

A heuristic international glimpse at SARS-CoV-2 effects on work-home equilibrium and women

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Abstract

This article takes a condensed look at the impact that SARS-CoV-2 has had on the work-life balance of women engineers across the world in industry, military and academia. The same impact has been felt by all women, not only in science, as it is this gender status that inevitably ties women together, facing the same challenges, and cannot be separated by category of employment, or lack thereof. Studies from around the world give us insight into how the pandemic has instigated changes and influenced choices made between work and domestic demands. Globally, women are burdened with challenges that may compromise their progression in male-dominated fields, such as engineering. Taking a glimpse at this issue for women through an international lens, we identify potential human factors methods to respond to this global problem, offering tools and forewarnings for improving our efforts in designing for, and maintaining equilibrium for women in engineering, technology, academia, and beyond.

KEYWORDS

COVID-19, gender, human factors, SARS-CoV-2, taskwork, women in engineering

1 | INTRODUCTION

“Women are silenced by their burdens” (McLaren et al., 2020, p. 7). Gender inequality and the compromise of the health and well-being of women, now require the attention of human factors engineers, practitioners, and researchers. With SARS-CoV-2 at the forefront of the world's challenges, many people have had to transform, redesign, and adapt to the plethora of changes it has brought. Directly impacting women, this event has only intensified women's roles at home and in the community, along with increasing challenges in the workforce. As engineers, women, and mothers, especially during this uncertain time, women are indeed forced to optimize work-home balance in an unrelenting wave of micro-decisions. The situation may

not solely be an independent gender issue as a single variable, but rather an interaction of variables, creating unique experiences within the degrees of gender divide for work and home stability during this SARS-CoV-2 event. Gains for women in science, technology, and math (STEM) are at risk, in a world they are already trying to balance (Finkel & Harvey-Smith, 2020). Several recent studies have identified challenges for women in engineering and technology fields that are intensified by the restrictions imposed from the response to SARS-CoV-2 (Kumar & Chaturvedi, 2018; Maji, 2019; Perez, 2019; Rincon & Nguyen, 2020, to name a few). Journal article submissions for women at this time are decreasing, indicating their productivity in research is being negatively affected by the crisis response (Flaherty, 2020). The increased challenges being placed on women globally,

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[Correction added after online publication on 28 May 2021: Figures has been updated.]

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observed through the intersections of themes such as health and responsibilities, may only be further compromising progression for women in engineering, an already male-dominated field. We take a glimpse at specific related issues for women through an international lens, and call for action through Human Factors tools and methods to improve our efforts in designing for, and maintaining optimal equilibrium for women in STEM fields and academia, as well as for all women globally.

1.1 | Women in engineering and science

"Pre-COVID, I was in a department with several women, the highest percentage of women of any of the engineering departments. I am now the sole female survivor..." (Rincon & Nguyen, 2020, p. 3). The Society of Women Engineers (SWE) conducted a survey of the impact of this health crisis, finding concerns for women engineers and the disproportionate impact on those underrepresented and marginalized. Potential reversal in diversity and inclusion also exist (Rincon & Nguyen, 2020). Of the nearly 1800 members responding to the SWE survey (including college students and employed professionals), 1360 members in the workforce, mechanical, electrical, and aerospace engineers represented the top fields at 36%. Among SWE respondents, dissatisfaction in work-home balance was recorded at 52% of those employed in academia and 42% in the military, more than other fields (Rincon & Nguyen, 2020). Forty-four percent of members eighteen to 24 years old, and 42% of those 35–45 years old, reflected the highest levels of dissatisfaction with work and family balance. The effects of COVID-19 have created challenges across all sectors of the engineering community in industry, military, and academia. Rincon and Nguyen (2020) also highlight that the SWE survey report found the learning ability of in-class students and visual learners to have been negatively impacted by online courses. An engineering manager stated that due to virtual interviews, hiring diversity is lacking, along with biases of already established relationships among big companies. Women in engineering and technology, who replied to the survey, also had strong concerns of their ability to find employment, if they were to be let go from their current positions. Additionally, the challenge of increasing roles is reflected in this manufacturing engineer's statement, a woman of mixed ethnicities: "I am not the primary caregiver for my parents or my partner's surviving parent, but now the grocery shopping, picking up medication, and other various errands/chores are my responsibility" (Rincon & Nguyen, 2020, p. 9).

During this health crisis, within academia, the research work of female professionals has observably decreased in productivity and journal submissions. Flaherty (2020) points out that social-distancing and the responsibilities of home and community are devouring women's research time, and many journal editors are finding unusual patterns of gender-based article submissions that are unprecedented. A deputy editor of a British science journal said she received negligible research submissions from female authors and had never seen this happen before (Flaherty, 2020).

Another journal's coeditor reported that journal submissions were up 25%, but the spike was composed by men, while the rate of female author submissions remained flat. One journal editor found article submissions from female authors up, but single-author research articles by women considerably down (Flaherty, 2020).

Other editors reported 33% of female-authored articles during the crisis, up from 25% the previous 3 years. They found a little more than their typical article submission by at least one female author at 41%, but still found the health crisis to have a negative impact on women, particularly for single-author female articles (Flaherty, 2020). During the crisis, only 8 of the 46 single-authored submissions were women, which is 17% compared against 22% of single-author articles in the entire set of data. Flaherty (2020, para. 8) quotes the editors: "As a percentage change, that's substantial. Even if women's overall submission rates are up, they seem to have less time to submit their own work than men do amid the crisis."

Women were already trying to balance home and work duties, and the decisions made in response to this pandemic took away pre-existing support systems such as childcare and workspace outside the home. One academic reports that many demands are being placed on her, such as videoconferencing availability, while also caring for a young son. She finds silence critical to focusing on her research and teaching, and the demands are resulting in less time for scientific endeavors, as reflected in her statement: "This means I have less time for writing scientific articles" (Flaherty, 2020, para 17). Some women in engineering and science, who have young children, are taking advantage of the health crisis and using it as an opportunity for research. Other women are finding themselves "paralyzed," experiencing high levels of emotional labor (Flaherty, 2020). Maji (2019) identifies the work-family conflict as a global problem, especially among women in male-dominated STEM fields, where the perceived discrimination adds extra stress and workload to adjust to the work environment.

1.2 | Task burdens

McLaren et al. (2020) highlight the challenges of the triple burden on women of productive work, reproduction and home care, and community duties. The responsibilities placed on women are only exacerbated during events such as wartime, disease, and scarcity. Even before the onset of the SARS-CoV-2 anomaly, gender burdens were strongly established. While not all women engineers are the primary caregiver in the family, they are now forced to complete many household chores that might previously have been distributed among generations of family members. Women working in mostly male fields, such as in science, are needing to spread their time and energy. The authors predict that this pandemic has, and will only continue to, increase those burdens upon women. With the virus response, and domestic violence fears of children and women being forced inside during

lockdowns with abusers, there were “grave concerns being raised for women’s wellbeing, safety and advancement” (McLaren et al., 2020, p. 3). Information from multiple sources and studies were extrapolated by Blundell et al. (2020), revealing strong inequality impacts on health, family, and employability. Data indicates an interaction of variables, as “these new fissures interact with existing inequalities along various key dimensions, including socio-economic status, education, age, gender, ethnicity and geography” (Blundell et al., 2020, p. 1). Blundell et al. (2020) also ascertain there is a high chance that the SARS-CoV-2 crisis will have lasting consequences on inequalities long into the future.

After considering STEM workforce data in Australia, Finkel and Harvey (2020) found that advances made for women in STEM are at risk from the economic effects of this health event. Their report found that full-time working women were twice as likely than men to spend over 15 h weekly on domestic work and during the pandemic, take on more childcare. There are already challenges for women in STEM as “women in STEM jobs experience significantly more barriers than men, including sexism, workplace culture, exclusion and a lack of career progression. Two-thirds of women reported having their voices devalued at work.” (Finkel & Harvey-Smith, 2020, para. 14).

McLaren et al. (2020) focused on Sri Lanka, Malaysia, Vietnam, and Australia. Research and analyses on media reports with iterative refining were conducted during the early months of the disease outbreak. They reflected increasing loads on women, particularly in “frontline work, unpaid care work and community activities.” There is a lack of better-quality health initiatives and public policy that even recognize gender and contagion outbreaks, and the multiple alarms directly resulting from this association. Just some of these concerns include discrimination, physical and mental health risks, less valued, less social support, stigma, neglect, and violence (McLaren et al., 2020). In Sri Lanka, women compose over 67% of healthcare workers who are on the frontlines and engage in intimate patient care. The female workers have experienced loss of family and community support in childcare, fear of viral transmission, discrimination, no access to markets or transportation, and evictions, all of which are intensifying and increasing gender-based responsibilities (McLaren et al., 2020). The authors also highlight that ninety percent of quarantined healthcare workers are mostly-female nurses, and services that allow them productive work have been taken away from them, increasing their burdens of transport and multiple roles.

Del Boca et al. (2020) applied empirical estimates and analysis to survey data from April 2020 on Italian women. They studied the effects of SARS-CoV-2 on caring for children, housework, and work arrangements. Results reflected an increase of housework for women (those not working at their typical place of employment) and less time spent with children (those working away from home). When compared to men, the authors found that “The link between time devoted to childcare and working arrangements is more symmetric, with both women and men spending less time with their children if

they continue to work away from home” (Del Boca et al., 2020, p. 1). Comparable results were also found for nonworking women. When analyzing “work-life balance satisfaction,” working women indicated an increase in difficulty of family and work stability during SARS-CoV-2 for those whose children were under 5 years of age (Del Boca et al., 2020).

1.3 | Lack of support systems

Continuing with the global repercussions, in the United Kingdom, large economic sectors were shut down in the name of preventing the spread of viral contagion. Blundell et al. (2020), illustrate how the impact of these decisions directly affected young women who were low-paid, as the employees of these areas were “disproportionately female.” Since the economic lockdown, mothers had higher likelihoods of being furloughed, losing their job, or having to quit. Blundell et al. (2020) found that time demands have also been placed on women, when female employment was just reaching record highs. Lack of childcare facilities due to closures and not having access to other forms of childcare have contributed to this burden. Employed single mothers with the lowest education qualifications were strongly affected, as they constitute large portions of economic sectors that were shut down (Blundell et al., 2020). Blundell et al. (2020) also found workers in the lowest 10% of weekly pay distribution seven times more likely to work in shut-down sectors, compared to workers in the highest 10% of weekly pay.

Chung et al. (2020), utilized online survey data from parents in Singapore, latent profile analyses, and linear regression to study work-home interaction, parenting, and marital congruence within the economic effects of the SARS-CoV-2 crisis. In Singapore, workplaces and schools had been shut down for a period of time, challenging parents. Work family balance profiles were created and social support levels, with 43% found as strong work family balance, 38% at moderate levels, and 19% as poor. Chung et al. (2020) reported that social support and work-family balance for mothers were found to be worse than for fathers, with mothers more likely in the poor and moderate profile levels. Poor work-family balance was connected to high stress and conflict in parenting and marriage. This intensified for parents with greater lack of social support and work-family balance. The authors stressed the importance of providing support for such parents in combating problems in work-home interaction during economic lockdowns (Chung et al., 2020).

“It seems the catchphrase of the 21st century ‘balancing work and family’ continues to ring true for Australian women today despite them achieving significant milestones over the past 100 years” (Cassells et al., 2009, p. 4). Work-family balance and gender effects from the SARS-CoV-2 health crisis within Australia were examined by Craig and Churchill (2020) utilizing a subsample taken from a national survey administered in May 2020. The authors applied *t* tests and χ^2 tests of independence to variables such as time and satisfaction. Before the health event, 84% of fathers were working full-time, while mothers were at 49%. For part-time work, fathers

were at 16% and mothers at 51%. Craig and Churchill (2020) reported that the gaps in gender narrowed during SARS-CoV-2 mainly because of employment changes for fathers. Proportion of full-time work for fathers decreased by eleven percent and for part-time work, increased eleven percent. The authors believed more work generally turned into part-time, reflecting the little change found for mothers. For mothers, as compared to fathers, paid work time decreased, while unpaid work time increased. During the lockdown, compared to before, weekly earnings of fathers reduced on average 100 dollars, and for mothers, weekly pay reduced an average of 75 dollars (Craig & Churchill, 2020). Though daily care of mothers for children went up, fathers also increased their childcare, helping to narrow a gender gap. Prepandemic, active caretaking for children was reflected at 3.41 h per day for mothers and 2.21 h per day for fathers, a 54% gender gap. Craig and Churchill (2020) found the gap reduced to 40% during the health crisis, with fatherly daily care of children at 3.64 h and motherly daily care at 5.13 h. For most parents, satisfaction in work-family balance and their partner's share of the work, deteriorated (Craig & Churchill, 2020).

2 | A CALL TO ACTION TO HUMAN FACTORS RESEARCHERS AND PRACTITIONERS

It has been shown that globally there is inequity in experience and performance outcomes for women during the SARS-CoV-2 crisis, created by a combination of an increase in domestic and caring tasks, and the reduction of support systems. Arrangements to juggle domestic, home schooling and work commitments embarked in a reactionary way to what was anticipated to be a "short-term lockdown" and could justify a "muddle through approach." A natural outcome is for the burden to fall on those actors typically associated with certain roles, or who have the most experience in the tasks in isolation (e.g., meal preparation, housework, homework with children, caring/shopping for elderly dependents). In many households this will frequently be women. When new "short-term" habits remain where lockdown is reinstated and restrictions continue long-term, the impact of inequities becomes amplified and a systematic review of how workload is distributed in the "new normal" is warranted to counter long term negative effects on the female representation in STEM roles.

Human factors and ergonomics are defined as the "science of work" and applies theory, principle, and data from relevant disciplines to the design and evaluation for tasks, jobs, products, environments and systems (IEA, 2021). The domestic work domain has been addressed only recently by Human Factors and ergonomics, primarily because the discipline grew from a focus on how to optimize performance and reduce errors in aviation control during the second world war (Chapanis, 1999), then military and defense during the cold war (Meister, 1999) and expanded into Human-Computer interaction (e.g., Card et al., 2018). However, the recent shift towards Human Factors and sustainability (Thatcher & Yeow, 2018) opens up

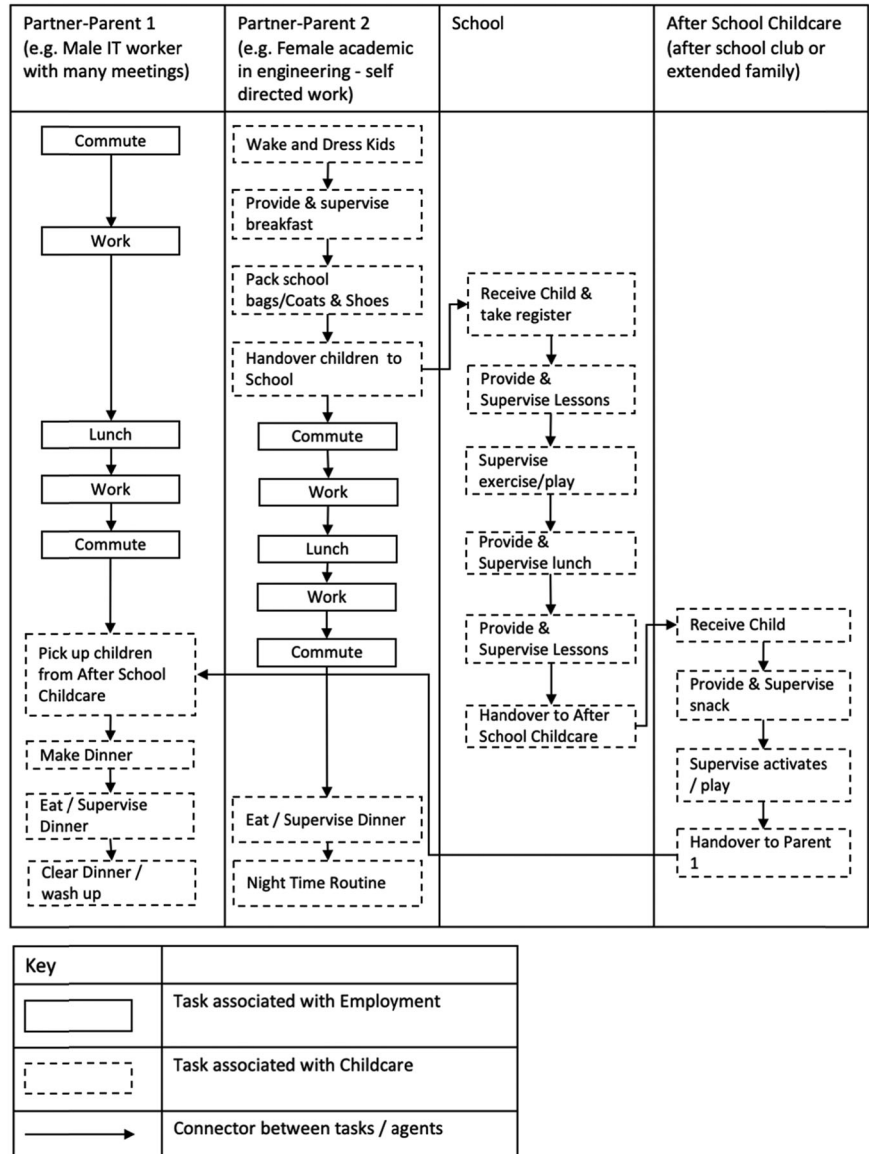
the domain for consideration of the impact on broader systems on society as a whole. Human factors methods provide design improvements for a growing at-home workforce. As human and technology interact more at home, work domain analysis complements design evaluations, and is useful in early system design processes, "including unanticipated conditions" (Naikar & Sanderson, 2001, p. 540). Home offices often include workstations that are poorly designed and can be improved through placing a pillow for lumbar support, raising a laptop for better posture, and ensuring windows are behind the monitor to avoid glare (Davis et al., 2020). Visual ergonomics in mobile technology and flexible work environments optimize the location of a device, along with display features and age specific needs (Long & Richter, 2019). However there has not been a focus on teamwork and allocation of tasks between household members within the domestic domain.

The lines between paid work and unpaid domestic work have blurred considerably during the SARS-CoV-2 crisis. The home during a pandemic has to support a number of different functions: an office for multiple organizations (if 2+ adults are in paid work); an education center (for school age children); a nursery (for preschool children); as well as its intended purpose for sleeping, eating, bathing and replenishment. The space and equipment requirements for the range of purposes are, in many households, less than optimal. The timings for tasks and activities to ensure a consistent level of performance for each of those functions requires considerable coordination and effective teamwork both within the domestic household, but also with virtual teams with the workplace and with education institutions.

Human factors methods can be applied to this structure, as this complex system is ultimately made up of teamwork and taskwork (Stanton et al., 2013). Fair distribution of tasks could reduce burdens on women in science and engineering globally, increasing productivity and satisfaction in work-home balance. Annett (2002) described human factors and ergonomics methods in terms of the dichotomy of analytic (understanding a system) and evaluative (measuring a parameter). Human factors can contribute considerably by describing the extent of the problem by fully articulating the new "system of the household" (and its virtual extensions to office and education institution) or conversely the new "system of the office" (and its virtual extensions to households). Evaluative methods can also be applied to understand workload for different members of a "work team" or "household team," for example, to help predict impact on performance in the near and long term.

A multitude of Human Factor (HF) methods exist, with proven track records in multiple domains and designed for generic application (Stanton et al., 2013). Methods to understand and decompose tasks such as Hierarchical Task Analysis, (Stanton, 2006) and could be applied to tasks novel to the pandemic (such as home schooling, SARS-CoV-2 safe shopping and distribution of resources) and can be conducted from the perspective of whether an individual, or team, is responsible for the task (Stanton et al., 2013). Human factors methods such as Operation Sequence diagrams can graphically depict the activities and interaction between teams of actors within a

FIGURE 1 Operational Event Sequence Diagram representing distribution of tasks before lockdown relating to employment, childcare and education. This depicts a fair balanced of taskload between genders



system (Kirwan & Ainsworth, 1992). These could be applied across the household and, to understand where opportunities and conflicts for effective coordination of multiple competing tasks and goals (e.g., home schooling, paid work, domestic unpaid work and additional caring tasks due to SARS-CoV-2 crisis). Coordination Demand Analysis can rate the coordination between actors (Stanton et al., 2013) both colocated in a household (sharing domestic and educational goals) and virtually with colleagues (sharing project goals). With the management of tasks from conflicting goals, mental workload could increase. Measures such as NASA TLX can be used to assess the individual mental workload of primary and secondary tasks (Stanton et al., 2013). During the SARS-CoV-2 crisis, a case could be made that where office, school and nursery combine, it is debatable which task should be considered “primary” and which “secondary” at different times of the day. The Team Workload Assessment (Bowers & Jentsch, 2005) extends this analysis to the team as a whole so could be applied in virtual work teams as well as households. Comparison of Individual and Team workload assessments between men and

women may yield comparative data on uneven distribution of domestic workload during enforced working from home.

The tools supporting virtual teamwork requires embracing technology to enable virtual communication and team collaboration. Most organizations will vary considerably in how they have embraced and trained staff to work on shared collaborative Software as a Service Systems such as cloud based drives, Google or MS Office 360 documents, and communication systems such as Teams and Zoom and for effective performance sufficient training is needed. These offerings, designed for adult professionals are now also being widely used for teaching primary school children whose lack of training and experience limit independent learning. The outcome of this can form additional burdens for parents. Human factors has a wealth to offer in terms of interface analysis methods to help re-design for different age groups that may need to rely on virtual learning and socializing for extended periods during a pandemic. Methods such as User Trials (Salvendy, 2012) and Walkthrough Analysis (Shah et al., 2009) would be appropriate to understand

where existing interfaces need to be amended for this audience group, to reduce the burden on parents and teachers alike.

Responsibility for change can occur at many levels of the system. Overarching systems such as Government or Official ergonomics organizations, at the organizational level such as academic institutions or STEM companies, at the team level such as group or project teams, and at the individual level in terms of negotiating fair distribution of tasks within the household.

The Chartered institute for Ergonomics and Human Factors (CIEHF) or International Ergonomics Association could both play a role in giving credibility to the focus on more effective and flexible task and mental workload distribution. The CIEHF provided useful infographics for setting up a home office using existing ergonomic and wellbeing advice for working from home during the pandemic (CIEHF, 2019). This type of initiative helps workers articulate and provide examples of what they need and validates this as a generic need not a “special request.” Additional guidance from either

government funded work or HF institutions is warranted for “teamwork within the home” and “virtual teamwork” with work colleagues and educational services to help project teams and household teams, now that home working, combined with caring and learning for many households, has become a long-term reality.

The authors believe that funding (either privately or through research funding bodies) needs to elevate the impact on the “domestic” as a valid focus for extensive and thorough research and recommendations, so that lessons are learnt for future pandemics or the changing nature of work post pandemic. Recognition that from an organization's perspective, the capacity of individuals within their organization varies considerably depending on their competing “secondary tasks” as “whole people” and that work projects and allocation of resource and support needs to factor this in. Projects objectives, timelines and teamwork needs to be more flexible as “one size fits all” approaches are no longer realistic. A clear depiction of this problem through HF methods would help make the case and

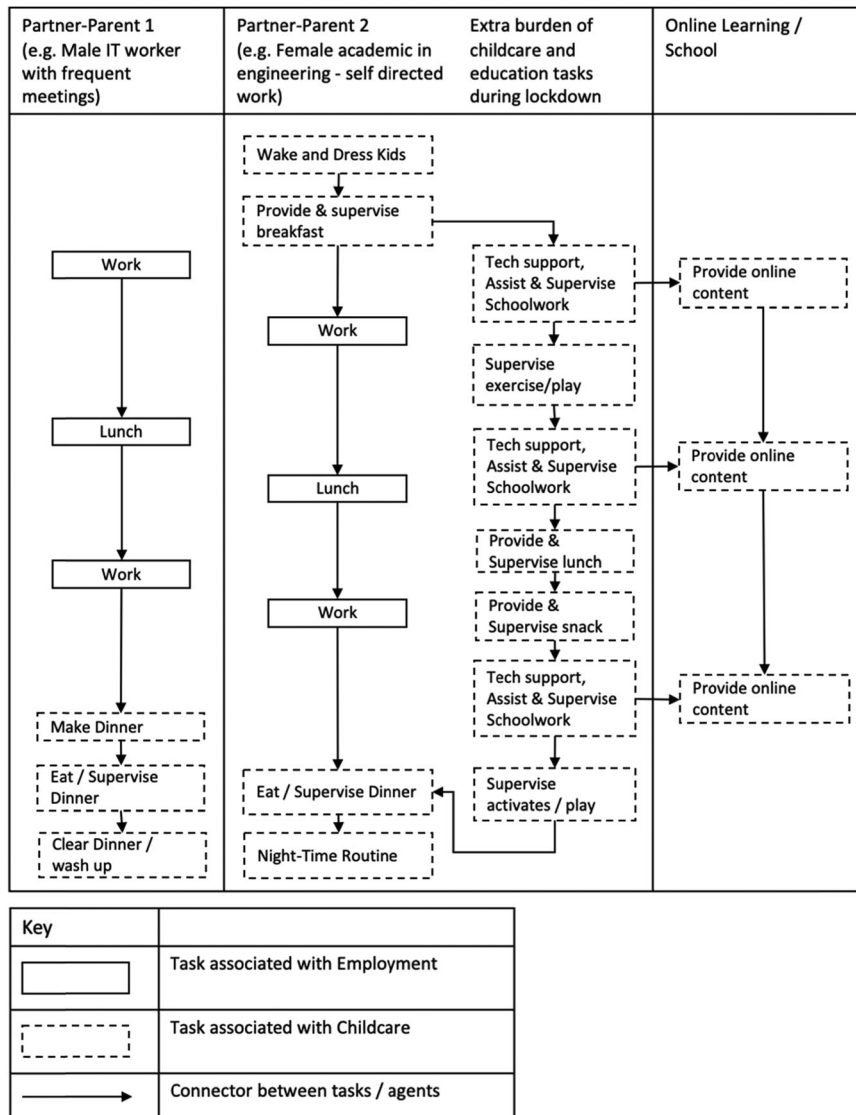


FIGURE 2 Operational Event Sequence Diagram representing distribution of tasks during lockdown relating to employment, childcare and education. This depicts how the additional tasks falling on parents due to schools and support systems closing, typically result in a far greater burden on women

highlight inherent biases that impact work performance, allowing systems to be put in place that can improve gender diversity at higher levels of STEM organizations.

An example of how representative HF methods could assist in highlighting the problem to make the case for further research is provided below in Figures 1 and 2 using Operational Sequence Diagrams. The diagram arranges the tasks allocated to different agents in parallel “swim lanes” shown by the columns. Arrow connectors depict the sequence of tasks and interactions with agents in another swimlane. Figure 1 shows a hypothetical working couple (Partner-Parent 1 and 2) with primary school children who attend a local school and after-school club. These are the four agents represented in the swim lanes and the rectangles are typical tasks falling to each agent. Figure 1 shows a typical arrangement in the UK with staggered working hours where partner-parent 1 starts and leaves work early, and partner-parent 2 other starts and leaves work late. This enables both parents to work full days and for the children to be dropped off and picked up from school/childcare (see connectors between agents in Figure 1). Here it is clear that the tasks associated with childcare (dashed-line rectangle) undertaken by Parent-Partners 1 and 3 are undertaken *in sequence* with employment related tasks (solid-line rectangle). Tasks relating to education, lunch, afternoon snack and supervised exercise and play are undertaken by the School and After-School Childcare *in parallel* to the employment related tasks with minimal interaction with Partner Parent 1 and 2 (unless sickness of an accident occurs to the child). This allows both parent-partners to be fully engaged with work tasks as their “primary” task during the work day.

Figure 2 depicts a hypothesis of how lockdown is likely to have affected a large number of women based on the literature presented previously in this paper. Systematic data collection and further research in this area is urged by the authors to test this hypothesis. Compared to Figure 1, Figure 2 shows that lockdown removed tasks relating to commuting and handovers of children between parents, school and childcare, due to the “stay at home” mandate. The nature of tasks undertaken by the school changed too with the school providing online content but no longer supervising the learning, exercise, play or lunch. With After School childcare closed and extended family initially not allowed to help with childcare, this swimlane is removed from Figure 2. The remaining tasks formally undertaken by the school and after school childcare, now fall to the parents. For primary school children both supervision and assistance of education, meals and play, require planning, monitoring and attention. In the scenario provided, the Male IT worker had a large number of online meetings at times allocated by other agents throughout the work day, making him physically remote in a home office and “unavailable” to assist or supervise schoolwork, activities or play. Conversely, the Female academic whose work day is self directed and involves analysis, thinking and writing, (rather than frequent meetings) was by default “more available” to undertake the extra burden of childcare and education tasks. With the home office occupied for online calls, partner-parent 2 was also having to

work in communal spaces at tables not setup ergonomically for computer use. Figure 2 shows the result is a considerably less equitable arrangement between genders with the childcare tasks undertaken not only in sequence but also in *parallel* with the Employment tasks of Parent-Partner 2. The parallel nature of these different tasks means this agent is having to constantly juggle two sets of incompatible “primary tasks.” This prevents clear focus of attention on employment tasks (or childcare tasks) as well as considerably increases their task load. Combined, these create the conditions for diminished performance and overwhelm, which is likely to have long-term consequences in terms of career progression and mental health. Lockdown was initially thought to be a short term measure promoting a “muddle through” response rather than a systematic reallocation of tasks. There was little understanding or guidance of how household partnerships should share the increased workload from school closures, nor an appreciation by employers of a likely inequitable impact on staff during this period.

The authors have made a clear case of the nature of the problem.

Gender inequity is a global problem prevalent across work domains, but highly biased against women in STEM industries and Academia. While progress has been made to increase female representation, the fundamental structures in those industries and academia present a strong bias towards males succeeding over females in the workplace. Strong cultural and social expectations relating to women's role in childcare domestically result in increased workload overall (employment and childcare) for women even during normal times. Lockdown has shown us how vulnerable women still are, to having their career aspirations sabotaged. Often by decisions made by male politicians without consultation with, nor consideration for, women. The rules during lockdown led to the unsustainable increase in workload on working women, with increasing childcare burdens and disappearing support systems. As lockdown has progressed, changes to task allocation within domestic partnerships have no doubt improved, but the impact on women's careers across the board, as well as in STEM may take longer to recover. The authors believe the best way forward is to see the inequitable impact lockdown has had on women as a clear symptom of a more serious problem. The systems of society need to change and HF has the tools, not only to depict the extent of the nature of the problem, but the methods to change the structures that show inherent bias. The authors urge HF practitioners, engineers, academics and policy makers to focus funding and resources on research in gender equity, so better policies can be made to create structures in the workplace and domestically that are far more robust for an uncertain future. This will allow everyone to pull together in crises without women having to make far greater sacrifices than men, something the authors are sure every reader will consider an essential goal for a fair and civilized society.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this article.

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