Envisioning Mobile Telemanipulator Robots for Long Covid

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ABSTRACT

Long Covid (LC) is a debilitating disease impacting over 65 million people worldwide. The heterogeneity, severity, and unpredictability of LC symptoms cause episodic disability, leading to widespread social isolation among People with Long Covid (PwLC). Mobile Telemanipulator Robots (MTRs) offer the potential to support the social inclusion of PwLC. However, nuanced MTR design is needed to accommodate PwLC's fluctuating needs and avoid perpetuating stigma. In this work, we engaged PwLC in a participatory design process to explore how MTRs can be designed to support them. We present design considerations, grounded in the lenses of critical disability studies and critical access studies, for accessible MTR systems to support PwLC. We plan to expand on this to develop new shared control algorithms and explore the social and ethical implications of autonomous behaviors in such MTR systems.

CCS CONCEPTS

• **Computer systems organization → Robotics**; • **Human-centered computing → Interaction design**; • **Social and professional topics → Medical technologies**.

KEYWORDS

Human robot interaction, Robotics, Healthcare robotics

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1 INTRODUCTION

Long Covid (LC) is a debilitating disease that has emerged as the largest mass-disabling event in recent history, impacting 14% of people in the United States [4, 15, 16]. LC is defined by a wide range of symptoms that are ongoing, relapsing, or new and persist for over 3 months after an acute phase of COVID-19 infection [32, 47]. Symptoms include fatigue and post-exertional malaise (PEM), which can last for days or even weeks after minimal physical or cognitive exertion [13, 20, 23, 42].

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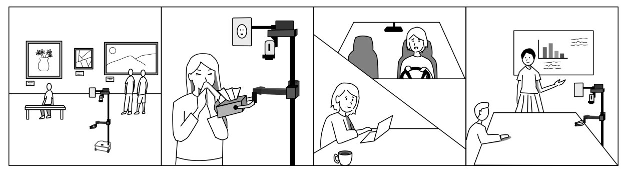

Figure 1: In our study, people with Long Covid described applications for mobile telemanipulator robots in various social contexts: (1) going to the museum, (2) supporting reinfection protection, (3) supporting pacing by reducing commute, (4) providing greater agency.

The heterogeneity and relapse-remitting nature of LC, combined with the lack of treatment options, leads to episodic disability. LC impedes PwLC's ability to engage in activities of daily living (ADLs) such as eating and bathing, and instrumental ADLs such as managing finances [15, 49]. PwLC also have difficulty maintaining social relationships and daily routines such as work or recreation [18, 46]. This social isolation adversely impacts mental health [9, 25, 45].

Telepresence robots present exciting opportunities for supporting the social inclusion of PwLC. These robots act as an extension of the operator, facilitating social connectedness and the operator's sense of presence in remote places [1, 34, 35, 50]. Mobile telemanipulator robots (MTRs) have been particularly desired as they enable operators to physically interact with the environment [1, 11, 41].

However, MTRs are difficult to control due to limited situational awareness, major multitasking requirements, low error tolerances, and lack of accessibility of control systems [12, 39]. These issues are further exacerbated for PwLC as they experience many symptoms, including cognitive impairments and reduced stamina [10].

There is limited research exploring the appropriate design of MTRs to support the remote inclusion of PwLC. Though one study highlighted the potential of assistive robots in supporting PwLC with household routines, it was not in the context of MTRs or social inclusion [40].

Additionally, people living with chronic illnesses may "internalize, experience, and anticipate stigma – social devaluation" due to their illness [17]. Experienced stigma is "direct overt experiences of discrimination," whereby individuals are treated unfairly due to their illness. Anticipated stigma is the expectation of bias or poor treatment by others [38]. Since PwLC especially experience these types of stigma while interacting with people [38, 43], there is concern that stigma will be exacerbated by MTR usage. This concern was also highlighted by Rode [41], a disabled HCI scholar.

She shared that limitations in a telepresence robot's design create a new form of disability which has its own social implications for stigma and ableism. As MTRs embody the operators, they must be carefully designed to avoid perpetuating these beliefs for an already stigmatized LC community.

Our work aims to design and develop MTRs that support the social inclusion of PwLC while safeguarding their wellbeing and mitigating stigma. We engaged PwLC in a participatory design process to understand their needs and preferences for MTR design. We grounded our findings through the lenses of critical disability studies (CDS) and critical access studies (CAS). Based on these findings, we developed a set of design considerations that lay the foundation for the development of accessible and socially acceptable MTR systems for people with chronic illnesses such as LC.

2 RELATED WORK

Telepresence Robots for People with Chronic Illnesses: Telepresence robots have been used to support the remote inclusion of people with chronic illnesses [30, 44, 50]. For example, researchers explored the use of AV1, a tabletop telepresence robot, to support students with myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS), which shares similarities to LC (e.g. fatigue and PEM) [26, 28, 48]. Though AV1 supported the prolonged and more frequent presence of ME/CFS youth in school, the effort required to use it inadvertently worsened some students' symptoms [5, 14]. Since PwLC experience many other symptoms that may impact or be impacted by MTR usage, there is a need for MTR designs that are uniquely suited to PwLC [10].

Furthermore, studies indicate that telepresence robot users are often excluded and subjected to "othering" behaviors [6, 29]. This is especially important to consider for operators with chronic illnesses and disabilities as this would reinforce the stigma they already experience. Thus, MTRs should be designed to avoid perpetuating stigma and ableism towards PwLC.

Contextualizing Chronic Illness in CDS and CAS: CDS is the intersectional analysis of the political, cultural, and historical experience of disability [19, 24]. CAS examines the values underlying common approaches to accessibility, and the means of achieving it [21]. Collective Access is one such idea which describes a collective responsibility for creating accessible spaces [22]. As PwLC face ableism and social barriers, we explore how their "critical, social, and personal position of disability" shapes MTR-mediated interactions [2].

3 OUR WORK TO DATE

As MTRs are challenging to control and can worsen symptoms, we explored how MTRs can be designed to accommodate PwLC's fluctuating needs and support long-term MTR usage. PwLC use pacing strategies to limit overexertion and avoid PEM. Pacing involves judicious management of periods of rest and activity, and has helped reduce fatigue and improve physical function in people with ME/CFS [40]. However, it can be difficult to integrate pacing strategies into MTRs due to the diversity of LC experiences which may shape PwLC's interactions with the robot.

Methodology: Given the limited research in this space, our work engaged PwLC in a participatory design process to understand how MTRs can effectively support social inclusion while safeguarding their wellbeing and mitigating stigma. We conducted a two-part online, qualitative study with 8 PwLC, and used the Stretch robot as a design probe [27]. It is a mobile manipulator with eight degrees of freedom and provides two-way audio-visual communication capabilities. We used a control interface for the Stretch created in an earlier project [34]).

In the first part of the study, participants watched two tutorial videos to familiarize them with (1) the capabilities and applications of the Stretch as a telepresence robot, and (2) the interface controls for Stretch operation. The second part involved (1) a semi-structured interview that explored PwLC's pacing strategies as well as their needs and preferences for MTRs in various social situations and (2) an ideation activity to explore how the MTR could be designed to adapt to the user's fluctuating capacities. During the interview, PwLC could operate the Stretch and experience remotely navigating, interacting with people, and engaging in a handover task with the robot. This helped shape PwLC's expectations for how the MTR could be better designed.

Three researchers independently coded the interview transcripts using Reflexive Thematic Analysis (RTA) and identified overarching themes after multiple rounds of discussions [7, 8]. We inductively and deductively developed these themes by grounding our analysis in the data and then applying theories in CDS/CAS to deepen our interpretations. Following RTA, we used the generated themes to identify important considerations for MTR design.

Results and Discussion All participants saw the utility of MTRs in supporting remote inclusion (Fig. 1). P4 shared, "I think it would be wonderful...to [go to] any of my meetings [...] to...feel like you are actually there [...] like watch a live show or watch my son play baseball...Go to museum like – It's not just the photos that I appreciate, but I really just love the sights and sounds of everything."

Remote participation in activities via MTRs also helps PwLC avoid reinfection and reduce their exertion. As P6 put it, "To use the metaphor of like, keep my battery charged [...] for things that I can't do telepresence for".

We report insights from PwLC, grounded in CDS/CAS paradigms, that are critical to the design, development, and deployment of MTRs to be used by people with chronic illnesses and disabilities. For example, we identified the need for MTRs to provide (1) adaptive pacing support to accomodate PwLC's fluctuating symptoms, (2) adjustable autonomy to support visibility and agency while minimizing exertion, and (3) social etiquette affordances for social acceptability of MTR usage.

Underlying all these ideas is the concept of "designing out stigma" [3]. It emphasizes the need to consider the social consequences of the appearance and capabilities of assistive technology and the ways they impact how disabled users navigate stigma and ableism when using them.

Our participants shared this concern for these consequences: the stigma they experienced in their lives affected how they anticipated the stigma they might experience using an MTR. This in turn affected their MTR design preferences. For example, P7 shared that they did not want MTRs to have a human-like appearance as it might further stigma, "I think that...the more human you would try

Table 1: Design Considerations for Accessible MTRs to Support PwLC.

Design Consideration	Description
Provide Control for Disability Visibility	Provide operators control over how the robot represents them and the visibility of their disability.
Social Etiquette	Support users in establishing "social etiquette" affordances on the robot.
Consider Crip Time	Robots need to adapt to operators' pacing needs while respecting their privacy concerns
Prevent Cognitive Load	Provide varying levels of abstractions to simplify robot control and reduce cognitive overload
Respect Personal Autonomy when Designing Robot Autonomy	It is important for MTRs to have adjustable autonomy to reduce cognitive load while also supporting PwLC's agency and decision making.
Robots Need to be Robust	Design to anticipate and reduce frustration with automation
Consider Infrastructure	Plan for logistics of widespread usage and robot deployment

to make it, the more it would be laughable almost. I think people would definitely parody it [...] I think people who are chronically ill are tired of not being taken seriously."

P7 also describes how the robot's behaviors could lead to negative social perceptions that may discourage MTR use: "that is a big part of [agreeing] to use [the robot...] to be your remote presence in a social activity [...] you don't want [other people] to be like, 'Oh God, Robot John['s] come in again. He's gonna knock over the tray of donuts. That's gonna be real fun. I don't understand why he can't put on a hazmat suit, just come in person."

Thus, our findings show that it is crucial to build accessible MTR systems that accommodate PwLC's fluctuating symptoms while also ensuring that they are socially acceptable. This would ultimately help to support widespread and long-term MTR usage by PwLC.

We generated design considerations for such MTR systems which lay the foundation for future work (see Table. 1). We describe the design considerations as follows:

- *Provide Control for Disability Visibility*: Due to the (in)visibility of their condition, PwLC experience stigma and want MTRs to be designed to support both disability covering and disclosure.
- *Social Etiquette*: PwLC anticipated stigma over MTR usage and expressed the need for appropriate robot behaviors and etiquette to increase social acceptance.
- *Consider Crip Time*: As PwLC experience a nonlinear flow of time, it is important for MTRs to be designed to adapt to their fluctuating access needs.
- *Prevent Cognitive Load*: Since robot control can be challenging, MTRs should be designed to reduce overexertion for PwLC.
- *Respect Personal Autonomy when Designing Robot Autonomy*: It is important for MTRs to have adjustable autonomy to support PwLC's agency and decision-making.
- *Robots Need to be Robust*: MTRs should have proper error handling and failure recovery systems without requiring substantial operator effort.
- *Consider Infrastructure*: To support widespread MTR usage, we should advocate for the creation of accessible spaces that consider physical, fiscal, and social barriers.

4 FUTURE WORK AND CONCLUSION

Moving forward, we will continue to work closely with PwLC to develop accessible MTR systems that support the social inclusion of a community that has been largely isolated and stigmatized. Our study highlights the need for a greater degree of automation to simplify robot control and reduce cognitive load, as well as adjustable autonomy to provide PwLC with a greater sense of agency over the robot's actions. Thus, we plan to explore the use of different arbitration methods such as partitioned controls or control blending of operator and robot inputs which have shown promise in various applications [31, 33, 36, 37]. We seek to develop new shared control methods for MTRs that seamlessly adapt their actions based on their comprehension of operator intentions and environmental perceptions, thereby minimizing cognitive load and frustration for PwLC.

It is also essential to explore the ethical and social implications of MTR designs for PwLC to avoid exacerbating existing inequities and fostering new ones. Social acceptability of MTRs is a major concern for PwLC. Hence, in future discussions with PwLC and other stakeholders, we will explore factors such as perceptions of prosocial/antisocial robot behaviors, and blame attribution when robots violate norms while behaving autonomously. These will serve as a basis for the establishment of social etiquette for MTRs and the design of semi-autonomous robot behaviors that are socially acceptable in the real world.

By adhering to principles of user-centered design, integrating perspectives from CDS/CAS, and considering the ethical and social implications of all aspects of our work, we aim to design accessible MTR systems that promote inclusivity for people with LC and other chronic conditions. We hope that the HRI community can draw on our work for further development of such technologies and evaluate how robot design can both contribute to and counteract the stigmatization of people with chronic illnesses and disabilities.

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