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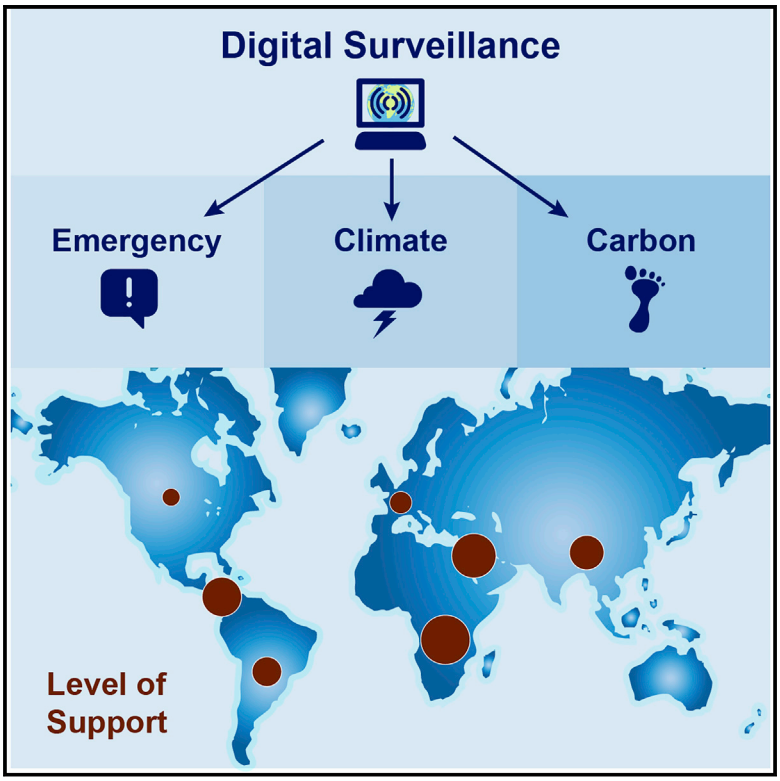
Article

Moderate support for the use of digital tracking to support climate-mitigation strategies

Graphical abstract



Highlights

- The climate crisis could cause expanded use of digital surveillance, as did COVID-19
- Digital emissions tracking can be useful for climate mitigation but raises concerns
- We assess global perspectives on digital surveillance for collective crisis response
- 50% support implementing personal carbon budgets to tackle climate change

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In brief

The COVID-19 pandemic triggered the use of digital surveillance as a collective emergency response. The climate crisis requires collective responses. Digital tracking could help but raises many concerns. We assessed global perspectives on the use of digital surveillance both to tackle COVID-19 and to mitigate climate change. Results show moderate support for its use for climate action, including for tracking personal carbon budgets, though support varies significantly by region.

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Article

Moderate support for the use of digital tracking to support climate-mitigation strategies

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SCIENCE FOR SOCIETY The coronavirus 2019 (COVID-19) pandemic triggered a surge in the use of digital surveillance as a public health tool and sparked debates over the effectiveness and ethics of digital tracking, even in times of emergency. As the collective threats of the climate crisis rise, digital surveillance—which includes the automated collection of personal data and monitoring of behavior, habits, and lifestyle choices through internet-enabled devices such as mobile phones—could be deployed to monitor and manage carbon emissions impacts of individual actions. While this could be a powerful tool, it raises many new questions and concerns. We conducted an international survey of nearly 3,000 respondents to explore public perceptions of the prospect of using digital surveillance as a tool to tackle climate change. We found moderate public support, with 50% of respondents explicitly stating they are open to the implementation of mechanisms to limit individual carbon emissions. We argue for the need to explore how and if digital tracking tools can be used in a way that respects individual rights and the pursuit of the collective goal of cutting global carbon emissions.

SUMMARY

The use of digital tracking of individuals throughout the coronavirus 2019 (COVID-19) pandemic renewed societal debates on the efficacy and ethics of digital surveillance to mitigate collective crises. While digital emissions tracking is being used to support climate-mitigation strategies, to date there has been limited exploration of the opportunities and challenges of deploying it at the individual level. Here, we assess temporal and regional differences in levels of support for the use of digital surveillance in times of crisis, such as climate change. Results from a global survey indicate moderate support for the use of digital tracking, including for personal carbon footprints. Response varied regionally, with the lowest support in North America and Europe. This study raises key questions—if digital surveillance tools could be part of a socially acceptable response to the climate crisis, is it worth exploring? Or is this an unacceptable risk for society?

INTRODUCTION

In a global race to combat the coronavirus 2019 (COVID-19) pandemic, nations have turned to digital surveillance and tracking tools to monitor and prevent the spread of the coronavirus. Digital surveillance and tracking refers to the automated collection of personal and aggregate data through digital technologies—including internet-based sources, personal cellular devices and mobile applications, social media, or biometric technologies.[1,2] It has been used extensively for contact tracing, disease monitoring, and forecasting during the pandemic and was widely and rapidly adapted as part of the public health arsenal.[2–4] In South Korea, for example, a monitoring system integrating data from financial transactions, mobile phones,

and a huge network of closed-circuit television cameras helped to enable an efficient and effective COVID-19 testing system.[5] In Rwanda, contact tracing through geo-localized hotspot mapping in conjunction with mobile applications formed a key part of the COVID-19 response strategy.[6] In Taiwan, a monitoring system integrated data from immigration, health insurance, and mobile phones to track the exact location and movement of individuals under quarantine and to alert police in the case of violations.[7] Facial recognition and data mining from smartphone apps have been deployed for quarantine control in several countries, including Spain, the United Kingdom, and the United States.[8,9] The adoption of surveillance and tracking tools to combat the global pandemic extends beyond governments: individual citizens have voluntarily taken up the use of many surveillance tools, such as the Google/Apple Exposure Notification system, a user-centric approach to contact tracing released on open-source platforms.[10,11] In Finland, 45.31% of the population was using the app, and uptake rates were above 20% in Germany and the United Kingdom at the end of 2020.[12] Following the roll out of the vaccine in some countries, digital tracking was being employed to facilitate the use of vaccine passports.[13] The rapid adoption of various digital surveillance tools to combat the COVID-19 pandemic has also been met with significant resistance. Some scholars have warned of growing threats to the nature of democracy as a result of this trend.[14–16]

The accelerated uptake of digital surveillance and tracking tools in the context of the pandemic raises questions about how readily we will turn to them to address other more severe global collective threats to human security—such as climate change.[17,18] The COVID-19 pandemic and climate change are similar in that both pose threats to global health and security, have outcomes that are diffuse and difficult to predict with great precision, and negatively impact the economy and socio-economic relationships. Both have impacts that differ across socio-economic contexts and can perpetuate pre-existing inequalities, and both are negative stock externalities—meaning that the speed of inflows is faster than outflows (greenhouse gas sources larger than sinks, in the case of climate change, and number of infected people increasing chances of others becoming infected, in the case of COVID-19)—that can only be effectively addressed through collective action.[19,20] Furthermore, both issues are less costly to prevent than to redress—though in both cases, early warnings from scientists were largely ignored, and mechanisms to address both issues have become politicized.[19,21] A key difference, however, is that impacts of the COVID-19 pandemic directly impact individual health and survival, are on a time horizon that is more quickly observable and attributable, and have individual mitigation actions that can have a more immediate and direct impact on tackling the underlying problem. This is not the case for climate change, so incentivizing behavioral changes to tackle the climate crisis is more challenging.[19–21]

Data collection for monitoring climate change is accelerating rapidly with the emergence of earth observation and Internet-of-Things technologies.[22] Advances in artificial intelligence (AI) and smart technologies allow for large-scale monitoring of individual emissions, and schemes for personal carbon allowance are already being explored in the United Kingdom, Ireland, California, USA, and France, for example.[23] As digital surveillance and tracking capabilities increase, the possibility that they may be used to monitor individual actions, particularly around carbon emissions, could become an increasingly important topic for societal debate. Understanding individual perspectives on digital surveillance and what differing perspectives may imply as we move toward increasingly digitalized and monitored societies will be central to exploring potential challenges and opportunities.

While research has explored the use of digital tracking to support corporate action in building sustainable production of goods—such as through digital tracking of supply chains[24,25]—there have been no assessments of the opportunities and risks of leveraging digital tracking tools to support climate actions at the individual level. This paper begins to explore this topic.

Here, we assess temporal and regional differences in levels of support for the use of digital surveillance in an emergency situation like COVID-19 as well as to address climate change, which poses an existential and collective threat where impacts are more diffuse and manifest in different ways around the world. We conducted an international survey of the general public (hereafter called the general population) and of subject-matter experts in the global sustainability science community (hereafter called the sustainability community; see experimental procedures for survey details). We asked both surveyed populations about their (1) level of support for the use of digital surveillance in times of emergency (with the COVID-19 pandemic as the leading example named) and to tackle the climate crisis; (2) level of support for the implementation of limits to personal carbon emissions to help tackle the climate crisis; (3) expectations for the extent of digital surveillance over the next 3 years; and (4) expectations for how trust in online interactions will change over the next 3 years. We also asked the sustainability community to contextualize their levels of support. Results show moderate support for the use of digital surveillance to tackle the climate crisis, and 50% of respondents support implementing limits to individual carbon emissions. Responses varied regionally, with the lowest support in North America and Europe. As the risks of the climate crisis become more evident to society, digital surveillance may emerge as a means of monitoring and managing carbon emissions impacts of individual actions. Our work begins to explore this topic by assessing public perceptions on the prospect of using digital surveillance as a tool to tackle climate change.

RESULTS

Responses from the general population

We found moderate public support for the use of digital surveillance tools as part of an emergency response strategy when they can save lives, as well as for their application to address the climate crisis. We also found support for the implementation of individual carbon-accounting mechanisms (Figure 1; see Figure S1 and Note S3 for details on the distribution of responses for each survey phase). Globally across all three survey phases, 51% of respondents from the general population supported the use of digital surveillance in times of emergency and 44% supported the use of digital surveillance to tackle the climate crisis (combining responses of supportive and strongly supportive;

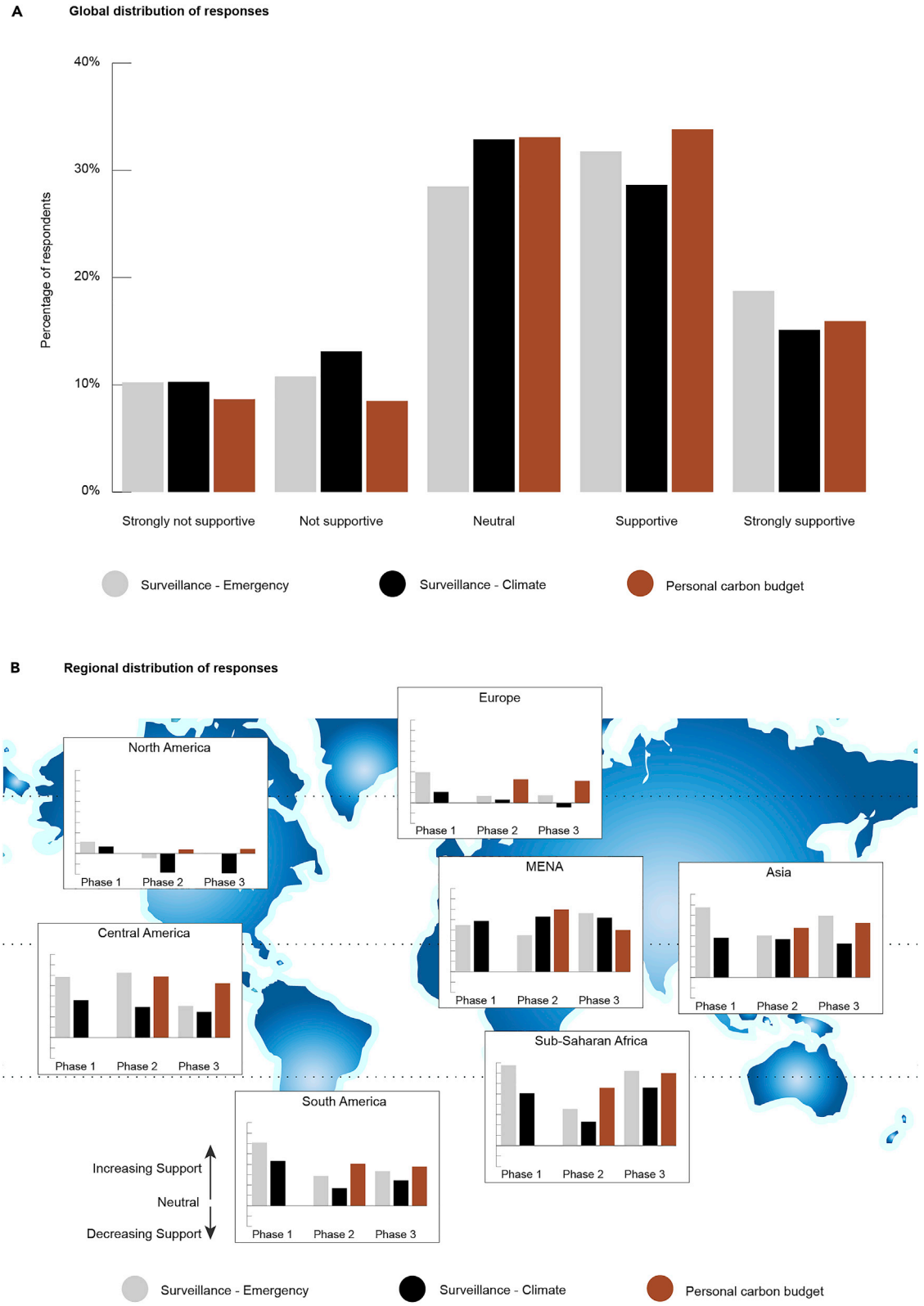

Figure 1. Responses from the general population: Global, regional, and temporal distribution of the support for digital surveillance

(A) The distribution of responses (percentage of total general population respondents across survey phases) to questions about level of support for the use of digital surveillance in times of emergency (gray bars, surveillance - emergency, n = 2,944, mean = 3.38 ± 1.20 [SD]), the use of digital surveillance to more

(legend continued on next page)

Figure 1A). In both cases, around one-third of respondents remained neutral (29% and 33%, respectively). In the second and third survey phases, nearly 50% of respondents supported the implementation of individual carbon budgets as a means to tackle the climate crisis, with 33% remaining neutral (noting that this question was not asked in the first survey phase; Figure 1A).

Global patterns of support carry important regional differences (Figure 1B). Support for digital surveillance both in times of emergency and to tackle the climate crisis was strongest in Sub-Saharan Africa and the Middle East and Northern Africa (MENA) regions, followed by the regions of South America, Asia, and Central America (Figure 1B, statistical means extending above the x axis). There was lower support or a lack of support (mean response of less than 3 on a converted Likert scale) for the use of digital surveillance in these two contexts in Europe and even more markedly in North America (Figure 1B, statistical means extending below the x axis).

Support for the implementation of limits to personal carbon emissions (mean = 3.40 ± 0.026 [SE]) was significantly stronger than support for the use of digital surveillance to tackle the climate crisis (mean = 3.22 ± 0.027 [SE], including only values from phases 2 and 3 when both questions were asked) when comparing globally (based on a two-way ANOVA of global means, $F = 3.84$, $p < 0.01$). Support for the implementation of personal carbon limits also varied regionally, with significantly lower support in Europe and North America compared with the rest of the world (Tukey's honestly significant difference [HSD], adjusted p value [adj-p] <0.05 for all comparisons with these two regions except for the comparison of Europe and South America, which was not statistically different).

Alongside their general support for digital surveillance, the majority of respondents expected that the world will be characterized by more digital surveillance in 3 years' time (Figure 2; 64% of respondents from the general population expect either "more" or "much more" digital surveillance, with an overall median response of "more"; see Figure S2 for distribution of responses across the 3 phases of the survey). There was a significant difference between North America on the one hand and Central America, South America, and Sub-Saharan Africa on the other (Tukey's HSD, adj-p < 0.05), where respondents from North America expressed a stronger expectation that society will be characterized by more digital surveillance compared with respondents from the other three world regions.

Expectations on how trust in online interactions will change over the coming 3 years was more mixed. In general, respondents from Central America and South America, and to a lesser extent Asia, Sub-Saharan Africa, and MENA, expressed an expectation that trust in online interactions will be strengthened over the next 3 years (Figure 2; see Figure S2 for distribution of responses across the 3 phases of the survey). This is significantly different compared with findings from North America and Europe (Tukey's HSD, adj-p <0.05 for all comparisons with these two regions), where there was a general expectation that trust will diminish.

To help contextualize the levels of support for digital surveillance found in the survey results, we examined the correlation coefficients between the variables analyzed above as well as two additional key factors—internet penetration rates and the level of individualism-collectivism as a measure of cultural variation (Figure 3; see Notes S4 and S5 for more details). Respondents were generally consistent in their level of support across survey questions, as indicated by strong and significant pairwise correlations among (1) support for digital surveillance in times of emergency, (2) support for digital surveillance to tackle the climate crisis, and (3) support for the implementation of limits to personal carbon emissions ($p < 0.001$ for all three comparisons). We found a significant and inverse correlation between these three factors and expectations for the extent of digital surveillance in the next 3 years ($p < 0.010$ for all comparisons), indicating that expectations that society will be characterized by more digital surveillance were often accompanied by lower levels of support for its use. We also found a somewhat weaker, but still significant and positive, correlation between these three factors and expectations that trust in online interactions will increase in the next 3 years ($p < 0.040$ for all comparisons), indicating that people who expressed an expectation that trust in their online interactions will increase also expressed higher levels of support for the use of digital surveillance.

Given the structured nature of the survey (see Note S1 for survey design), it was not possible to determine to what degree the order of questions in the survey may have influenced respondents' answers. For example, asking first about support for digital surveillance in times of emergencies (e.g., to help stem the spread of coronavirus) may have primed the nature of responses for the question that followed on the use of digital surveillance to tackle the climate crisis. If this was the case, support levels for surveillance to tackle the climate crisis and for individual carbon budgets should be interpreted with caution. For example, if a positive priming effect was present, support for digital surveillance to address the climate crisis could be lower than reported values, which were positive but moderate compared with support for digital surveillance in times of emergency. Interestingly, support for the application of a personal carbon budget was higher than for either digital surveillance for emergencies or for climate across many regions. If influenced by prior questions, respondents may have been primed to see this as a more effective or necessary measure to address the climate crisis.

In comparing the survey results with the measure of cultural individualism-collectivism by region, we found a significant and inverse correlation between the Individualism Distance Index (IDV; from Fuentes et al.[20] and van Dijk[27]) and support for (1)

effectively tackle the climate crisis (black bars, surveillance - climate, n = 2,944, mean = 3.25, ±1.17 [SD]), and the implementation of limits to personal carbon emissions (brown bars, carbon budget, phases 2 and 3 only, n = 1,920, mean = 3.40 ± 1.12 [SD]).

(B) The statistical mean level of regional support among general population respondents for each phase of the survey for these same three questions (noting that the question about personal carbon budget was only included in phases 2 and 3). n = 1,025 respondents completed the survey questions depicted here in phase 1, n = 967 in phase 2, and n = 952 in phase 3. Bars extending above the x axis indicate increasingly strong mean levels of support, while bars extending below the x axis indicate increasing strong mean levels of lack of support, and values at the x axis are neutral. Values on the y axis correspond to the numerical conversion of the five-point Likert scale. See Table S4 for mean and SE by region.

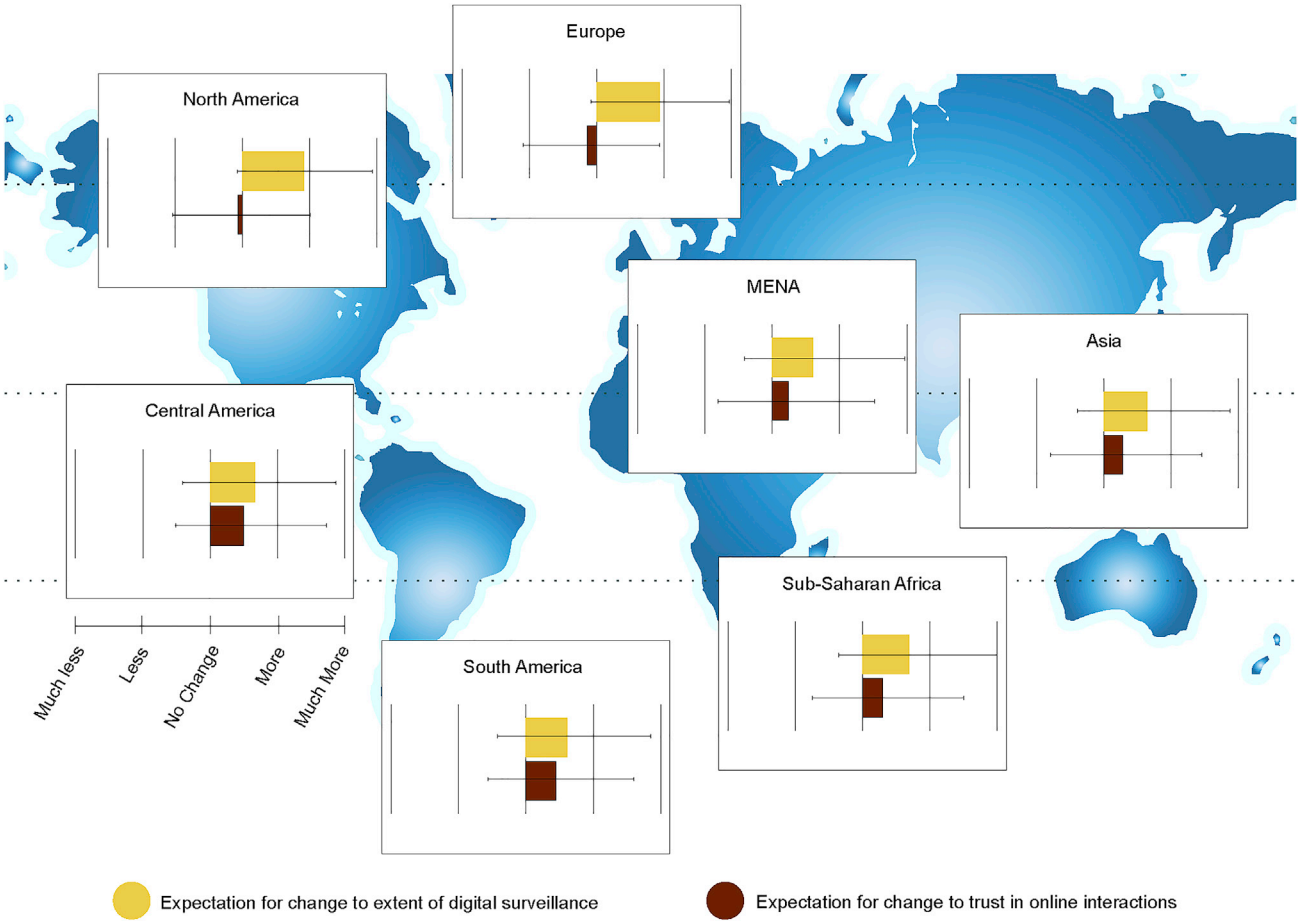

Figure 2. Responses from the general population: Expectations of changes in the extent of digital surveillance and trust in online interactions

Across all regions, respondents from the general population expect an increased extent of digital surveillance in 3 years' time (yellow bars; n = 2,915, global mean = 4.228 ± 0.014 [SE]). This was strongest in Europe and North America. Respondents in Europe and North America also expect trust in online interactions to decrease (brown bars; n = 2,944, global mean = 3.222 ± 0.021 [SE]), while all other regions expect it will increase. The error bars depict the SD by region. For mean values and SE by region see Table S4. The Likert scale, ranging from "much less" (1) to "much more" (5) on a five-point scale, is indicated for the Central America inset panel and remains the same for all world regions.

the use of digital surveillance in times of emergency ($p = 0.010$) and (2) the implementation of limits to personal carbon emissions ($p = 0.013$). This indicates that regions characterized by higher levels of cultural individualism tended to have lower levels of support for the use of digital surveillance. We also found a significant and inverse correlation between internet penetration rate (from Vehovar et al.[28]) and support for the use of digital surveillance ($p < 0.001$ for all comparisons). Thus, in general, there was higher support for digital surveillance in regions where there is lower access to the internet compared with regions with higher access to the internet.

Finally, the analysis shows that there was a stronger expectation that trust in online interactions will increase in regions characterized by higher levels of collectivism compared with more individualistic regions, indicated by a significant inverse correlation between the IDV and expectations for trust ($rs = -0.904$, $p < 0.001$). There was a significant and inverse correlation between expectations for trust in online interactions and (1) expectations for the extent of digital surveillance ($p = 0.010$) and (2) internet penetration rate ($p = 0.020$). We also found a significant and positive correlation between expectations for the extent of digital surveillance, the IDV, and the internet penetration rate ($p < 0.020$ for all comparisons).

Responses from the sustainability community

In the targeted survey of the sustainability community (April 2020), we asked the same questions regarding level of support for the use of digital surveillance. We also asked respondents to provide additional comments—in the form of conditions or concerns—to qualify their responses (analyzed using qualitative content analysis following Schreier[29] see experimental procedures for details). Given that the survey of this community was designed to reach a targeted respondent group and not to contrast perceptions between geographies, we do not disaggregate results by region. As with the general population results, the majority of respondents from the sustainability community were supportive of the use of digital surveillance in times of emergency (56.8% either supportive or strongly supportive, with 18.3% neutral), and many were also supportive of its use to tackle the climate crisis (41.1% either supportive or strongly supportive,

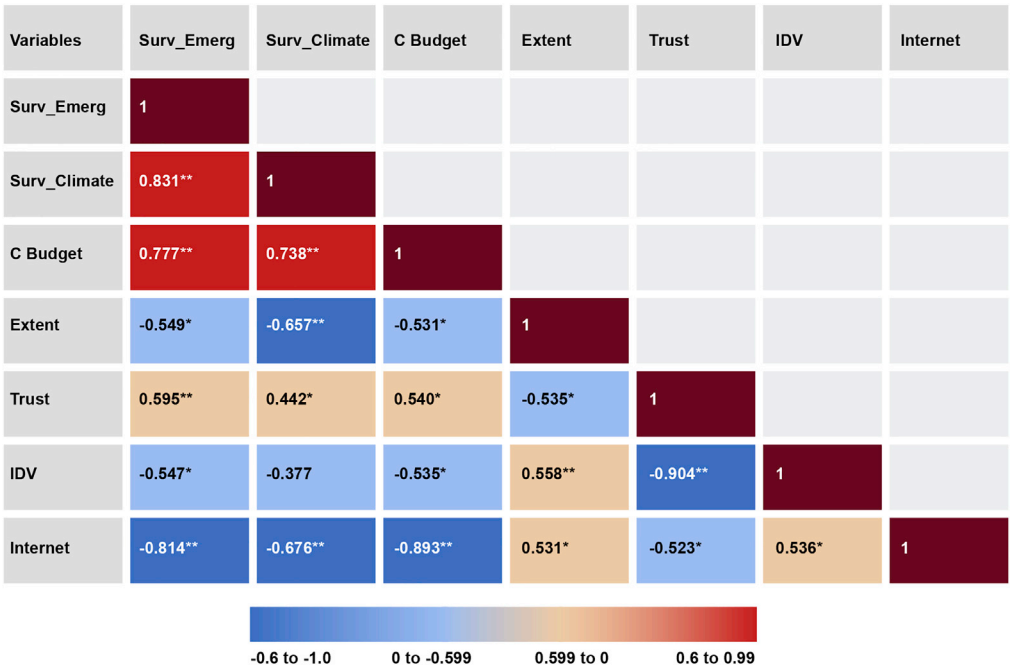

Figure 3. Contextualizing levels of support for digital surveillance: Correlations with cultural variation and internet penetration rates

Spearman's rank correlation coefficients rho (*rs*) estimating the relationship between average response values by region for the following variables: support for the use of digital surveillance in times of emergency (Surv_Emerg); support for the use of digital surveillance to more effectively tackle the climate crisis (Surv_Climate); support for the implementation of limits to personal carbon emissions (C budget); expectation of how trust in online interactions will change in 3 years (Trust); expectation of how extent of digital surveillance will change in three years (Extent); Individualism Distance Index (IDV; Table S3); and internet penetration rate (Internet; Table S3). For the first five variables, average value by region was taken for each phase of available responses from the general population and merged across phases. Asterisk (*) indicates a marginally strong correlation at 95% confidence level based on the table of critical values for Spearman's rho,[26] and two asterisks (**) indicate a strong correlation at 99% confidence level.

with 17.5% neutral; Figure 4A). Based on analysis of responses, the most prevalent condition to this support for digital surveillance pertained to how the data collected through digital surveillance would ultimately be used (Figure 4B). This primarily related to concerns about privacy and consent but also touched on transparency of data usage, concerns around the misuse of personal data, accountability of those with the power to use the data, and ensuring secure data storage.

Some respondents also highlighted the need for general oversight and/or regulation of digital surveillance to ensure robust governance frameworks and to clarify relationships (e.g., led by independent review committees or non-governmental organizations and involving collaborations across scales, sectors, and geographies). Other key considerations included data collection (e.g., implementing strict limitations to how long data can be stored) and democratic safeguards (e.g., avoiding the risk of digital dictatorships and protecting against surveillance capitalism). Finally, considerations for who is surveilled (in particular the surveillance of groups versus individuals) and who owns data (individuals, private companies, governments, or other arrangements) were also raised.

DISCUSSION

Our findings indicate that, globally, there is more support for the use of digital surveillance than there is opposition to its use to address collective threats such as the COVID-19 pandemic and climate change. Findings also highlight that support alone is not sufficient to ensure social acceptance. For the first time in human history, for better or for worse, societies have the capacity to digitally monitor nearly everything on the planet. While these enhanced capabilities could enable society to accurately measure point source emissions and stocks and flows of carbon, comprehensively track environmental and social impacts along value chains, and transparently verify compliance to regulations, it may also open the door to existential risks, such as human rights violations, privacy infringements, or the erosion of democracy.[3,30–33] For example, a surveillance system developed for individual carbon monitoring could spur the development of new social norms around reduced emissions, creating incentives for behavioral change as individuals strive to conform to the actions of others around them. Or this type of system could be used to identify and punish non-compliance, which could result in unequal distributional impacts across socio-economic groups. Existing mechanisms for monitoring emissions can provide important lessons to learn from as digital surveillance systems emerge and expand into this space. These lessons include the need for international cooperation (e.g., through the UNFCCC) to address concerns with new techniques, efforts to enhance access to the information collected, and the integration of economic and other forms of incentive structures into the design of monitoring

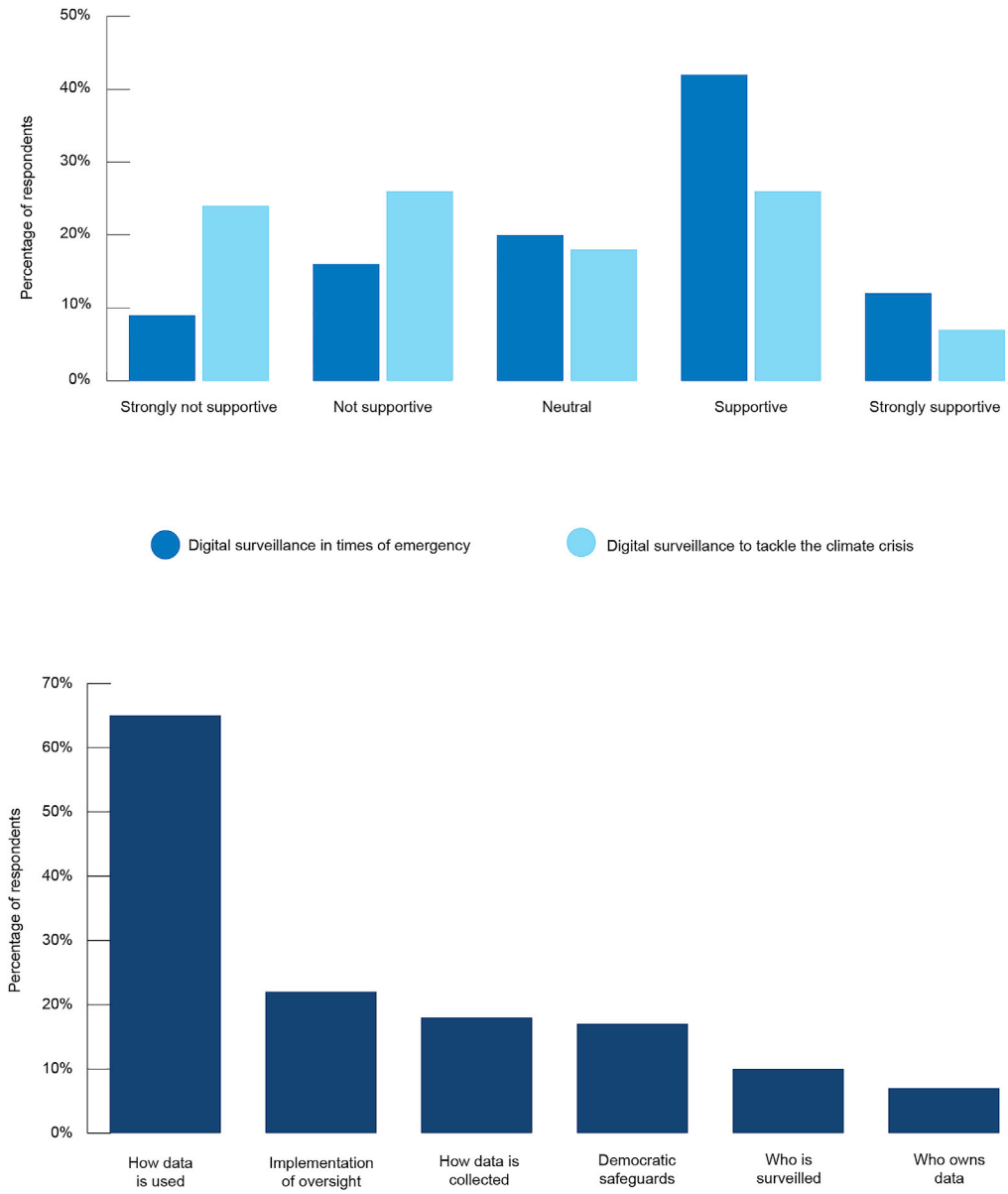

Figure 4. Responses from the sustainability community on the use of digital surveillance

(A) Level of support for the use of digital surveillance (1) in times of emergency and (2) to tackle the climate crisis. The distribution (%) of responses on the level of support for digital surveillance from the sustainability community (1) in times of emergency (royal blue bars, mean = 3.305 ± 1.156 [SD]) and (2) to tackle the climate crisis (light blue bars, mean = 2.671 ± 1.275 [SD]).

(B) Conditions or concerns qualifying the level of support for the use of digital surveillance. Distribution (%) of conditions or concerns (dark blue bars) from survey comments provided by respondents qualifying their level of support for the use of digital surveillance in both contexts (in times of emergency and to tackle the climate crisis). The comments were analyzed and categorized using qualitative content analysis. The six most frequently identified categories of priority considerations to qualify respondents' support are (1) how data are used, (2) implementation of oversight, (3) how data is collected, (4) democratic safeguards, (5) who is surveilled, and (6) who owns the data. The distribution (%) of responses shown in both panels is based on the total number of sustainability community respondents who provided a qualifying response to at least one of the two questions on level of support for digital surveillance in times of emergency and to tackle the climate crisis (n = 417).

systems.[34,35] It is important to note that developing any type of surveillance system for carbon monitoring would require the collection and analysis of complex datasets, as well as exploring many ethical, legal, and social issues that currently remain underrepresented in global discourse (as described by, e.g., Clarke[30] and Sweeney[36]).

As recently stated, with the vast amounts of highly valuable data being collected and their potential application to mitigating threats to human security, "the question is not whether to use new data sources […] but how" (Mello and Wang,[4] p. 951). This is a critical stock-taking moment to reflect on the extent to which society is willing to accommodate the risks of deploying

digital surveillance strategies in response to global collective threats and on how we ensure that socially acceptable frameworks for such deployment are both effective and ethical. Doing so, however, will require that governments, private companies, producers, and end users of data and other key actors collaboratively address numerous concerns, which include those highlighted in Figure 3. Many of these concerns are already manifesting today, for example around how data are used and who ultimately owns them—an issue particularly prevalent with regards to health data (e.g., Sweeney,[36] Ienca and Vayena,[37] Lenert and McSwain,[38] and Kostkova et al.[39]) but which also applies much more broadly (e.g., European Union's General Data Regulation and Protection [GDRP] law). It will also be critical to prioritize the inclusion of supportive as well as unsupportive viewpoints in order to better understand the rationales underlying different perspectives.

In the fast-advancing landscape of digital surveillance, results from the survey presented here suggest that additional research is urgently needed to understand drivers and concerns behind differing levels of support for digital surveillance. While it is not possible to know exactly how respondents interpreted the concept of digital surveillance, the high number of neutral responses and associated qualifying comments may indicate fundamental uncertainties around what digital surveillance entails and/or support for only certain forms of digital surveillance. Similar to the results shown in Figure 3, a review of the comments provided by respondents from the sustainability community who expressed a neutral support for digital surveillance to address the climate crisis (n = 58/139 responses, results not shown) indicates that many, although not all, expressed conditional support for surveillance. This support depends on who was surveilled (individuals versus corporations, governments, etc.), for how long (temporary or permanent state of surveillance), who would have access to and ownership of the data (companies, corporations, citizens), and how the data are used. While this is not surprising, it does highlight the importance of integrating perspectives and concerns from a diversity of actors into the design of digital surveillance systems if they are to be socially accepted, trusted, and effective.[40]

A key finding is that trust in online interactions has a central role in understanding levels of support for digital surveillance in times of emergency. In the online environment, research suggests that trust forms in a complex, longitudinal process.[41] We the authors thus understand people's level of trust in online interactions to be based on some pre-requisite experience with such interactions (for example through e-commerce, social media platforms, or other digital applications). Trust in online interactions is also shown to be increasingly mediated by user experiences over time.[41,42] Users of social media platforms, for example, "increasingly see trusted individuals within their peer networks who support production and exchange of valued information as authoritative sources of information. As that information is further disseminated, it often increases in its perceived legitimacy."[43] This echoes literature that explores the role of online trust in determining people's response to, and ultimately their uptake of, digital tools[40] as well as the critical importance of trust in addressing large-scale collective action problems.[18] It is notable, however, that regions with lower support for the use of digital surveillance and lower expectations that trust in online interactions will improve in the coming years are also the regions that have the highest internet penetration rates. This will be an important relationship to explore, as more than 60% of the global population uses the internet and more are gaining access each year.[44]

To further contextualize the perspectives surveyed, we explore individualism-collectivism as one of many determinants of cultural norms and values. This has been a useful framework in other contexts, for example in relationship to risk and disaster response.[23,24] Here, we consider how the gradient of individualism-collectivism relates to trust in online interactions and to receptivity to digital surveillance technologies for crisis mitigation. The authors acknowledge that the gradient from individual to collective includes a multitude of actors, including transnational, national, subnational, and non-state institutions and companies, so agency does not lie solely with the individual.[45] One might expect that in collectivist societies—which tend toward placing the good of the collective before that of the individual—there may be more support for digital surveillance to address global crises than in more individualistic societies—which place greater value on personal freedoms.[46] Unsurprisingly, among all regions surveyed, respondents from those with the highest individualism ranking also showed the weakest levels of support for digital surveillance in times of emergency and to address the climate crisis and the lowest expectations that trust in online interactions will increase. Interestingly, however, though support for digital surveillance and expectation that trust will increase were weakest among those respondents, there was relatively low opposition to the use of these technologies reported overall. One explanation for this may be a tendency to shift toward broader collectivist values and a sense of community as a response to crisis (see, e.g., Greenfield[47] and Grant[48] for theories of how shifts in cultural dimensions such as individualism-collectivism might occur), suggesting that the degree of urgency or imminent threat is an important factor driving support for digital surveillance to address global crises. Significant transdisciplinary and transregional research is needed to explore how trust in digital interactions is built, reinforced, and maintained and how it determines perceptions of digital surveillance in the context of global threats such as the climate crisis. Further exploration of the role of cultural norms and values and the implications of the digital divide is critical to understanding and contextualizing support for the use of digital surveillance. This is key, as it is difficult to assess the added security that digital surveillance might generate without widespread uptake, and until effectiveness is proven, widespread use at a population scale is hard to justify.[40]

These interconnected factors are likely just a few among many that highlight the diversity in perspectives among users and/or targets of digital surveillance. Key considerations for deploying such tools include oversight and transparency—for example, to develop guidelines on the ethical use of data collected. Significant cross-sectoral collaboration among countries is another consideration, given that the digital world increasingly transcends geographical boundaries and political borders. It is also important to note in this context that digital surveillance and tracking are already being deployed in many other domains—for example, to increase security in travel via biometric passports,[49] to develop innovative methods to tackle criminal

Table 1. Survey respondents

	Phase 1 general population	Phase 1 sustainability community	Phase 2 general population	Phase 3 general population
Number of respondents	1,025	1,334	1,907	1,902
Number of countries surveyed	29	87	29	29
Percentage of respondents by world region, %				
Asia	12	15	13	15
Central America	12	>1	12	15
Europe	16	45	14	14
MENA	9	>1	14	14
North America	15	27	17	14
South America	27	3	14	14
Sub-Saharan Africa	9	8	16	14
Percentage of respondents by gender, %				
female	39	52	31	36
male	42	28	50	45
prefer not to say	19	>1	19	19

Overview of the distribution of survey respondents from the two communities surveyed, with information for all three phases of the survey for the general population. Data presented include the number of respondents, number of countries in which survey respondents are based, and percentage of total number of respondents from each world region and by gender. For additional demographic data collected on age and area of work, see Table S2.

activity and terrorism,[50,51] or to predict and monitor activities within smart cities,[52] recalling debates on trade-offs between security and privacy.[8,53] Furthermore, it will be critical to evaluate the appropriateness of deploying digital surveillance tools by referencing a counterfactual, as argued recently by Mello and Wang—if it is not employed, what is the alternative?.[4] These conclusions strengthen the argument that simply deploying these types of tools to mitigate global crises without deep consideration of and engagement with public perspectives will hinder their effectiveness. As stated by Alessandro Blasimme and Effy Vayena, "Technological uptake does not just rapidly happen by virtue of technology's presumed usefulness (technological determinism), but owes instead to complex cycles of cultural and political adaptation,"[40] p. 761). Addressing such issues in a transparent, open, collective, and deliberative manner may create the foundations needed to build a trusted digital surveillance system to tackle the climate crisis. But this will only be the case if efforts are made immediately to initiate inclusive debates regarding the rationale for its use and to explore alternative frameworks for co-developing and implementing such a system.

Conclusions

This paper begins addressing the opportunities and challenges around using digital surveillance to support climate action at the level of the individual, a topic largely underexplored to date. Our analysis suggests that the increase in digital surveillance, accelerated by the pressures of COVID-19, has been met with moderate support in many parts of the world, though responses varied regionally, with the lowest support in North America and Europe. Further, we found support for the use of digital surveillance to tackle climate change, another more severe collective threat. But this support comes with several important caveats including the implementation of transparent and reflexive oversight and public engagement.

Without proactive efforts to mitigate the ongoing climate crisis, societies around the world may once again be forced to use digital surveillance tools in reaction to an imminent and escalated collective threat. There is an opportunity to learn from society's experience with surveillance during the pandemic and to better understand how differences in perspectives impact current and future crisis responses. Further insight is needed into how perspectives differ by region and according to factors such as trust in online interactions and cultural norms and values (i.e., how the relationship of individualism-collectivism to risk and disaster response relates to perspectives on digital surveillance for crisis management). Public support for the use of digital surveillance as a response to the climate crisis, however, is not the limiting factor for global buy in and effectiveness. Rather, the analysis shows that a robust global governance framework is critical—one that takes into account the diversity of perspectives and priority considerations for the deployment of digital surveillance to mitigate climate change while also explicitly addressing the main barriers to collective action.[54] This will require dialogues—including both supportive and unsupportive viewpoints—with the goal of co-creating strategies for responsive, transparent, trustworthy, and adaptive mechanisms to govern the deployment of digital surveillance for climate action. Fostering these debates now will be critical to explore whether digital surveillance tools can be used to address global collective threats in socially acceptable ways.

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

Further information and requests for resources should be directed to the lead contact, Nilufar Sabet-Kassouf (nilufar.sabet-kassouf@sustainabilitydigitalage.org).

Materials availability

This study did not generate new unique materials.

Data and code availability

This paper analyzes results from surveys conducted by the authors. Details on the survey design and survey questions are given in Notes S1 and S2. The datasets generated and analyzed during the study are given in the supplemental tables and supplemental figures. Existing, publicly available data were also used and are given in Table S3. This paper does not report original code. Any additional information required to reanalyze the data reported in this paper is available from the lead contact upon request.

Survey design

Two populations were surveyed initially: the general population (a broad spectrum of general citizens from around the world) and the environmental sustainability community (the sustainability community, experts in sustainability research and practice). Responses from the sustainability community were treated as distinct from responses from the general population. Two additional follow-up surveys were circulated to the general population in July (phase 2) and October 2020 (phase 3) to assess changes in perceptions over time.

The survey tool and dissemination were slightly different for the two communities. For the general population, Google Surveys were targeted to specific countries across six major geographic regions to provide a balanced survey design from countries where Google Surveys was offered in 2020 and employed a repeated cross-sectional survey design composed of quantitative questions with data collected on a five-point Likert scale. The respondents to the survey were not the same across phases. In a rapidly evolving context such as COVID-19, repeated cross-sectional surveys of the general public[55,56] and of targeted groups[57] have been used to track changes in perception on a number of pandemic-related topics and was considered appropriate for this study. For the sustainability community, a Survey Monkey tool was shared through the Future Earth, Sustainability in the Digital Age, and Grantham Institute professional networks to reach the target population. The survey to the sustainability community included the exact same questions as the survey to the general population in phase 1 (both circulated in April 2020), as well as additional questions to probe further into expert perspectives (see Note S2 for survey questions). As the surveys were administered exclusively online and on a voluntary basis, it was not possible to ensure a representative sample of the two targeted communities. Despite the potential for non-representativeness in the sample, this approach was taken to facilitate a rapid survey methodology as the aim was to take the pulse of the two populations at a critical moment in time. In order to understand the composition of participants, a number of demographic questions were asked on gender, location (Table 1), age, and area of work (Tables S1 and S2).

In the survey, a broad definition of digital surveillance was purposefully not provided. This was done to take an open and inclusive approach to different understandings of the concept of digital surveillance, as it can take many forms and is often defined using examples of how it is deployed rather than a fixed conceptual definition. In the case of questions focused on digital surveillance for the climate crisis and carbon budgets, we provided examples of the types of activities that could be surveilled to help orient respondents who are less familiar with potential applications of digital surveillance in these contexts. For questions related to COVID-19, we intentionally left the definition open to the respondents' understanding in the context of the rapidly evolving COVID-19 landscape. As a result of decisions taken regarding survey methodology, we do not present these results as representing the global population directly; rather, we present them as a preliminary input to spark a broader societal debate on a critical topic—digital surveillance to address global collective threats.

Variables

In addition to the individual demographic variables identified from survey responses, we also explore two additional regional variables in recognition of the fact that perspectives on the trade-offs between privacy and security can vary greatly across regions and cultures. Hofstede's dimensions of cultural variation[46] provide a framework through which to investigate interconnections between the cultural history of a society and the expressed perspectives of its members. This framework posits that the behaviors of individuals can be, in part, understood by the cultural values of the society in which they live.[22] Hofstede identifies six cultural dimensions of interpretation: individualism-collectivism, uncertainty avoidance, power distance, masculine-feminine, long-term orientation, and self-restraint[58]. We posit that Hofstede's dimension of individualism-collectivism, measured on a scale from 0 to 100, is particularly relevant to understanding expressed perceptions in our survey responses in light of its known relationships to risk and disaster management,[59,60] to the trade-off between security and privacy,[61] and as a predictor of the uptake of public health response to the pandemic.[62] We further posit that rates of internet access by region, measured as the percentage of total population with access to the internet, as a proxy for the global digital divide, (i.e., the gap between those who do and do not have access to internet and digital technologies; see van Dijk,[27] Vehovar et al.,[28] and International Telecommunication Union[63]), play a role here as well. See Table S3 for an overview of individualism-collectivism and internet penetration rates by region (data for these variables from Hofstede,[46] Allik and Realo,[64] and Earth[65]).

Analysis

All analyses of data from the two populations were carried out separately. Quantitative analysis was performed in the statistical software R Project v.3.6.1, RStudio v.1.2.1335, and Excel v.16.49. In some cases, Likert scale responses were converted to a numeric ordinal scale from 1 to 5 to calculate mean responses, standard error, and distribution of responses. In presenting results, we consider Likert responses of "not supportive" and "strongly not supportive" to indicate opposition and responses of "supportive" and "strongly supportive" to indicate support. We present "neutral" responses separately, as these cannot be assigned as either opposed or supportive without additional research or insights into respondent mentality. The order of the questions in the survey was structured across respondents, and thus it was not possible to test whether the order of questions could have influenced survey responses.

Relationships between continuous variables were characterized using Spearman's rank non-parametric test to identify correlation coefficient rho (rs), with significance measured at $\alpha = 0.05$.[66] Significant differences between categorical variables were characterized through two-way ANOVA tests (following Sullivan and Artino[66]), verified by non-parametric Kruskal-Wallis tests where possible, and followed by Tukey's HSD tests as necessary to identify which regions or survey phases demonstrated significant differences. Data were pooled across survey phases only when no significant difference was detected. All statistical tests were two sided.

The sustainability community was also asked to qualify their level of support for the use of digital surveillance. These responses were analyzed by a team of three researchers using qualitative content analysis methodology in MaxQDA (Max QDA Standard 2020 v.20.0.8) to uncover the latent meaning of open-ended responses (following Schreier[29]). In analyzing the spread of responses across the globe, we used seven world regions: Asia and the Pacific (Asia), Central America, Europe, MENA, North America, South America, and Sub-Saharan Africa.

See the supplemental experimental procedures for more information on survey design, questions, respondents, and analysis.

Ethics

The study was overseen by Future Earth, and the research design and survey methodology were approved by the Future Earth Secretariat following the advice of the scientific advisors. Prior informed consent was obtained for all surveys, which were voluntary, and participants had the option to withdraw participation at any time.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2022.08.005.

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AUTHOR CONTRIBUTIONS

Conceptualization, A.L.L., J.G., S.L.R.W., K.C., and M.I.; methodology, S.L.R.W., J.G., K.C., M.I., and A.L.L.; validation, S.L.R.W. and J.G.; formal analysis, J.G., S.L.R.W., and N.S.-K.; investigation, J.G. and S.L.R.W.; data curation, J.G., S.L.R.W., and N.S.-K.; writing – original draft, J.G. and S.L.R.W.; writing – review & editing, J.G., N.S.-K., A.V., H.D.M., and E.U.; visualization, J.G., N.S.-K., and S.L.R.W.; supervision, A.L.L. and E.U.; funding acquisition, A.L.L.; project administration, J.G. and N.S.-K.

DECLARATION OF INTERESTS

The authors declare no competing interests. A.L.L. has an additional affiliation with Microsoft Corporation, a technology company, and S.L.R.W. has changed their affiliation to Habitat, an independent consulting company for the implementation of nature-based solutions. Both changes occurred after the study was commissioned, conducted, written, and initially submitted.

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