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Student at a distance: exploring the potential and prerequisites of using telepresence robots in schools

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ABSTRACT
'Homebound' children are unable to attend school for illness-related reasons. To lessen their predicament, schools have begun experimenting with 'telepresence robots' that can enable remote participation. While promising, we know little about the use of telepresence robots in practice. To begin to redress this, we draw on 159 semi-structured interviews to explore the experiences of 37 child users of the robot 'AV1' in Norwegian schools. The children's experiences varied, with some benefitting greatly and others not getting any benefit from using the robot. To explain these variations, we reconstruct the robot's *critical component structure* – that is, the assembly of sociomaterial elements that determines whether and how the robot works in practice. We also explore the benefits of using the robot when these critical components align. In so doing, we provide in-depth knowledge about the potential and prerequisites of using telepresence robots in schools – to the benefit of users, producers and scholars of telepresence technology.

KEYWORDS
Homebound children; sociomaterial networks; telepresence robots; virtual inclusion; science and technology studies

Introduction

Recent decades have seen an increased interest in 'homebound' children, who are unable to attend school because of symptoms, treatments or recovery from illness (Newhart et al., 2016). In becoming homebound, a child is 'removed from a social context that constitutes four to six hours of their daily lives' (Newhart et al., 2016, p. 9). This can lead to both educational and social setbacks, with the child becoming likely to 'fall behind in instruction, feel isolated from their peers, and experience loneliness and depression' (Newhart et al., 2016, p. 9). Policy has accordingly seen an increased emphasis on inclusive education, stressing, for instance, that 'all children have the right to be educated together, regardless of their physical, intellectual, emotional, social, linguistic or other condition' (UNESCO 1999, p. 9). Inclusion has also come to the centre of public attention during the ongoing COVID-19 pandemic, with school closures affecting more than 1.5 billion children in April 2020 (UNESCO, 2020) and unknown numbers facing long-term home schooling because of pre-existing conditions and infection risks.

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One promising development for homebound children is the recent advances in communication technologies. Infrastructural upgrades, along with new and innovative services, have significantly increased the opportunities for remote participation (Sheehy & Green, 2011). While mostly taking place outside education, there have been recent attempts to introduce technologies for 'virtual inclusion' within the school system (Newhart et al., 2016). A key example is the piloting of telepresence robots in an increasing number of schools. Telepresence robots are video conferencing devices fitted onto remote-controlled robots, allowing homebound children to communicate with peers and navigate a remote environment autonomously (Kristoffersson et al., 2013). In theory, these robots have great potential to be immersive links between the homebound child and schools. However, as research on this technology mostly comprises small-scale explorations of pilot versions within a few contexts (cf., Børsting & Culén, 2016), relatively little is known about whether and how telepresence robots work in practice.

To advance our knowledge, this article draws on 159 semi-structured interviews to explore the experiences of 37 child users of the robot AV1 in Norwegian schools. The users were homebound because of various conditions (from cancer to chronic fatigue syndrome) and used the robot in all stages of education from kindergarten to upper secondary school.[1] By combining a broad sample with an in-depth qualitative approach, this article provides the most extensive study of telepresence robots in school to date.

Telepresence robots

Telepresence robots aim to offer presence at a distance. While telepresence technologies also encompass traditional video chat solutions (e.g. Skype, Zoom), telepresence *robots* stand out by enabling users to control an anthropomorphic 'body' in a remote location (Kristoffersson et al., 2013). Such robots are used in many different settings, from schools to hospitals, office environments and assisted living facilities for the elderly (Kristoffersson et al., 2013). This study focuses on the use of the robot AV1 in school. AV1 (see Figure 1) is produced by the Norwegian start-up company *No Isolation*; released in 2016, it is meant to facilitate learning and social contact by acting as the child's 'eyes, ears and voice in the classroom' (No Isolation, 2020). As of December 2021, there are more than 1600 active robots in Norway, Sweden, the UK and ten other European countries, according to the producers.

As with other telepresence robots, AV1 connects two remote parties: in this case, a homebound child or adolescent and teachers and classmates in school. The robot is placed in the classroom; the homebound child follows the robot via an app on their phone or tablet, which enables them to see, hear and talk to those in class.

In contrast to most other telepresence robots, AV1 does not have a screen to show the remote user's face and surroundings but features instead an anonymous surface with two LED eyes. This design choice is meant to protect the homebound children who might not want to show their face, for reasons such as looking tired, being connected to tubes, or losing their hair due to chemotherapy. AV1 is also less mobile than many other telepresence robots, as it does not come with wheels; it does, however, allow the homebound child to rotate the robot's head 360 degrees horizontally and 40 degrees vertically.

Figure 1. AV1. (photo: No Isolation)

In Norway, where the present study was carried out, there are two main ways of acquiring AV1. The first is a *centralised* model, where the school (or its municipal owners) acquires a pool of robots that they distribute to those in need. At the time of writing, this model is used sparingly. More common is a *decentralised* model where it is the home-bound child's parents/guardians[2] who (1) acquire the robot and (2) try to convince their child's school to use it. In the latter model, the guardians can either buy or lease the robot with their own money or apply to a charity to borrow one for free. Given the cost of the robot (approx. £2000), the charity option is preferred by most, and it is this group of users that we focus on in this article.

As a novel technology, there is currently little research on AV1. However, a small collection of studies has explored the use of a 'high-fidelity prototype' by nine 12–16-year-olds with chronic fatigue syndrome or ME (Børsting & Culén, 2016, 2017, 2018; Culén et al., 2019). Among their key conclusions is that while 'the robot-avatar, the added work tasks for teachers and organizational issues still needs more work', 'the technology has the potential to support youth suffering from ME to access school and reduce their exposure to social isolation' (Børsting & Culén, 2016, p. 43). A similar conclusion was reached in a recent Danish study that focused on three 12–14-year-olds with cancer and found that the robot contributes to 'facilitating social interaction processes with classmates and inclusion in learning activities, reducing their sense of loneliness and lacking behind educationally' (Weibel et al., 2020, p. 988).

If we expand our scope to include other telepresence robots, the number of studies is larger, yet most have focused on robot use in office environments or hospitals (Kristoffersson et al., 2013). An important exception is the studies by Newhart and colleagues (Newhart & Olson, 2017, 2019; Newhart et al., 2016). Exploring the use of the robot VGo by five 6–16-year-olds in US schools, Newhart et al. (2016) found that the robot was valued for allowing the homebound users to stay socially connected with friends. Moreover, they found that social connection was in part premised on the anthropomorphic shape of VGo, which facilitated social acceptance from the homebound child's peers (Newhart et al., 2016). Newhart and Olson (2019) extended the sample to include 19 children aged between 5–18 years with either cancer, spinal muscular atrophy, immunodeficiency disorder, heart failure, or unintentional injury, reporting largely overlapping findings, as well as a range of recommendations for optimal use. Shifting the focus to the perspective of the school, Newhart and Olson (2017) show a range of practical challenges that complicated the use of such robots in schools, such as internet issues and scepticism from teachers. In a similar vein, a French study focused specifically on pedagogical challenges, highlighting issues such as difficulties with including the robot in classroom exercises (Gallon et al., 2019). For an in-depth discussion of these and older studies, see the review by Page et al. (2020).

In sum, these studies suggest that telepresence robots can serve as a helpful bridge between homebound students and their school, if both students and teachers manage to overcome a range of contextual barriers. However, as these are mostly small-scale pilot studies – and as some researchers have focused only on schools that are positively inclined towards telepresence robots (Newhart & Olson, 2017, p. 22), or have contributed significantly to facilitating their use (Børsting & Culén, 2016, pp. 34, 38) – there is much uncertainty about the potential and prerequisites of using telepresence robots in schools.

Theoretical perspective

To explore the potential and prerequisites of AV1, this study utilises insights from the field of science and technology studies (STS; see, Felt et al., 2016). STS views technological development and implementation as a 'nondetermined, multidirectional flux that involves constant negotiation and renegotiation' (Bijker et al., 2012, p. 7). The effects of a technology are therefore contingent and something to be determined through empirical investigation on a case-to-case basis.

Our study particularly draws inspiration from STS' insistence on studying technologies *relationally*, as part of larger *sociomaterial networks*. Within such a network, 'entities take their form and acquire their attributes as a result of their relations with other entities' (Law, 1999, p. 3). This means that the identity and effects of a technology are dependent on the technology's relationships to a range of technical, economic, organisational, political and cultural elements (MacKenzie & Wajcman, 1999); indeed, these relationships ultimately constitute what a given technology is and how it functions.

This relational view of technology is meant to combat our common tendency to 'punctualise' technology (Law, 1992); that is, treating technologies as if they 'were a single unified block or point' (Prout, 1996, p. 201). The tendency towards punctualisation is widespread in so-called 'impact' studies of technology, where 'unified blocks' are studied according to 'a billiard-ball model, in which a technological development rolls in from outside and "impacts" elements of society' (Fischer, 1992, p. 8). What this model fails to realise, according to STS, is that '[b]ehind and beyond any such point there lies a complex network which orders people and things' (Prout, 1996, p. 201). Accordingly, impact studies tend to overlook the contingency and context-dependence of technological implementation, drawing too bombastic claims about the effects of the technologies they study.

When studied relationally, the question of *whether* a technology functions is expanded to include *how, where, when* and *according to whom* – and their answers require an in-depth exploration of the technology's broader sociomaterial network. In AV1's case, this means exploring the robot's relationship to a range of other humans (e.g. teachers, healthcare workers and bureaucrats) and nonhumans (e.g. technical infrastructures, legislation and the school's timetable), which all contribute to the effects of AV1.

A problem with the network concept, however, is that of boundary and relevance – how do we delimit the range of elements that belong in (a meaningful description of) the robot's sociomaterial network? As others have shown, there are innumerable 'invisible' infrastructural aspects that need to be in place for any technology to work (Star, 1999), concerning everything from electrical standards to an agreeable atmospheric pressure. To give extensive descriptions of *all* these aspects would be practically impossible and analytically impotent. Instead, we wish to elucidate the most crucial elements of the network; those that give us the greatest understanding of why the robot is working well in some cases but poorly in others.

To distinguish the broader 'network of everything' from the more delimited web of differences that make a difference, we use the term *critical component structure*. The term refers to those parts of the sociomaterial network that are found, at times, to be misaligned, creating challenges for the users of the technology. This distinction sets focus on the analytically most vital elements and excludes not just those that are irrelevant for the functioning of the robot, but also those that are relevant but always present. Air, for instance, is necessary for the survival of AV1's users, but it is not something that is typically missing from homes or classrooms – and therefore not part of the robot's critical component structure as we define the term here. By focusing instead on crucial *and* variably present components, we ensure that our account is analytically potent and relevant – for scholars, users, producers and policy makers alike.

Data and methods

The article is based mainly on semi-structured interviews. While interviews rarely offer the same insight into local context as ethnography does (cf., Jerolmack & Khan, 2014), 'a skilled interviewer can encourage the interviewee to evoke a variety of interactional settings, social contexts, and institutional situations and can probe their meanings in ways ethnography can rarely do' (Lamont & Swidler, 2014, pp. 159–60). Moreover, the method allows for the recruitment of a relatively large number of cases, thus sensitising the researcher to multiple contexts and their relevance for the technology under study (Lamont & Swidler, 2014).

Specifically, the article draws on 159 qualitative interviews (lasting on average approx. 45 minutes); conducted between September 2018 to February 2021, they are distributed as follows:

- 69 interviews with 37 homebound children and/or their guardians
- 49 interviews with 44 school workers
- 22 interviews with 19 employees in No Isolation
- 8 interviews with 3 bureaucrats and 3 workers in non-governmental organisations
- 6 interviews with 6 healthcare workers

- 4 interviews with 12 classmates (of which three were focus group interviews)[3]

The 69 interviews with the 37 homebound children and/or their guardians are primary for this article. Twenty of these children were girls, 17 were boys; 2 were in kindergarten, 14 in primary school, 10 in secondary school and 9 in upper secondary school.[4] They used the robot for different illness-related reasons, including chronic fatigue problems (N = 14); cancer (N = 11); operation-related absences (N = 5); school avoidance (N = 2); and severe intolerances, pains or other problems that regularly kept them home from school (N = 5).

All 37 children were recruited through the Gjensidige Foundation (a private charity that lends out AV1 robots for free in Norway), through three rounds of emails. Most recruitment emails went to one of the children's guardians. For reasons of convenience and rapport, we typically started by interviewing the guardian with whom we first came into contact. Their child was sometimes present during the initial interview; if not, we tried to arrange a follow-up interview with them. In total, we were in direct contact with 17 of 37 children. While this number should ideally have been higher, not all children were interested in or able to talk to us.

Of the 69 child/guardian interviews, 58 were conducted by telephone. As methodological textbooks often deem telephone interviews unsuited for in-depth interviewing (cf., Rubin & Rubin, 1995, p. 141), we had initially planned to do only short, introductory interviews by phone.[5] However, as our interviewees responded surprisingly well to this method, we decided to expand its use. While the telephone is not conducive to certain techniques of face-to-face interviewing (e.g. being silent to encourage elaboration), we found that well-timed probing and well-prepared follow-up questions could facilitate extensive answers to our questions (as corroborated in the small literature on telephone interviewing; cf., Oltmann, 2016). And while telephone interviews inevitably entail the loss of certain data (e.g. the interviewee's body language), these limitations were more than made up for by the method's advantages. Most importantly, telephone interviews gave the interviewees great flexibility in when and where to conduct the interview, thus significantly increasing our pool of potential informants and allowing us to recruit a geographically diverse sample.

Our interview guide included questions about the homebound child's (1) background; (2) reason for acquiring AV1; (3) loneliness and social isolation; (4) experiences with implementing and using AV1; and (5) potential dilemmas and pitfalls of using the robot. To facilitate detailed, context-sensitive accounts, we mostly used 'descriptive questions' in line with Spradley's (1979) 'ethnographic interview' approach.

Our study was reported to the Norwegian Centre for Research Data (NSD) and approved in September 2018. All interviewees gave their written consent to participate in the study. To ensure confidentiality, their names and other identifying information have been made anonymous.

All interviews were transcribed verbatim. The included quotes have been translated from Norwegian, making minor grammatical and aesthetic adjustments. The transcripts were first sorted by use of 'broad brush coding' (Bazeley & Jackson, 2013) in QSR Nvivo 12, before relevant broad-brush codes were analysed using thematic analysis (Braun & Clarke, 2006). In coding and categorising data, we were interested in associations between user experiences and the context of use, paying particular attention to the differences between cases where the children felt that the robot worked or did something useful, and cases where they did not. We then theorised those associations as resulting from alignments and misalignments of elements in what we eventually called AV1's critical component structure.

Results

Our 37 child users had varying experiences with AV1. A discretionary count shows that 16 users had mainly positive experiences with the robot, 11 users had mixed experiences and 10 users had mainly negative experiences with the robot.

To account for these variations, our analysis is twofold. Firstly, we reconstruct the critical component structure of AV1 (see Figure 2) and elaborate the four categories of elements that were found to have the greatest importance to the robot's functioning, related to: 1) the child's state of health, 2) the school's approach to the robot, 3) technical aspects of implementation, and 4) the child's informal network of supporters and alliances. When these were misaligned, the robot worked poorly; when they were aligned, however, the homebound children experienced several benefits of using AV1. To elaborate the latter, we will look, secondly, at how the children describe using AV1 under these 'ideal' conditions. Together, the following sections illuminate both the prerequisites and potential of using AV1 in school.

The child

The success of AV1 depends in part on the child using it. Three elements stand out as particularly important.

Is the child 'suitably' ill?

To benefit from using AV1, we found that the homebound child had to be 'suitably' ill; that is, well enough to use the robot, but not so well that they could attend school physically. Most of our sample was located between these two extremes: Their general condition was reduced, but not so much that they were unable to look at a screen for a couple of hours at a time.

However, we found that a few children were 'too well' to use AV1, in the sense that they were able to attend school in person. These typically experienced a speedier recovery than expected, and thus saw less need for the robot than assumed. We also found that almost a quarter of our sample were too ill to use the robot. This was particularly the case for those with chronic fatigue problems; among these, seven of 14 users reported that they found the robot too energy consuming. This can partially be explained by their sensitivity towards light and other sensory impressions, and partially by their issues with internet connectivity; as one mother told us about her 15-year-old daughter: '[With ME], you become extra sensitive towards sound and touch and light and all that – and some of those crackling noises were enough to overwhelm her'. In cases like these, the robot could be of little help to its child user.

Does the child have an existing social network in school?

AV1 presupposes that the homebound child has a network of friends to stay in touch with. While this was true for most children in this study, a minority lacked such a social network, for reasons such as transferring to a new school or having been isolated for several years

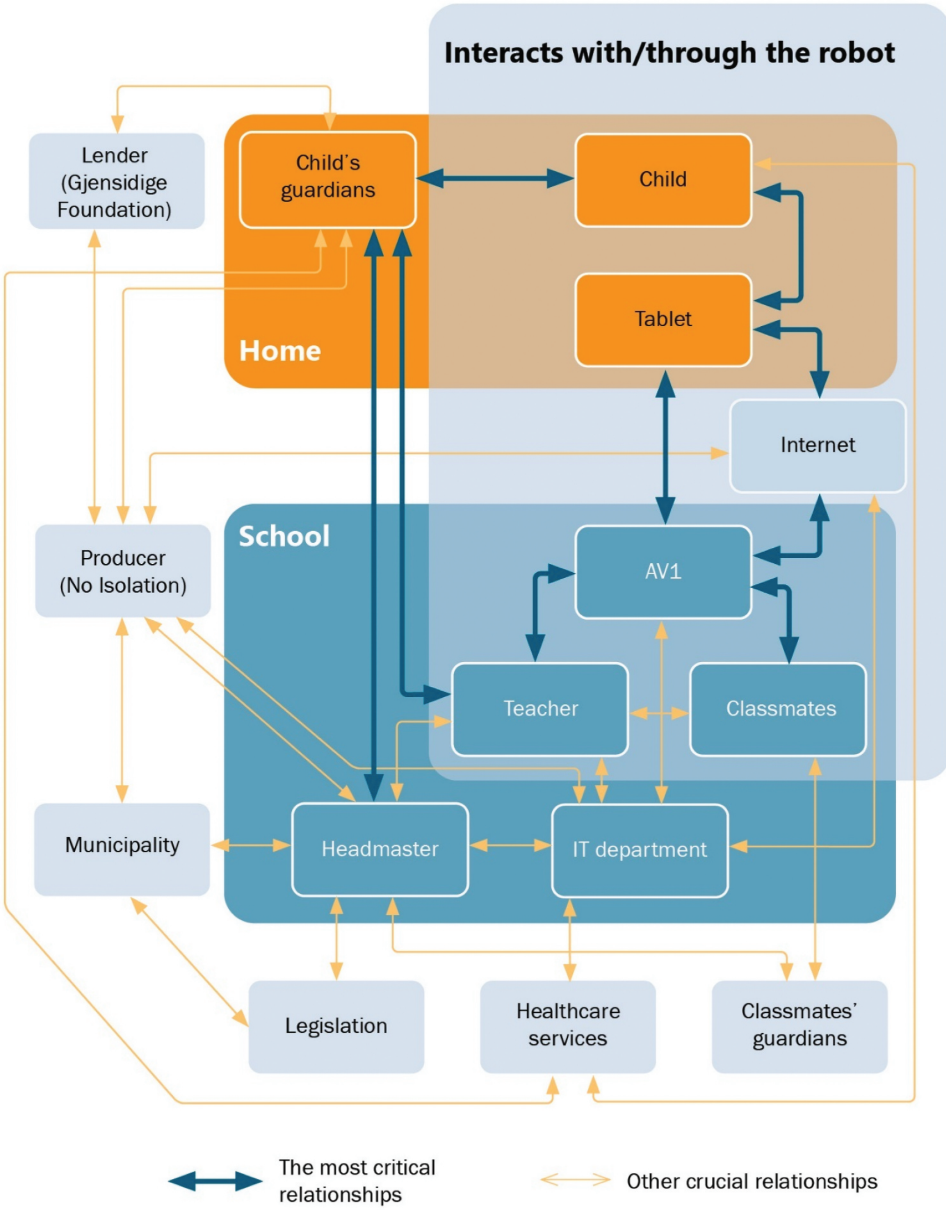

Figure 2. AV1's critical component structure. (design: Tore Gulden)

because of their illness. The children who lacked such a social network considered it weird to use the robot for social purposes, as they had no one to *re*-connect with and found it strange to make *new* friends through a robot. Lacking relationships was also claimed to complicate use for educational purposes. For instance, we interviewed an 18-year-old student who tried to use the robot in her mathematics class, where she did not know a single classmate. She said she felt like a 'surveillance camera' and that her classmates had seemed reluctant to talk to her. By contrast, when she had tried using the robot in lessons where her classmates were known, everyone seemed more at ease with her presence. This suggests that for the robot to act like the homebound child's representative, the child has to already be familiar to the class; otherwise, the robot might seem an uncanny and unwelcome presence.

Is the child comfortable with 'being' a robot?

'Being' a robot is different to being physically present in school, and this was found to generate some complications for certain homebound children. Firstly, child users across all ages told us that the robot generates a lot of interest and enthusiasm – at least in the beginning, before everyone gets used to it. While most appreciated this attention, a few homebound children felt uncomfortable with suddenly being at the centre of attention. These could, for instance, feel an uncomfortable pressure to perform whenever a classmate or the teacher talked to them.

Secondly, participation is necessarily more restricted through AV1 than in physical interaction. While most homebound children seemed not to be bothered by this (instead seeing the robot as a good alternative when physical presence was difficult or impossible), about a quarter of the children in our sample were reluctant to use AV1 because they felt that the robot only let them see what they were missing. This seemed to depend, in part, on what the child was exposed to; for instance, some considered it more difficult to use the robot in 'fun' situations than in a 'boring' maths class. Some saw this as a reason to restrict the robot to educational activities; as one mother explained, 'When [my son] is sad because he can't attend football practice, I'm reluctant to send the robot to watch all the others run around'.

The school

As implied above, schools are the primary arena for using AV1 – and not without reason, as the school is a key arena for learning and being social with friends. At the same time, schools are complex institutions with a myriad of roles, rules and regulations, posing several challenges for those wanting to use AV1 in this context.

Formal approval

Our data show great variations in how the schools view the robot. While some homebound children and guardians experienced few or no issues, others found that their schools were reluctant to allow the use of AV1. Some schools simply refused to use the robot, whereas others initiated thorough processes for legal clarification. A key question was privacy, given how AV1 transfers sound and video out of school. While some schools were reassured by the producer's privacy measures (for instance, the robot can only stream, not record, what goes on in class), there was also great uncertainty about the legal aspects of this new technology, especially in light of GDPR – the EU's *General Data Protection Regulation* – which came into force just before our data collection started. As one school worker phrased it, 'With the new Privacy Act, we have to be sceptical, almost'. And as schools are neither legally obliged nor financially incentivised to use AV1, this uncertainty posed a serious obstacle for many who wanted to use the robot.

Informal acceptance

Another issue was whether the robot was accepted informally by those in the classroom. Here, the teachers were found to play a particularly crucial role.[6] As with schools in general, some teachers were positive towards using the robot; having good relations with the homebound child and their guardians, they considered AV1 a helpful tool for social contact and learning. Other teachers, however, were more sceptical towards AV1. Some feared that the robot would be like other 'niggling' technology in school, be it confusing IT systems or failing projectors. Others feared that guardians would 'run their own course' and insist on using the robot, with little concern for all other aspects of teaching a class. Still others feared that the robot would displace existing services, such as the home tuition that schools are obliged to offer homebound children. And many were worried about the robot's virtual extension of the classroom; as a teacher in secondary school phrased it, 'When the robot enters the picture, the classroom is extended to include the student's home – and then we lose control of who is watching, or who is part of what goes on in class'.

Teachers thus saw plenty of reasons for hesitance towards using the robot. We should also add that these issues played out differently in different levels of schooling: in primary schools, the homebound child relied on a single teacher accepting the robot, whereas in higher levels, the child had more teachers to rely on or convince. And again, such details are crucial for the implementation of AV1 within each context.

Establishing routines

If granted permission to use the robot, another issue was how the robot was to be introduced and routinised in the school in question. As this was the first time most schools had tried using a robot, they started mostly from scratch in figuring out such practicalities. The responsibility typically fell on the teachers, who rarely received any formal training; instead, they had to acquire knowledge by trying, failing and 'googling'. Many teachers were found to struggle with the practical details of integrating the robot in class. For instance, they had to decide where to place the robot, how to include the robot in classroom activities and, more generally, how to best interact with this unfamiliar technology. All these questions were complicated by the robot not having a screen that shows the homebound child's face. For instance, the lack of visual feedback made it difficult for the teacher to assess how the homebound child reacted to their teaching; it also created some confusion as to whether the child was having technical issues or was simply observing, whenever the robot had been silent for some time. Thus, while this design choice was appreciated by many homebound children, it also complicated teachers' interactions with the robot.

Technical aspects

AV1 is commonly referred to as a 'simple' technology. It has a limited set of functions and presupposes little technical know-how on behalf of its users. Its simplicity notwithstanding, some technical issues need to be sorted out for the robot to function properly.

The robot

A working robot is perhaps the most obvious precondition for getting any use out of AV1. This is mostly outside the users' control, as the producers have designed AV1 as a 'black-boxed' technology and encourage limited technical tinkering from non-producers.

However, one crucial task has been delegated to the users, namely supplying the robot with power. The robot is powered by a battery that should last at least six hours in use and 12 hours in standby mode. When the battery nears empty, the quality of the video feed is drastically reduced; and if the battery is completely drained, the robot must be charged approximately two hours before functioning normally again.[7] A drained battery also precludes the robot from receiving software updates from the producers, which might create further problems down the line.

For these reasons, it is imperative that schools establish proper charging routines for the robot. While many were successful in doing so, some teachers reported issues. For instance, some used the robot too sporadically, making it difficult to establish routines. Others were unaware that the robot uses power in standby mode, and thus forgot to charge the robot before the next day of school. Some were also reluctant to charge the robot overnight, as they believed this could pose a fire hazard (in fact, the robot comes with a 'fireproof' slow charger, but no one had made the teachers aware of this). These are further examples, then, of 'mundane, but potentially prohibitive' (Greenhalgh et al., 2017, p. 5) issues with using the robot.

Internet connections

Another prerequisite for robot use is to establish working internet connections – not just to the robot, but also to the homebound child's tablet. The latter was often overlooked, in part, perhaps, because most Norwegians are assumed to have good internet connections at home. However, internet conditions vary, and some also used the robot from hospitals or other institutions with less than perfect connections.

That said, the most challenging task was typically getting the robot online in school. Firstly, the robot had to be connected to a suitable network. The robot supports both 4G and wi-fi connections, yet 4G signals were often found to be unable to penetrate the concrete walls of Norwegian schools. Many of our users thus had to log onto the school's wi-fi network – and this was found to be a surprisingly challenging task, as these networks typically have firewalls and other security measures that prevent the robot from just logging onto the network. In some cases, a network administrator had to grant access to the robot. This could be done by an IT worker at the local school level; by the municipality's IT department; or at an even higher administrative level. In the latter two scenarios, some children told us that they had waited weeks or even months before someone decided to grant their robot access to the school's network.

A second issue was whether the network quality was good enough to support live streaming. This often failed to be the case. Almost three in four child users reported problems, including issues with latency and losing one's connection. Whether such problems ruined their user experience depended, in part, on what the robot was used for. A bad stream was considered most problematic for engaging in conversation and other activities that require a high level of responsivity. One 18-year-old said she felt she was 'bothering' her friends whenever she talked to them through the robot; she had thus given up using AV1 for conversational purposes. On the other hand, internet issues were considered less serious when AV1 was used for more 'observation-friendly' activities, such as observing events or joining classmates on hikes. These were cases where the children lost little crucial information if the stream experienced some latency, and where they found value in the very fact of being able to participate, albeit in a limited sense. Nevertheless, working internet connections are crucial to AV1's functioning, and were one of the main reasons why some children were dissatisfied with the robot.

Supporters and alliances

So far, we have seen a range of obstacles that might complicate the use of AV1. A final meta-category that deserves mention, is the importance of supporters and alliances that can help with overcoming these obstacles. This proved especially important for our sample: Having borrowed a robot for free from the Gjensidige Foundation, they also had to convince their school to adopt the robot. This task usually fell on one of the homebound children's guardians, who at times found this to be a daunting prospect, especially if lacking in support. For instance, after being denied use of the robot for privacy reasons, a mother conveyed her frustration as follows:

> One of the hardest things is, like, where do you begin? Who do you call to get it approved? I mean, we've had positive responses that this might be a good thing, from the special education service and from the school and from here and there, but to what effect? Do they write statements? Must it go all the way to the Ministry of Education? Must one use other municipalities as examples? I've talked to the school office, and with privacy officials and ... Where do you start if you want to get it approved? Who do you talk to? The politicians, the school board or its administration, or ... ? I certainly haven't had the energy to keep this up.

The mother ended up returning the robot, without her daughter having ever used it. Facing the school's bureaucratic system on one's own can thus be a highly discouraging experience.

Other interviewees received greater support. For instance, many cited how teachers and principals had worked hard to clear hurdles and establish routines for the robot. Classmates were also cited as key supporters, especially at higher levels, where they could be key to coordinating the robot between different classrooms and teachers. Some also highlighted how No Isolation had helped them convince and routinise the robot in schools. This is something the producers put a premium on; as one employee explained: 'We know that the parents are in an extremely difficult situation, so we're trying, as far as we're able, to take the fight for them'. At the same time, our interviews show that many guardians were unaware that No Isolation provides this form of support. As they assumed that customer support only offered technical assistance, they could not imagine that the company could help with other aspects of the robot's implementation.

When the elements align: benefits of using AV1

So far, we have considered the critical components of AV1's sociomaterial network. This array of heterogeneous elements was often misaligned, causing mixed or negative user experiences. When they did align, however, the children reported positive experiences with the robot.

Reducing loneliness and keeping them in the loop

The homebound children who got AV1 up and running emphasised that the robot helped to reduce their feelings of loneliness. Many missed their friends, particularly during the day, when everyone was busy in school. One mother explained how the robot helped her son (16) feel that he 'wasn't all alone in this world'. Others explained how the robot broke the monotony of being homebound, and still others emphasised how using AV1 reduced their 'cravings' for social contact. Illustrating the latter, a boy (16) explained:

> Having used it, it's been easier to come to terms with being alone for a while. You've had your dosage, sort of. I can also feel that being with people is a bit exhausting too. And it's sort of nice to feel that you get a bit worn from using it. Because then it's like, 'you know what, I hadn't been able to do this anyway'.

For him, the robot served as a useful reminder that social contacts, while sick, have costs as well as rewards. As such, the robot gave him his 'fix' of social contact, while helping him avoid a romanticised notion of togetherness during his period of illness.

Our findings also suggest that AV1 can make homebound children less estranged from their school. As one of our healthcare interviewees explained, children can often experience uncertainty and anxiety after longer-term isolation; they start feeling like they are missing out and grow afraid that their friends will forget them. Many children and guardians claimed that AV1 helped counteract such feelings, as it facilitated regular interactions with teachers and classmates and thus kept them 'in the loop'. This made it easier for the homebound children to cope with isolation and helped ease the return to school once their period of illness was over.

Enabling energy-efficient interactions

AV1 was said to offer an energy-efficient form of interaction, in the sense that it enabled real-time participation without all the costs of physical copresence. Among other things, our interviewees emphasised how they saved energy by not having to travel to and from their school. The robot's lack of screen was also considered advantageous by many, as this allowed them to meet others without much preparation. As a girl (17) with cancer explained,

> I don't have to wear nice clothes, I don't have to sit upright—I can lie on the couch and look half dead, something I wouldn't have been comfortable with if they could see me all the time.

Being faceless thus reduced the need for most impression management that characterises face-to-face interaction (Goffman, 1959). Moreover, by allowing them to adjust the volume and the brightness of the screen, the robot also increased the child's control over the intensity of sensory impressions. The robot thus offered a more controllable form of participation, which enabled homebound children to interact with friends when they felt unfit for face-to-face participation.

Allowing the child to follow lessons

Of the 37 homebound children in our sample, 24 pictured using it completely or partially for educational purposes. On the one hand, their experiences were mixed. Besides the complications mentioned above (e.g. bad internet connections), many emphasised that the robot supported only certain pedagogical activities. Specifically, they argued the robot was best suited for blackboard teaching and less suited for practical lessons (e.g. physical education) or lessons with a high degree of oral participation (as these could be noisy and hard to follow).

On the other hand, many children praised the robot's qualities as an educational tool, citing the simple reason that it gave them access to classroom activities, and that following selected lessons helped them stay up to speed with and prioritise what to read before tests. This was considered particularly important for the subset of homebound children who were fully fit for education but isolated because of infection risks (e.g. those undergoing certain cancer treatments). Thus, despite its limitations, many children valued the robot also as an educational tool.

A cool and non-stigmatising assistive technology

Finally, many children complemented AV1 on its design. The robot was considered cool and modern – especially in comparison to other assistive technologies. Many were also enthusiastic about the robot's cute and friendly design. One compared AV1 to a puppy; another to a celebrity, as it was widely known from TV commercials (which were aired frequently after the robot's release in 2016). The robot was thus perceived to be a cool and desirable tool, which it was neither embarrassing nor stigmatising to use.

Discussion and concluding remarks

This study has drawn on 159 semi-structured interviews to explore the experiences of 37 child users of the robot AV1. The children had varying experiences with AV1, with some benefitting greatly, others experiencing severe challenges, and some failing to use the robot at all. To understand these variations, we reconstructed the robot's *critical component structure*; that is, the assembly of sociomaterial elements that determines whether and how the robot works in practice. Specifically, we highlighted four categories of critical components, related to: 1) the child's state of health, 2) the school's approach to the robot, 3) technical aspects of implementation, and 4) the child's informal network of supporters and alliances. While crucial for the functioning of the robot, these elements were at times misaligned, creating challenges for those seeking to use the technology. When they aligned, however, AV1 was found to produce several positive outcomes for homebound children, who complimented on how it: reduced their loneliness and kept them 'in the loop'; enabled energy-efficient interactions; allowed them to follow lessons; and served as a cool and non-stigmatising assistive technology.

Considering our theoretical perspective, it remains an open question whether and how our findings might bear on the implementation of AV1 (or other telepresence robots) in other cases and contexts. On the one hand, our findings align closely with those of previous studies, which have demonstrated the importance of elements such as internet connections (Newhart & Olson, 2019), the homebound child's health (Børsting & Culén, 2016), and teacher scepticism (Gallon et al., 2019). However, exactly how these elements matter will depend on their relationship to the other elements in the sociomaterial network in question (Law, 1992). Their 'effects' must therefore be assessed empirically on a case-by-case basis.

This insistence on 'localism' is not to say, however, that it is impossible to improve the fit between a technology and its sociomaterial network. Local variation can be reduced by what Law (2012) refers to as 'heterogeneous engineering', where various forms of knowledge (e.g. technical, sociological, economic, rhetoric) are mobilised to adapt a technology to its surroundings – and vice versa. Heterogeneous engineering is predominantly associated with the work of the producers of a technology (Law, 2012). In this respect, it is worth noting that No Isolation has released a second edition of AV1 that, among other things, should perform better under sup-optimal internet conditions. Moreover, the producers continually work on the sociomaterial network of AV1, through promotional campaigns, meetings with politicians and school officials, and attempts to adapt legislation and procure formal endorsement from government agencies. All this is likely to help 'streamline' the implementation of AV1.

Beyond the producers, there are several other agents that might also count as heterogeneous engineers. For one, we have seen how the homebound children and their families can work to align the critical components of AV1's sociomaterial network. While this can be overwhelming work, the families can fruitfully seek to establish alliances with local champions in schools, who might offer crucial help in creating a well-functioning network around the robot (see, also Greenhalgh et al., 2017). Furthermore, regional and national authorities can also work to reduce frictions in the robot's network; for instance, by upgrading the technical infrastructure and adapting legislature to the uses of AV1 in schools.

Adding to this, there are some indications that the COVID-19 pandemic might facilitate structural changes to the benefit of those using telepresence robots. For one, the widespread closing of schools has forced many teachers to establish routines for home schooling, thereby updating their knowledge and reconsidering many of their assumptions about remote participation. Moreover, as societies have gone into lockdown to prevent infection, masses of people have experienced some of the loneliness that accompanies social isolation – and how rewarding it can be to get in touch with friends, if 'only' through a video conferencing tool or by phone. Although it remains to be seen, COVID-19 might turn out to be an exogenous shock that helps level the barriers for telepresence robots in schools. This is certainly an issue for further research to explore.

Notes

1. The Norwegian school system comprises primary school (6–12-year-olds), secondary school (13–15-year-olds) and upper secondary school (16–18-year-olds). Most schools are public institutions and thus free of charge.
2. We use 'guardian' rather than 'parent' because the former is more inclusive, covering birth or adoptive parents, legal guardians, and others having responsibility for a child.
3. We also conducted eight hours of classroom observation and borrowed an AV1 to 'play around with' on our own.
4. One homebound user had finished school; the last did not tell us their age.
5. We opted to do interviews by telephone rather than use videoconferencing tools because the sociomaterial network of the telephone is more stable (this was particularly true when we began our data collection, pre-COVID-19).
6. As Figure 2 shows, healthcare workers could at times be critical components, as they occasionally give schools input on whether the robot should be used in a particular case.

7. Hardware upgrades have seen this number reduce to 30 minutes of charging.

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