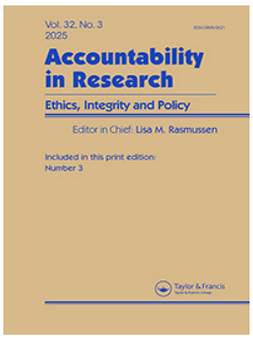

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Perceptions of network-level ethics in an engineering research center: Analysis of ethical issues & practices reported by scientific & engineering participants

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ABSTRACT

Background: Despite the rise of big-team science and multi-institutional, multidisciplinary research networks, little research has explored the unique challenges that large, distributed research networks face in ensuring the ethical and responsible conduct of research (RCR) at the network level.

Methods: This qualitative case study explored the views of the scientists, engineers, clinicians, and trainees within a large Engineering Research Center (ERC) on ethical and RCR issues arising at the network level.

Results: Semi-structured interviews of 26 ERC members were analyzed and revealed five major themes: (1) data sharing, (2) authorship or inventorship credit, (3) ethics and regulation, (4) collaboration, and (5) network leadership, norms, and policy. Interviews revealed cross-laboratory differences and disciplinary differences as sources of challenge.

Conclusions: This study illuminates ethical challenges that a large, multi-institutional research network is likely to face. Research collaboration across disciplines, laboratories, and institutions invites conflict over norms and practices. Network leadership requires anticipating, monitoring, and addressing the ethical challenges in order to ensure the network's ethical and responsible conduct of research and optimize research collaboration. Studying perceived ethical issues that arise at the meso-level of a research network is essential for understanding how to advance network ethics.

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Introduction

The rise of complex multi-institutional research networks in science and engineering poses challenges to ethics and the responsible conduct of

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research (RCR). There is extensive literature on science and engineering research ethics at the micro level (i.e., individual researchers working within research laboratories) (e.g., Institute of Medicine 2009, National Academies of Sciences, Engineering, and Medicine 2019). Similarly, at the macro-level, research addresses the societal implications of scientific and engineering advances (e.g., Foley and Gibbs 2019; Maynard 2015; Owen and Pansera 2019). However, little research has explored ethics at the intermediate meso-level, across dispersed research groups working together as a collaborative network. Indeed, the NAE (2016) report on teaching engineering ethics only addresses macro-ethics and micro-ethics. Similarly, the NASEM (2017b) report on National Science Foundation (NSF) Engineering Research Centers (ERC) emphasizes team success and macro-ethics, but not the ethical and RCR challenges faced by ERCs at the network level. Thus, this study explores how science and engineering participants in a multi-institutional ERC understand and experience network level ethics within the ERC. The central research question guiding this study was: How do members of a large, multi-institutional, and multidisciplinary engineering research center think about ethics at the network level?

Background literature

The importance of this question arises from the growth of big-team science conducted in multi-institutional networks, but the relative lack of research on the ethical challenges of conducting research in a dispersed network. Scientific and engineering research increasingly involves large, multidisciplinary teams networked across multiple institutions – what are sometimes called multiteam systems (National Research Council 2015). Such networks use different collaborative models, such as multi-institutional research centers (e.g., NSF-funded ERCs and Industry – University Cooperative Research Centers) and consortia (e.g., Horizon Europe Consortia). For example, ERCs are multidisciplinary networks that span institutions, stakeholders, and geographical sites (Jensen-Ryan et al. 2020) and pursue convergent engineering, "a deeply collaborative, team-based engineering approach for defining and solving important, complex societal problems" (National Academy of Sciences, Engineering, and Medicine 2017b, 3). As such, "[i]ndividual scientists work within a much broader system that profoundly influences the integrity of research results" (National Academies of Sciences, Engineering, and Medicine 2017a, 29).

The literature on big-team science addresses challenges faced by such networks in achieving scientific effectiveness (e.g., Hall et al. 2018; National Research Council 2015; Vogel et al. 2021). Seven team features have been reported to produce these challenges: (1) member diversity, (2) multidisciplinarity, (3) team size, (4) goal misalignment across labs, (5) changing membership, (6) being dispersed geographically, and (7) conflict arising

from task interdependence (National Research Council 2015). However, the word ethics appears only twice in the National Research Council (2015) report; indeed, the focus of the literature on team science is predominantly on effectiveness in achieving scientific goals, rather than network ethics.

The literature that does exist on research ethics and team science reveals indicators of ethics and RCR values that may be important at the network level but need further investigation. For example, National Academies of Sciences, Engineering, and Medicine (2017a) identifies risks of collaborative science, such as "miscommunication, misunderstandings, unrealistic expectations, and unresolved disputes" (p. 42). While guidance on collaboration exists (e.g., ALLEA 2023), it may not specifically address the ethical challenges arising in large networks. Other work identifies risks associated with multidisciplinary teams, including differences in ethics and RCR training, which suggests the need for joint approaches to ethics and RCR (Lee and Jabloner 2017; Mathur et al. 2019). The literature suggests the need for network policies on authorship and credit, protection of human research participants, data sharing, and reconciling ethical norms and IRBs across cooperating institutions (Bozeman and Youtie 2017; Fontanarosa, Baucher, and Flanagan 2017; Forscher et al. 2020; National Research Council 2015; Smith, Williams-Jones, Master, Larivière, Sugimoto, Paul-Hus, Shi, Diller, et al. 2020; Smith, Williams-Jones, Master, Larivière, Sugimoto, Paul-Hus, Shi, and Resnick 2020). Networks such as ERCs will face ethical issues across the full translational arc of their work, from bench science through clinical trials to commercialization.

Clearly, more work is needed to conceptualize the elements of ethics and RCR at the network level. While the existing literature offers a starting point, there is an urgent need to identify issues in network ethics, study how these are perceived by network participants, and develop tools to advance ethics and RCR at the network level.

Methods

Given the exploratory nature of the research, we used a qualitative case study approach to inductively ascertain the perspectives of network participants (Merriam 1998). The case study was conducted within a single ERC with individual members of the ERC serving as embedded units of analysis. Guided by Merriam (1998), the case study explored how members of the ERC view and experience ethics at the network level. This constructivist view of case study research explored participants' views through analysis of semi-structured interview transcripts, yielding rich descriptions that illustrate participants' understanding of ethics at the network level.

Context

This ERC is a multi-institutional team focused on the development of transformative technologies designed to preserve biological systems and extend the ability to bank and transport living materials including cells, tissues, organs, microphysiological systems, and whole organisms. The ERC includes six institutions (five Research 1 universities consisting of four public universities, one private university (American Council on Education 2025)), and one research hospital) spread across the continental U.S. The ERC consists of clinicians, scientists, and engineers, in addition to staff and faculty working on issues related to engineering workforce development, diversity and culture of inclusion, and ethics and public policy. Scientific research within the ERC is organized into three thrust areas (TAs): TA 1 focuses on biological engineering to eliminate toxicity related to the cryo-protective agents used to biopreserve biological systems, TA 2 focuses on the multi-scale thermodynamics of water to understand how to eliminate ice formation as biological systems are cooled, and TA 3 focuses on the rapid and uniform warming of the cryogenically cooled biological systems. Scientists and engineers within each TA work on one (or more) of four testbeds – cells, tissues, organs, and organisms.

Participants

All members involved in the scientific and engineering aspects of the ERC (120 at the time of this study) were invited to participate. This included principal investigators (PIs), clinicians, research scientists and engineers, technicians, postdoctoral trainees, and graduate and professional students in the sciences, engineering, and medicine. We excluded undergraduate students, as their work was more transient within the ERC. A total of 26 ERC members agreed to participate in the study, a response rate of 21.7%, which is considered acceptable in such qualitative studies (Morton et al. 2012). The participants represented the breadth of ERC membership, including participants at different career stages from five of the ERC's institutions, representing all three TAs and four testbeds (see Table 1). Note that sex, racial, and ethnic demographics are not included in Table 1 to preserve the anonymity of the study participants. The University of Minnesota IRB determined that this study met the criteria for exemption from IRB review (STUDY00019262).

Data collection

Interviews were conducted in summer 2023. Each participant completed a 30-minute semi-structured interview through Zoom. Questions were developed based on a review of the literature, with input from the project's

Table 1. Participant Demographics.

Institution						
	Institution 1	Institution 2	Institution 3	Institution 4	Institution 5	
Number of respondents	12	1	3	2	8	
Thrust Area (TA)						
	TA 1	TA 2	TA 3	Multiple	Unsure	
Number of respondents	15	2	3	5	1	
Testbed						
	Cells	Tissues	Organs	Organisms	Multiple	Unsure
Number of respondents	2	1	5	4	11	3
Role						
	Faculty	Technician	Research Staff	Post-doc	Graduate student	
Number of respondents	6	2	3	5	10	

Sex, racial, and ethnic demographics are not included to preserve the anonymity of the study participants.

external advisory board of 12 ethics experts (see Appendix for the complete semi-structured interview script). Some interviews were conducted by the lead author (G.R.) and others by a graduate student (S.R.) trained by the lead author. Interviews were recorded with permission of the participant. Transcripts were generated by Zoom, checking the recording where the Zoom transcript was ambiguous. The resulting transcripts were de-identified prior to analysis.

Data analysis

Two researchers (G.R. and S.M.W.) completed a preliminary open-ended analysis, with each researcher independently coding three random transcripts (six total). The researchers then met to discuss their preliminary coding and developed a set of eight codes, organized into 25 sub-codes (see Table A1 for details). Following this meeting, each researcher independently coded the remaining 20 transcripts (10 transcripts each), for a combined total of 26 transcripts. At a final meeting, the two researchers shared and discussed their codes and generated five themes.

One coder (G.R.) generated a preliminary findings document based on the 13 transcripts they coded, using quotes as evidence for themes and sub-themes. The other coder (S.M.W.) then did the same, based on the 13 transcripts they coded. These two authors then conferred to reconcile their categories and themes. The combined document was reviewed by the other authors and the external advisory board.

Results

Five themes resulted from the qualitative analysis of the interviews: (1) data sharing, (2) authorship or inventorship credit, (3) ethics and regulation, (4) collaboration, and (5) network leadership, norms, and policy. The results are presented by theme and include direct quotes from participants as evidence for the respective themes and sub-themes.

Data sharing

Data sharing was discussed at different levels within the network: data sharing within a research laboratory or project group (micro), data sharing between research laboratories or groups within the network (meso), and occasionally data sharing outside of the network. Within a laboratory or project, data sharing was described as open and collegial. For example, Participant 22 said, "Everyone in the group has access [to the data] on my project, rather has access to the Box folder, where I upload data like every couple of months or so."

Although participants were clear on disclosure guidelines for sharing data, protocols, or technologies outside the network, data sharing was more complicated at the network level and depended on how well-established a collaboration was between research groups. In existing collaborations where trust was established, data sharing was not described as problematic. For example, Participant 15 said, "We have that trust within our collaborators ….. if it's just to collaborators we show unpublished data and we share unpublished data." Participant 24 clarified, "[Data sharing] depends on the collaborators. If they are very close, like friends of us, we will share everything that we think is reasonable."

However, the ERC also brings together research groups without well-established collaborations; in these cases, concerns surfaced about data sharing at the meso-level. Participants' comments revealed that labs have diverse norms about data sharing. Participant 2 explained that some groups are less willing to share data than others, "We share our data very openly in the lab. There are differences I find in other labs at [Institutions A and B], they're, I think a little bit more secretive."

Some participants expressed reluctance to share data with other research groups in the network, as they were concerned about protecting a patent application or publication. For example,

> I'm thinking about how we can share data with other groups or how we can share technology with other groups. Because, you know, we are doing some cutting-edge research. So like, before the paper is published, we need to wait …. [E]verything should be confidential before we publish or file for patent. (Participant 24)

Some participants indicated a lack of trust in sharing data in case the another group might beat them to publication:

> It shouldn't be like, you know, we share our ideas before they are concrete . . . .and another lab whose approach is to wait for a publication might just be able to make use of these statements and go public, or, you know, have a manuscript ready. Then, the researcher who [first] had these ideas would later on realize, oh, it's already published. (Participant 15)

> It's like a concern, like if I send this data to you, you already have everything. You can easily repeat everything, and then publish a similar paper. So that would be a big loss . . . . (Participant 24)

With more collaborators, participants perceived more complexity in managing data sharing:

> . . . we have a lot of collaborators. So, we are trying to balance everything between them. Because sometimes, even our collaborators, they have some conflicts among themselves. So, for example, one group has some research topic, or shares very closely to another group. Then we have to handle those two groups, like how we can share proper data with them. We don't want to let them know what each other is doing right now, so that might be some conflict. (Participant 24)

While most participants expressed concerns about data sharing at the meso-level, a few participants demanded open data sharing as a condition of collaboration. For example, Participant 1 stated, "There are people like that [not willing to share data], but I would not work with someone like that too long."

Authorship or inventorship credit

Within this theme, three sub-themes were identified: (1) determining authorship, (2) conflicts in publication strategy, and (3) concerns about inventorship.

Determining authorship

Participants reported a range of laboratory approaches to authorship, from proactive decisions about authorship to deciding after the fact:

> When we start writing a manuscript, we decide upfront who is going to collaborate, like what is going to be the contribution of each author. And what is going to be like, the author list? What is it going to look like? We do that beforehand. It's purely based on the contribution. (Participant 15)

> Basically, we pretty much do the work first, and then when the data, when the results are ready, we are close to publication, we just start writing the papers. After the paper is ready the advisors will discuss the authorship. (Participant 14)

Authorship order was usually based on the level of contribution to the work. However, decisions were sometimes based on other considerations. For example, Participant 20 said, "Our default protocol is that everybody's

name goes on the work. and then the order depends on what the specific topic is . . . . My policy is that everyone's name goes on the paper."

Despite these stated norms for determining authorship, some participants described previous experiences (outside of the ERC) when authors were added even though their contributions did not reach the level of authorship. For example:

> I've been on [several] papers so far, I guess, I would say in probably half of those papers, we kind of get to the end of the process, and someone thinks, oh, so and so should be on this paper, and so it happens. (Participant 16)

Participants described different approaches to determining author order. For example, one participant indicated that authorship depended on interest and career trajectory:

> The team lead will be the first author, they'll do the majority of the writing. Then let's say there are some technicians here who want to go into PhD schools or MDs. Then they will take on kind of a secondary role in the writing, and then they'll typically be second author. Then for myself, because I want to go into industry. I'm not as interested in learning how to write a scientific paper so that I would be like third or fourth. It just kind of goes off both people's roles in the project itself, and also their interest level in what they want to do after. (Participant 17)

More common was the use of a publication's disciplinary focus to determine first authorship:

> Because the first paper, for example, focused on the success itself that's made possible by engineering innovation, [I would be the author]. The next paper could focus on more of the clinical side, so of course, [another trainee] will be the first author this time. (Participant 14)

However, another participant indicated that the cutting-edge nature of research in the ERC made authorship decisions more complex:

> The work is highly collaborative and requires important inputs from a lot of different people. So, it is sometimes difficult at the end of a project, to assign even first authorship. Because a lot of the advancements do require significant inputs from multiple different disciplines. So, it can be difficult to determine and assign, because often there are multiple leaders. . . that makes it difficult at the end, when you reach a paper to determine kind of who the lead collaborator was, and I think we oftentimes, end up with co-first authors. But . . . then there's discussion around which co-first author [should be] listed first. (Participant 19)

Conflicts in publication strategy

Participants also indicated differences in publication strategy based on disciplinary norms about the preferred type of publication (e.g., a brief communication vs. a rigorous empirical study):

> A cryobiologist, someone who is not on the engineering side may think that it's appropriate to publish something smaller, especially, I mean cryobiology does short communications and all this kind of stuff. So maybe there's a disciplinary thing there. Whereas if you're coming through the engineering PhD, it's expected that you're going to write a technically rigorous paper with a bunch of data. (Participant 16)

Differences were also noted based on the impact factor of the target journal. For example, one participant prioritized getting into print:

> I have to say, I think that science sometimes is so driven by this impact factor. And you know, I want the results disseminated. But yeah, I'm not that person who's gonna say, we could have had a higher impact paper. As long as the paper is out there, and people are interested. (Participant 1)

However, another participant noted that some researchers prioritize high-impact journal publications:

> Different researchers have different goals. They have different timelines and different ideas … . In my view, they have different ideas of what a publishable result or a good paper is. And there's this tension between - We got our result, get it out there in publication, but it's going to be a low impact paper versus sit on it for a year, build it up … into a really solid paper that we're going to take to a really good journal. I see that conflict absolutely in, very much in my work. And navigating that is going to be a little tricky, and I don't know what the answer is, but I know the conflict is there. (Participant 16)

Concerns about inventorship

While most participants discussed issues related to authorship in journals, only two mentioned inventorship and patent applications. While the ERC aims to generate technologies that will benefit society, this interview study was conducted relatively early in the life of the ERC, so participants may have been more focused on the fundamental science and engineering than securing intellectual property. As such, issues involving intellectual property and patents were seen as future rather than present challenges:

> My feeling, there'll be issues in IP in the longer run. There are never issues until anything makes money. When something starts making money, then it suddenly rises up to the top, right … . You need to do your homework well in the inventorship assessment, and you can't be giving those like you know, candy to people and please them because somebody could actually invalidate the patent - if somebody's name is included and it shouldn't be there. (Participant 2)

Ethics and Regulation

Four sub-themes emerged related to ethics and regulation: (1) ethics in disciplinary silos, (2) role of ethics in research, (3) role of regulations in research, and (4) the need to learn more about ethics.

Ethics in disciplinary silos

At the micro-level, participants described compliance with relevant guidelines in their lab, such as those governing animal research and chemical hygiene/safety. However, at the network level, ethics was discussed as being siloed by disciplinary expertise, with the engineers counting on their biology and medical partners to consider ethics. For example, Participant 6 explained, "I know that we have to learn something about the animal stuff, but we are not qualified to work directly with the animals. We are just like the instrument person." Another participant similarly stated,

> We are not too involved with [the ethical] aspects, for the simple reason that what we're doing is material science. We are not getting involved with, for instance, considerations of cell or tissue preservation. I'm aware of those discussions. I mean I go to the PI meetings. I know it's important within this project, and ethical implication of any new technology…. But my group is not directly involved with those kinds of discussions. (Participant 8)

Role of ethics in research

Some engineering-focused ERC members were unsure about the role of ethics in their work. For example, one participant stated:

> I have to be honest, before [ERC name], I didn't think much about ethics. As a scientist I like to believe whatever I do is good for the benefit of society, I don't have any bad intentions, so it can't be bad. But now I understand that there might be some unintended consequences to the work we do. (Participant 3)

Even when a participant recognized the societal impact of their work, it did not impact research decisions:

> Part of the reason that I chose to work on this project is that I do think it has a societal impact, which is very important. But you know, how much does it guide individual daily decision making like you know, at a granular level? Probably not so much. (Participant 10)

Role of regulations in research

Even in research on biomedical applications, FDA regulations and issues were not much discussed:

> We are not that close to putting things into a human being. So, we don't have a lot of FDA discussions at this point … it should probably get much more intensive after [ERC] renewal. We started large animal work, which is, you know, the step before we start putting things into humans. So, the FDA thing is going to become a bigger issue. (Participant 2)

Indeed, Participant 2 went on to argue that existing regulations should not stifle creativity:

> Let's worry about the science of it, and not worry about the FDA issues … We think about [FDA regulations], but you also want to be careful … you don't want to limit good ideas, because something is gonna be, you know, you have to kind of make sure you don't kill creativity by rules and regulations. (Participant 2)

In contrast, others did not want to waste time pursuing a research direction that could be blocked due to regulatory issues:

> But then, [a PI] proposed that, oh, this particle's performance is good, but maybe raises some concerns by the toxicity part. So maybe the NIH or like the government won't agree with that. So, this is the part that I think there will be kind of the bottom line. (Participant 5)

Only three participants were anticipating the need to ensure that relevant policies and regulations were in place ahead of technological innovation. As one participant noted,

> You hope that if you comply with regulation, then you're snapping yourself into an existing ethical framework that lets you avoid thinking hard about it, and that's not necessarily true … . my sense from talking to people is that in some regards the regulations simply aren't there right now. (Participant 16)

Another participant addressed the need to engage with organ procurement and allocation policy:

> As we start to think about the ability of the technology to cryopreserve organs, there's great disparity in the organ transplant world with minority populations not receiving, you know, organs in the way that other populations do. So, as we engage [we need to consider] how organ procurement and cryopreservation could help that situation, improve that situation, or how it could potentially worsen that situation. (Participant 25)

Need to learn more about ethics

While many participants struggled to articulate the role of ethics beyond the micro-level, they recognized the importance of and the need to learn more about ethics:

> In [the ethics] area we're literally five-year-olds, because … we don't absolutely understand the importance of it. We know what ethical engineering work looks like in our lab space, but in terms of the policies in terms of broader implications globally, I think we're still a bit lost. (Participant 11)

> I'm not an expert in ethics. I'm still learning a lot. I learned more about all of this honestly after working in [the ERC] … we need to understand more of the ethics and public policy part of things. (Participant 15)

Collaboration

Participants described a variety of group meetings – project-specific, entire research group, and meetings between collaborating groups. At this early stage of the ERC, network-level meetings were generally idea-driven without specific collaborations forming:

> Materially, there has not been any like real collaboration. There's a lot of prospective future collaboration people saying like, oh, once I get to this point, then it would be helpful. Or if you can design something that looks like this, it would be helpful. So, the extent to which I've collaborated is mostly just having a lot of conversations … but no material results yet. (Participant 10)

New collaborations were just starting to form. Many participants talked about the process of getting to know each other and generating the trust needed to further the collaboration. While expertise was part of the decision to collaborate, participants placed a heavier emphasis on liking their potential partners:

> We just recently started [a new collaboration] … . They came and saw our lab space. So, it's kind of still more like we're getting to know each other. … We're still figuring it out. (Participant 4)

> For collaborations to continue I think usually you really have to like the people. It can't just be expertise that you're looking for, you need to have a friendship also. So that requires some effort to put in right. You have to give some of yourself and expect reciprocation … but it takes time to build that productive relationship. (Participant 3)

Participant 2 went as far to compare their research group to a family: "We work like family. We live like a family. We just do things together, and different people lead different parts. It's a much more collaborative, internal structure."

Network leadership, norms, and policy

Most participants talked about data sharing and publication strategies at the lab level or within the confines of an existing collaboration between two labs. However, some participants articulated the need for center-wide policies related to data sharing and publication strategy:

> It would be good for us to get an understanding as a center for when we should share data. The timeframe should be similar for all the labs, it shouldn't happen that some labs are more upfront about data sharing. They go and share it faster and it kind of puts them at back. So, I think a timeline, a unified timeline for each lab would be a good measure for disclosures within. [the ERC] (Participant 15)

> I hesitate to add another requirement, but it feels like there should be some sort of a stop and check where it's like, okay, let's have a quick look at why these people

> are authors, or you know what's your research plan, or what? . . . . If there's some resource in [the ERC] to help with that, maybe I don't know quite what the answer is, or a checklist even. You know something as simple as that. (Participant 16)

Another area where participants expressed a need for center-wide direction was learning more about ethics and its application to the network's research. As noted earlier, participants recognized the need to learn more about ethics. However, as noted by one participant, participation in the ERC's ethics seminars was limited, an issue that needed to be addressed at the center leadership level.

> I've joined a few of the ethics seminars . . . and I don't really see a lot of participation, either from faculty or trainees. I think you know we're all very busy and don't have time, but I don't think it's a priority for people to make time for those events. I don't know what would, or what could change to make it a priority. But that's just something that I've witnessed, I don't think the general populace is making a huge effort towards the ethics pillar of. [the ERC] (Participant 23)

Discussion

Data sharing

Network-level concerns expressed by our participants about sharing data with other research groups within the ERC were related to trust. Our findings align with Cragin et al. (2010) who noted that almost half of the researchers they interviewed strictly limited sharing any data before publication or embargo to "known and trusted individuals who were either immediate collaborators or known associates" (p. 4031). Similarly, Wu and Worrall (2019) reported that sharing data prior to publication outside the immediate project team was limited to friends or colleagues in whom the researchers had trust. Trust was a significant concern for our participants as they started to interact with new researchers and tentatively forge new collaborations.

Barriers to data sharing reported in the literature include concerns over data quality, potential misuse, losing a competitive advantage, protecting future publications, and data ownership (e.g., Bertzky and Stoll-Kleemann 2009; Foster and Sharp 2007; Zuiderwijk et al. 2020). These concerns impact researchers' willingness not only to share data openly after publication but also within research networks. Our participants did not express concerns about the quality of data being produced by other ERC labs, rather they were concerned about how other labs would use their data and potentially beat them to publication. Like scientists in other studies (e.g., Cragin et al. 2010; Wu and Worrall 2019), our participants shared stories about misuse of data leading to loss of publication that impacted their willingness to share, even within the ERC. Interestingly, these stories did not have to be firsthand –

junior members of the ERC used stories they had heard from their PI or other senior members as cautionary tales related to data sharing.

Authorship

Authorship serves as the basis for career advancement in science (Babor, Morisano, and Noel 2017; Smith, Williams-Jones, Master, Larivière, Sugimoto, Paul-Hus, Shi, Diller, et al. 2020), thus, it is not surprising that our participants articulated authorship concerns. Structures and processes for assigning credit for publications can become problematic in large, collaborative teams (Petersen, Pavlidis, and Semendeferi 2014; Smith, Williams-Jones, Master, Larivière, Sugimoto, Paul-Hus, Shi, Diller, et al. 2020). Indeed, research indicates that as team size increases, so does the difficulty in assigning first and corresponding authorship (Dance 2012). Interestingly, only one participant in our study expressed such difficulty had arisen in their ERC work. However, as new collaborations emerge in the network, issues with navigating authorship will likely increase.

Current practices within the ERC include generating multiple different publications with different disciplinary foci, allowing a range of collaborating authors to function as first author. This practice is common in collaborative teams to avoid conflict about first authorship (Chen 2011). However, Chen (2011) cautions that one significant paper could be "more impactful in the field than several minor papers" (p. 425). Indeed, publication strategy was a concern raised by some of our participants.

We found a range of authorship norms across the ERC, as others have observed in research on multidisciplinary research networks (Petersen, Pavlidis, and Semendeferi 2014; Smith and Williams-Jones 2012). Research also suggests that multidisciplinary teams are less likely to adhere to authorship guidelines (Malički et al. 2012) with a tendency to be overly liberal in distributing authorship (Elliott et al. 2017), in part because it is difficult to determine and discriminate the efforts of individual researchers (Petersen, Pavlidis, and Semendeferi 2014) but also because researchers fear and avoid authorship discussions (Smith, Williams-Jones, Master, Larivière, Sugimoto, Paul-Hus, Shi, Diller, et al. 2020). The issues described by our participants clearly indicate that the ethics of authorship cannot be ignored, and that leadership is needed to establish norms and practices that bridge the different disciplines within the ERC. Leadership is also important to align authorship practices with established ethical standards and journal expectations, such as conformance with the standards of the (International Committee of Medical Journal Editors 2025) and use of the CRediT taxonomy (NISO 2025). Without leadership and guidance on these ethical issues, an ERC or other large multidisciplinary network will struggle to conform consistently with

established ethical norms and agree on network-wide standards that can help realize the true potential of research collaboration across teams.

Collaboration

As noted by our participants, once trust was established in a collaboration across research groups, data sharing and authorship became less problematic. Indeed, a common sentiment was that a collaboration was about more than assembling the necessary expertise, rather it was important to "like the people" on the team. However, research indicates this inclination to work with "like-minded" people has benefits and drawbacks (Smith, Williams-Jones, Master, Larivière, Sugimoto, Paul-Hus, Shi, Diller, et al. 2020). The creation of teams that work well together avoids the negative consequences of conflict about issues such as data sharing and authorship, but could lead to detrimental impacts on team diversity and innovation if ideas are not shared and debated (Packer 2009; Smith, Williams-Jones, Master, Larivière, Sugimoto, Paul-Hus, Shi, Diller, et al. 2020).

Ethics and Regulation

It was evident from our participants that ethics conversations were not a routine part of research dialogue and decisions. However, the literature indicates that better ethical decision making occurs when teams "communicate frequently about the downstream consequences of their decisions" and "consult with others (including knowledgeable external stakeholders) about potential courses of action" (Watts et al. 2024, 5). While a few of our participants indicated a need for more training on ethics, most simply did not mention ethics beyond expectations at the disciplinary or individual laboratory level. In addition, our participants reported deferring on ethics issues to those on the biological side of the research, creating a more homogeneous perspective on ethics than if all researchers participated. Deferring or outsourcing one's personal responsibility for ethical decisions to others can lead to decision bias which degrades team ethical decision making (Medeiros et al. 2014; Watts et al. 2024).

Role of ERC leadership

Our participants indicated the desire for network leadership to create policy to address and mitigate ethical concerns within the network. Leadership needs to advance ethical conduct of research within the network; ensure appropriate mechanisms to resolve disputes when they cross laboratories, institutions, and disciplines; and prevent new conflicts. However, given the range of norms related to issues such as

authorship and data sharing, norms which are often deeply ingrained within the collaborating disciplines, formulating a single policy may prove difficult. However, leadership needs to model routine attention to ethics and RCR (Antes, Mart, and DuBois 2016; Mathur et al. 2019; Watts et al. 2024) to build a network culture and set of practices that prioritize the ethical and responsible conduct of research.

While research suggests that the presence of an "ethical champion" is important to promote ethical awareness and communication (Chen, Treviño, and Humphrey 2020; Watts et al. 2024), in a large network, the role of ethical champion cannot fall only to ERC leadership. Indeed, Watts et al. (2024) suggest training for all researchers as a mechanism to routinize ethical communication, for example by "incorporating everyday scripts around ethics into research meetings on a regular basis" (p.18).

Conclusions

Research ethics has historically been studied from a micro (individual researchers or labs) or macro (social impact) perspective (Miller et al. 2018; Watts et al. 2024), with limited analysis at the network level (Miller et al. 2018; Zhu et al. 2014). This study provides insights into network ethics as perceived by scientific and engineering participants. Their perceptions cluster around the themes of (1) data sharing, (2) authorship or inventorship credit, (3) ethics and regulation, (4) collaboration, and (5) network leadership, norms, and policy. Interestingly, core elements of RCR such as accurate and honest accounting of observations and scientific rigor and reproducibility did not emerge as themes. Participants were relatively confident about appropriate attention to RCR and ethics at the micro-level, particularly within their research lab. The major concern arising at the meso-level was the creation of an environment that promotes data security/safety and fair attribution of credit for the ideas/results.

Ultimately, ERC members look to center leadership to provide an organizational structure that promotes trust and collaboration. A large, multidisciplinary research network relies on effective collaborations. As indicated by our participants and the research literature (Cragin et al. 2010; Wu and Worrall 2019; Zuiderwijk et al. 2020), trust is central. It is clear that as participants in our ERC forge new collaborations, there is an important role for ERC leadership in establishing center-wide policies around data sharing and authorship that "lay the groundwork to allow team members to build the mutual trust that is necessary for collaboration" (Forscher et al. 2020, 14).

Limitations and future research

While the qualitative nature of our study within one multi-institutional research network cannot yield generalizable results, the resulting themes provide a strong starting point for future studies of research ethics and RCR in complex research networks. Our study shows that interviewing research network participants can illuminate the perceived ethical issues, while suggesting gaps in attention to network ethics. Investigating perceived issues in other research networks can provide further data to inform development of network ethics. Studying multiple research networks and using that research to build understanding of network ethics is a crucial next step.

Given the central role of trust in the success of team science, future research should consider the possible development of measures that can assess the presence and effectiveness of meso-level approaches to ethics and to collaborations within a network. For the reality of big-team science to live up to its potential, it will be essential to understand the role of network leadership in promoting and monitoring ethics and collaborations at the network level.

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Appendix

Interviewer Script for NetEthics Study 2 – Semi-structured Interviews

You should have received by e-mail an information sheet about this study. Did you get that? Do you have any questions about the purpose of the study or study procedures?

We would like to record the interview to help us to accurately document your answers. Only myself and my GRA will have access to the recording and once we have an accurate transcript, the recording will be deleted. Do I have your permission to record? [Turn on recording]

For the record, do I have your consent to participate in the study and permission to record?

[IF YES] Thank you for agreeing to be interviewed. As a reminder NetEthics is an NSF-funded grant that is exploring ethics and Responsible Conduct of Research (RCR) issues arising in engineering research networks, such as ERC, and values important for addressing them. We are particularly interested in issues arising at the network level, across the ERC and involving investigators from multiple labs, disciplines, and institutions. We want to learn about the issues you have experienced or challenges that have been successfully addressed across the network and what might be important for addressing these issues.

None of your responses will be attributed directly to you and only two social science researchers from NetEthics (Dr. Gillian Roehrig and her graduate research assistant) will know who has been interviewed. Dr. Roehrig and her GRA will generate a written transcript of the interview with any identifiers removed and then will destroy the recording. Only the five NetEthics PIs and their research staff will have access to the transcript, we will not share the de-identified transcript with your PI or any within your lab or ERC.

Do you have any questions before we start the interview?

(1) To start, let me confirm what thrust area(s) and test bed(s) you work with in ERC.
(2) Can you briefly share what you are working on, your elevator pitch for your research projects?
(3) As part of this research do you work with researchers in other ERC labs? Can you tell me about the nature of this collaboration? [listen for issues related to data management, assigning credit, and managing conflict – if necessary, probe for these issues. For example, how is authorship decided for collaborative papers or patents? What are procedures for sharing data across labs? How are conflicts resolved?]
(4) What are the consequences and outcomes of your research? [Possible probes depending on the nature of their research: Do you consider it ethical to utilize research animals during your work?[Probe if there are specific aspects they are uncomfortable with.] Do you consider it ethical to use human tissues or data during your work? [Probe if there are specific aspects they are uncomfortable with.] Do you have concerns about the current or potential hazardous nature of the materials or equipment you use? [Probe if there are specific aspects they are uncomfortable with.]
(5) What kinds of conversations do you have with your collaborators and team about the implications of your work? [Probe for any specific conversations with collaborators related to ethics and RCR, make sure they provide explicit examples.]
(6) [Based on the responses to the questions above, we will follow up specific issues not addressed by the participant]. Another potential issue we are curious about is [culture of ethics, positive interactions, assigning credit, data management, culture of research

excellence, societal impact]. Is this an issue that you have experienced or thought about? Do you see this as a challenge or issue in your work with ERC or something that is handled positively?

[**Culture of ethics** – Navigating disciplinary, lab, and institutional differences in RCR, ethics, including differences in managing conflicts of interest

Positive interactions – Building positive interactions within the network, climate is respectful and inclusive.

Assigning credit – ensuring responsible and harmonize approaches to authorship, inventorship, and equity ownership across the network

Data management – ensuring responsible and harmonized data collection practices, data quality control, data sharing, and data security across the network

Culture of research excellence – Creating a culture of research excellence, while deterring research misconduct and detrimental research practices

Societal impact – Ensuring positive societal impact and building meaningful stakeholder engagement]

(1) Is there anything else related to research ethics and RCR at the network level that you would like to tell us?

Table A1. Summary of codes and sub-codes.

Main codes	Sub-codes
Data sharing	Within research group
	Across research groups (within network)
	External to network
Collaboration	Reputation
	Competition
	Collegiality
	Psychological safety
	Hierarchy
Rigor	Speed to publication
	Scientific accuracy
	Data sharing
Lab management	Mentoring
	Ethical obligations
	Adjudicating disputes
	Leadership
	Transitions
Culture and climate	Collegiality
	Getting to know people
Commercialization	Research direction
	Societal Impact
Publishing	Authorship
	Strategy
Regulatory compliance	Adherence
	Questioning
	Failure to anticipate