live with the new reality the person finds themselves with, finding a new equilibrium that does not have the same emotional highs and lows of the previous four stages (Craytor and Kubler-Ross 1969). Some scholars suggest hope

could be a sixth stage to the Kübler-Ross model; however, the model suggests hope is present throughout all stages of grief and simply reasserts itself during acceptance (Craytor and Kubler-Ross 1969).

Respondents were provided with a list of 37 randomized feeling words, each of which has been previously attributed to a stage of the Kübler-Ross model (Kearney 2002). They were asked if they had experienced any of these feelings during the laboratory shutdown period, while working from home, and when they thought about the future (Fig. 6). Respondents could also include other emotions they felt during these periods, which were then classified into Kübler-Ross stages based on categorization by Clapper (1991) and Kearney (2002).

Anxiousness was highly reported across all three timepoints, mirroring the symptoms of distress reported in Fig. 4 (Fig. 6A). The trend of anxiousness reflects most feeling words in the bargaining stage, showing a decrease in reporting at the second time point and increasing in the third (Fig. 6A). Conversely, depression stage feelings like "lonely", "discouraged", "depressed", or "apathetic" had higher levels of reporting while respondents were working at home compared to other

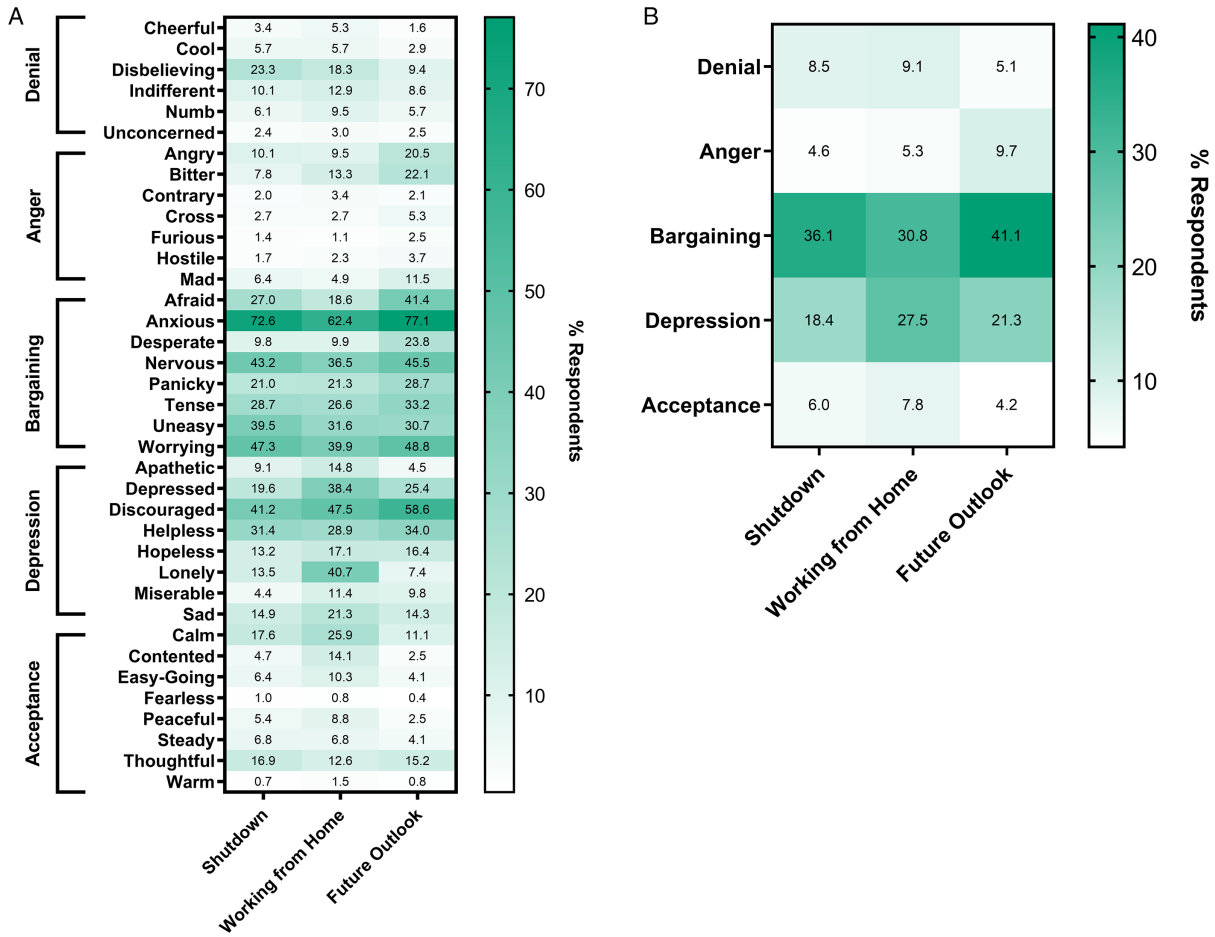

Fig. 6. Kübler-Ross analysis of emotions experienced by graduate students and postdoctoral fellows across timepoints. Percentage of respondents reporting indicated emotions during laboratory shutdown, while working from home, and when they think of the future. Categorization of emotions by the Kübler-Ross model of grief based on work by Clapper (1991). (A) Full list of emotions experienced during COVID-19. (B) Composite score of overall Kübler-Ross groupings of emotions.

time points (Fig. 6A). A similar trend was found with "calm", "contented", and "easy-going", three acceptance stage feelings (Fig. 6A). More subtle trends included the reporting levels of "disbelieving" decreasing at each subsequent time point (Fig. 6A). Three feeling words with the opposite trend were "anger", "bitterness", and "afraid" both of which saw the highest levels of reporting when respondents were asked to think of the future (Fig. 6A).

When observing Kübler-Ross stages as a whole, rather than individual feeling words, more respondents reported bargaining-associated feelings across all three timepoints (Fig. 6B). The second most-reported feeling category was depression, which saw an increase in self-reported feelings during the work from home period (Fig. 6B). The three remaining Kübler-Ross stages have more subtle variations, with overall denial decreasing, anger increasing, and acceptance having a similar trend to depression (Fig. 6B).

Although the majority of respondent data focused on negative feelings deriving from being in a pandemic, there were small undercurrents of optimism for the future within narrative responses. This overall negativity may be in part due to when respondent data was collected, three months or less following initial laboratory closures. With time and distance from the laboratory shutdown, these may grow further. As succinctly pointed out by one respondent: "I really hope it's all going to be okay" (Survey ID 265).

Discussion

In this study, we assessed the self-reported impact of the COVID-19 laboratory closures on graduate students and postdoctoral fellows. This was done through a mixed-methods research design with online survey data collected from 315 unique respondents and 18 semi-structured interviews. Some data collected were highly specific to individual respondents and laboratories, emphasizing there is no one-size-fits-all protocol for laboratory shutdown or reopening. The distinctive characteristics inherent to each laboratory across Canada will require any plans made to account for their unique context. However, some generalizations can be made, rooted in experiences, feelings, and concerns shared by respondents across the country. These findings also align with those found in a larger nationwide survey of graduate students, which included respondents of non-research based and professional programs (Toronto Science Policy Network 2020). A summary of fundamental recommendations derived from our findings are summarized in Table 8.

Respondents' experiences of initial laboratory shutdowns were, for the most part, chaotic, confusing, and abrupt. Institutional and laboratory policies changed quite rapidly, including the decision whether to close research laboratories at all. This uncertainty mainly stemmed from a lack of clear, consistent communication from administrators. The lack of consistency in policy within research institutions, as well as between institutions, left many graduate students and postdoctoral fellows feeling anxious and adrift. Much of this is understandable, as administrators themselves were reacting to an unanticipated and emerging situation for which they did not have prior experience to inform them how to proceed. However, this uncertainty was compounded as information and decisions were released, from administrators to principal investigators to graduate students and postdoctoral fellows. If similar situations arise in the future, minimizing discrepancies in messaging, as well as abrupt changes in policy, will minimize potential harms and stresses on graduate students and postdoctoral fellows.

In terms of the physical closure of the laboratory space, respondents had a clear understanding of what was required to pause their research projects in terms of preservation of data and safety procedures. When asked what they would do differently if they had to repeat the closure experience, most focused on beginning the shutdown earlier and bringing more materials home with them.

Table 8. Recommended widespread laboratory shutdown procedure guidelines.

During the initial shutdown period
• Provide clear communication regarding shutdown decisions to graduate students and postdoctoral fellows
• Ensure communications and decisions are consistent between laboratories, departments, and research institutes at the same institution, where possible
• If major differences in policy are required between research groups due to research contexts, make the reason shutdown procedures differ explicit to graduate students and postdoctoral fellows to minimize confusion
• If possible, minimize sudden changes between policies that are contradictory over short time periods. In certain emerging situations, this may not be possible. In these cases, acknowledge why this decision has been made on short notice.
• Encourage uniform laboratory closures across departments and research institutions.
• In the event staggered closures are necessary to preserve data, be explicit as to why some individuals are continuing to work when others are not. This will minimize the potential for an implied hierarchy between those with perceived high-priority and low-priority projects
• Set up remote access to laboratory servers and data for all lab members
• Distribute technology from the laboratory (computers, monitors, hard drives, etc.) when possible for laboratory members to set up their homework spaces
• Remind laboratory members to bring home more personal belongings and resources than they think they should (i.e., plan for a longer shutdown rather than a short one)
While working from home
• Encourage graduate students and postdoctoral fellows to develop and maintain a routine, as well as create a dedicated working space if possible
• Help maintain routine and personal connections through virtual one-on-one meetings, laboratory meetings, journal clubs, and other social activities
• When connecting with graduate students and postdoctoral fellows, inquire about their emotional and mental wellbeing in addition to progress on work
• Provide information about mental health and financial supports available to students and fellows
• Provide clear updates on changes in policy on returning to the laboratory or other relevant information
Facilitating the return to the laboratory
• Continue to provide information about mental health and financial supports available to students and fellows
• Be empathetic and provide moral support to students and fellows returning to the laboratory.
• Be explicit in understanding the circumstances surrounding the return to the laboratory, including reduced levels of productivity and data production compared to pre-shutdown.
• Consult laboratory members on their circumstances and build flexibility into the return to work plans to account for individual differences (for example, researchers who are responsible childcare, are immunocompromised, international researchers, etc.)
• Have one-on-one meetings with returning graduate students and postdoctoral fellows to develop a plan to restart their project. Outline specific research goals and outcomes.
• Ensure students and fellows will not be financially penalized for time lost during the laboratory shutdown, such as loss of funding for going overtime
• Have explicit guidelines as to how degree milestones and timelines will be affected by the laboratory shutdown. If changes are made to previously set guidelines before the shutdown, make these changes in consultation with students who will be affected.

These recommendations, in addition to a desire for better communication from administrators, stem from an underestimation of the gravity of the COVID-19 pandemic and how long the laboratory closure would last. Many lamented limited access to data and laboratory notebooks. One solution that some laboratories implemented was setting up remote access to laboratories resources, software, and data. Although there was a technological requirement needed to support this remote access, respondents who identified that they were able to access data remotely found it valuable. This strategy could be used by others to pre-emptively prepare for future laboratory closures.

Another factor to consider for future laboratory shutdowns is the decision to end all work at approximately the same time or allow some laboratory members to continue working during a partial shutdown. Graduate students and postdoctoral fellows who experienced uniform and staggered laboratory closures had distinct emotional responses to the shutdown. Although both groups experienced anxiety, the root of the anxiety came from different sources. For those from staggered closures, this unease came from fear of falling behind in data collection for those who were at home, and fear of putting themselves or others at risk from those who were in the lab. In contrast, respondents from uniform closures cited a realization of the seriousness of the situation as the source of their anxiety. Another key contrast is that respondents from uniform closures reported a sense of safety coming from the solidarity and unity of everyone stopping work at once, which did not occur for those with staggered closures. This suggests that a uniform approach to laboratory closures should be used whenever possible, with exceptions for certain types of experiments that take longer to pause, such as animal model research. Not only will this minimize negative outcomes for graduate students and postdoctoral fellows at the time of the closure but will also prevent a hierarchy between those with high-priority and low-priority projects from emerging in the long term.

Overall, research institutions should proactively plan for their future pandemic response, rather than have another reactive situation like that seen with COVID-19 laboratory closures. Developing official guidelines on pandemic responses, similar to other emergency situation response guidelines already in place will help promote consistency in implementation and minimize potential chaos or confusion. It will also reduce the need for abrupt changes in policy and sudden closures.

Graduate students and postdoctoral fellows reported completing a variety of activities while working from home. This included research-related activities, despite not having access to the laboratory space. Although some differences in activities were identified when respondents were divided by reported gender, all significant differences were identified between respondents in different academic positions. Differences between graduate student and postdoctoral fellow respondents in research-related activities may reflect the greater level of professional responsibility associated with postdoctoral researchers in laboratories. Understanding differences in activities being completed at home by respondents across different subpopulations can help to identify what kinds of supports to provide in the event of another widespread laboratory closure.

Unlike previous research, 66.1% of respondents believed that there was an even distribution of household labour activities. For some, this distribution was intentional, to assign tasks based on free-time availability. This was not the case for many respondents who cited gender roles around domestic tasks and caregiving as one contributing factor. This, in part, could explain some of the trends we see, as the majority of respondents did not report childcare responsibilities. The challenges of parenting while conducting research, especially for female researchers, have been previously documented in the literature and have been cited as a COVID-19-related barrier (Sallee et al. 2015; Langin 2020; Staniscuaski et al. 2020).

Although not unexpected, respondents reported high levels of distress while working from home. Compared to past Canadian data using the NCHA II distress items, a greater proportion of male and female respondents reported experiencing these symptoms of distress than reported on past surveys (**Table S6**) (Linden and Stuart 2019). Respondents are typically asked whether they experienced any of the NCHA II distress items over the past 12-month period. Our data display a trend of more frequent instances of distress over a shorter period. This aligns with the respondent reports of their own mental health and feelings of apathy being major barriers to getting work done at home. Unlike technological barriers, which for many could be solved with additional financial support to improve technology and internet connectivity, both negative mental health and loss of motivation do not have straightforward solutions. These cause long-term impacts for people, even beyond the

pandemic. There has been growing concern for lack of mental health services for graduate students and postdoctoral fellows (Tsai and Muindi 2016; Evans et al. 2018). The aftereffects of the pandemic may exacerbate this need for increased resources and professional support. Some respondents already reported seeking new or using previously established mental health supports to cope during this time. This, along with social connections with friends or family and emotional support from supervisors, paints a picture of respondents who are reaching out to a variety of sources to cope with the distress they are experiencing.

When looking at the key concerns of graduate students, many are pre-existing concerns that have been amplified by the pandemic, such as those related to research productivity and career prospects (Tsai and Muindi 2016). This is consistent with other postsecondary students across Canada, with recent data identifying that 67% of students were very or extremely concerned about their job prospects in the future (Statistics Canada 2020). Many institutions are already scaling back hiring of new academic research positions due to predicted economic uncertainty (Bodin 2020). Due to an already small prospective job pool becoming even smaller as a result of these cuts, this has increased the pressure on graduate students and postdoctoral fellows to "publish or perish". However, many are currently unable to collect data due to laboratory closures or are working at reduced capacity as laboratories slowly reopen. The pressure to perform to secure their financial and academic future has run up against the outside force of the pandemic, which they do not have control over. This lack of agency over when and how they will return to the laboratory can partially explain the high reported levels of distress, as well as the concern that this will decrease their competitiveness as a researcher.

These concerns are also reflected in the support requested from supervisors: understanding and empathy surrounding the return to the laboratory and guidance on how to best approach the return to ensure productivity. As graduate students and postdoctoral fellows are already placing internal pressure and stress on themselves following laboratory shutdowns, they do not want to receive additional external pressure from their supervisors. Instead, they want to receive emotional support from their mentor to process and cope with this stress. Respondents also want clear guidance and direction from their supervisors, thereby increasing productivity and data collection to minimize potential negative impacts respondents are predicting the laboratory closure will have on their career. Although both supports will be helpful to graduate students and postdoctoral fellows at large, the authors would also like to acknowledge that these supports will be especially important for those researchers with children. Respondents with childcare responsibilities, primarily women, were a minority in the survey data; however, they had unique challenges trying to balance full-time research and parenting responsibilities. Data have already emerged showing women have begun to publish less and start fewer new projects during the pandemic, with increased caregiving responsibilities being cited as one potential explanation (Viglione 2020). Supervisor understanding and guidance during this period will be key to minimize negative repercussions as a result of researchers with children decreasing research activities.

Other more generalizable COVID-19-related concerns reported by respondents mimic those amongst many Canadians: concerns about maintaining social connectedness, financial worries, and concerns about the health of family, friends, or oneself (LaRochelle-Côté and Uppal 2020a, 2020b). Respondents reported lower levels of concern related to personal finances (56.6%) than the total population of postsecondary students in Canada (77%) (Statistics Canada 2020). This may be partially explained by respondents receiving stipends and other continued research funding, while the postsecondary population surveyed by Statistics Canada included undergraduate students who do not have these supports. Unlike many Canadians who are struggling to cover living expenses and food costs (Daily Bread Food Bank 2020), we only had a handful of respondents cite these as major concerns. This could be in part from differences between our target population and the Canadian population

as a whole, as it has been documented that many individuals who are able to attend graduate school have pre-existing economic privileges (Mullen et al. 2003; Lee 2017). In this sense, most financial concerns were tied to long-term outcomes, such as not being able to find employment or provide for family in the future, rather than immediate concerns related to food or shelter. This is consistent with support requested from administration and universities and research institutions, asking for guarantees of long-term financial and degree timeline support to minimize these longer-term concerns.

All of this is framed in the context of the emotional response to laboratory closures. Graduate students and postdoctoral fellows were grieving, in a variety of ways, the research that might have been and the loss of the pre-COVID-19 research landscape. Most respondents reported emotions associated with bargaining and depression stages of the Kübler-Ross grief construct, which can inform ways to approach supporting this population now and during the return to laboratories. Kübler-Ross described bargaining as "an attempt to postpone" an inevitable change from occurring (Craytor and Kubler-Ross 1969). Respondents are anxious, nervous, and afraid about how the laboratory closures will impact their research careers. By making these unconscious bargains with themselves, they are still trying to negotiate a way for things to return to the way they were prior to COVID-19 (Craytor and Kubler-Ross 1969; Leybourne 2016). With depression, respondents are realizing that the change they have been bargaining to avoid, is unavoidable (Leybourne 2016). Respondents in this stage are becoming aware that the consequences of missing multiple months of research time will impact them, leaving them discouraged. Both bargaining and depression stages have been documented in the literature as being associated with respondents beginning to come to terms with the new reality post-change (Craytor and Kubler-Ross 1969; Leybourne 2016). This is a significant challenge, both cognitively and emotionally, and often results in respondents cycling between these two stages, as well as the anger stage (Leybourne 2016). This previously documented pattern is consistent with our data trends from respondents. What is known on how to support persons during these stages aligns with supports previously identified by respondents, listening to the person experiencing grief and then providing empathy and compassion (Shoolin 2010; Leybourne 2016; Oates and Maani-Fogelman 2019).

Coping and processing change events takes time. Our data suggest graduate students and postdoctoral fellows are still processing the impacts caused by COVID-19. For many junior researchers, the 2020 COVID-19 laboratory closures will be a turning point in their careers. In the coming months, the support provided by supervisors and administrators will be key in assisting graduate students and postdoctoral fellows to cope and adapt. It is important to note that supervisors and administrators may also be experiencing similar grief and stress responses to the COVID-19 pandemic. Further research into the shutdown experiences and support needed by those in more senior positions is necessary. As laboratories slowly begin to reopen, a new normal for research will be found. When this stability is established, this will allow for acceptance and hope to start growing again.

Limitations

One limitation of this study was the use of self-reported measures, which can be impacted by social desirability bias (Althubaiti 2016). We attempted to minimize this by having an anonymous data gathering tool with options to skip questions to have respondents feel secure in giving their answers. This research design choice did lead to approximately a quarter of respondents declining to provide demographic information. This lack of information must be considered when making statements about demographic trends.

We are also reliant on accurate self-reporting, as respondents may provide inaccurate information. Past research supports validity of self-reported demographic information (Celis-Morales et al. 2015). Self-reported data on emotion has been documented to change over time (Levine et al. 2009).

Thus, we launched the study as close to the beginning of laboratory shutdowns in Canada as possible to collect a snapshot of respondent emotions.

Another limitation is our respondents' sample size is relatively small compared to the potential total number of graduate students and postdoctoral fellows in Canada. In 2015, there were over 140 000 graduate students registered at Canadian Universities (Looker 2018). Of these, approximately 66 000 were registered in disciplines where laboratory research is a major component (Looker 2018). There are less data available on the number of postdoctoral fellows in Canada; however, in 2013 there was an estimated 9000 (Mitchell et al. 2013). Thus, our respondent sample represents 0.4% of this total population. This small sample size could lead to population biases in experience, such as most of the respondents were from biology or health research-based backgrounds. The geographic distribution of respondents was concentrated in Ontario and Quebec; however, these trends reflect known concentrations of graduate students across Canada (Looker 2018). These limitations due to sample size must be considered when making generalization about the Canadian laboratory-based graduate student and postdoctoral fellow population as a whole.

Additionally, the stress and increased responsibilities experienced by our target population may have led to potential respondents self-selecting to be those who have the time to participate in a qualitative research study. When applying our findings to their own unique contexts, readers should consult their graduate students and postdoctoral fellows to ensure the themes identified within this manuscript are reflective of their own experiences.

Conclusion

Overall, we have documented the experiences of Canadian graduate students and postdoctoral fellows conducting laboratory-based research during the COVID-19 research shutdown. We used the Kübler-Ross model as a lens to analyse respondents' grief and emotional response resulting from laboratory closures. We identified that unclear and inconsistent communication from supervisors and administrators led to a sense of chaos and confusion leading up to laboratory closures. The process of stopping experiments, either with uniform or staggered closures, impacted respondents' emotional response to laboratory closures. Respondents reported experiencing high levels of distress while working from home. We identified four main barriers to working from home, including technical issues, distractions in the home, decreased motivation, and worsening mental health. Five main categories of supports while working from home were also identified, including financial support, social connections, establishing and maintaining routine, mental health support, and support from supervisors or other administrative figures. Concerns regarding the impact of laboratory closures on graduate students and postdoctoral fellows were identified, particularly those concerning competitiveness of candidate and availability of future research positions. Based on concerns of graduate students and postdoctoral fellows surrounding return to in-person work, we compiled a list of support strategies to facilitate return to the laboratory including mental health and financial resource, explicit communication on safety protocols, flexibility for personal circumstances, and explicit discussions of productivity expectations including degree timelines.

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Author contributions

CS conceived and designed the study. CS and TNS performed the experiments/collected the data. CS, TNS, and KG analyzed and interpreted the data. CS contributed resources. CS, TNS, KG, and RT drafted or revised the manuscript.

Competing interests

The authors state no conflict of interest.

Supplementary materials

The following Supplementary Material is available with the article through the journal website at doi:10.1139/facets-2020-0077.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

Supplementary Material 6

Supplementary Material 7

Supplementary Material 8

Supplementary Material 9

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