Accessibility Guidelines For Neuroinclusive Digital Citizen Science: Results From The Neuro(Minorities)Science Collaboration

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Abstract

Digital citizen science (DCS) operates as a socio-technical mode of public participation in research. Whilst many DCS participants self-identify as neurodivergent, the perspectives of neurodivergent contributors have rarely been treated as a distinct design lens. Drawing on a large-scale 2024 survey of Zooniverse volunteers and a participatory international collaboration with 89 adult neurodivergent citizen scientists and allies contributing across multiple DCS platforms, this study develops actionable accessibility guidelines for neuroinclusive DCS. Using thematic text analysis across two qualitative datasets (84 working-group contributions and 1,669 de-identified survey responses), we identified recurring accessibility barriers and organised 91 recommended features into 11 functional domains spanning all stages of participation, from onboarding and task engagement to interface customisation, moderation, safety and outreach. The resulting framework positions neuroinclusive accessibility as a methodological component shaping participation, retention and research practice. Although grounded in neurodivergent lived experience, the guidelines create pathways for more flexible participation across diverse DCS contexts.

Keywords

digital citizen science, neurodiversity, neuroinclusive design, accessibility, participatory research, open science

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Introduction

This study discusses accessibility guidelines to support the inclusion of neurodivergent volunteers in digital citizen science, prepared by an international working group of adult neurodivergent volunteers and allies.

According to the 2025 Worldmetrics report, “Neurodivergence affects over a billion people with diverse challenges and strengths” (WorldMetrics, 2025). “**Neurodiversity**”, or “neurological diversity” is a highly debated, but widely used, social concept that originated in the 1990s (Singer 2016; Baron-Cohen 2017; Botha et al 2024). It describes the full spectrum of human neurocognitive, communicative, and sensorimotor differences from the social equality perspective. In the broadest interpretation, “**neurodivergence**” is a difference in mental or neurological function from what is considered statistically typical, or “**neurotypical**” (Goldberg

2023). Neurodivergence thus includes innate and acquired nervous system differences, which may or may not result in a disability and a medical diagnosis such as autism, attention deficit hyperactivity disorder (ADHD), dyslexia, colour blindness, stroke, anxiety, post-traumatic stress disorder (PTSD), depression, chronic fatigue syndrome (CFS), sensory processing disorder, etc. (Baron-Cohen 2017; Goldberg 2023; Jones & Orchard 2024).

"Neurodivergence" is not a medical, diagnostic term, but a word to describe the reality where people do not conform to one standard way of interacting with their environment. A group of neurodivergent people with a similar cognitive and sensorimotor profile (a "**neurotype**") will usually share similar challenges and strengths and might need similar support and accessibility accommodations. Doyle (2020) introduces the term "**neurominority**" to describe such a group in social context. The level and type of support a neurodivergent person needs varies, depending on their condition and the demands of their environment.

Citizen science engages the public in scientific research, fostering collaboration, knowledge creation and more inclusive scientific practice (Hecker et al. 2018; European Citizen Science Association 2020; Vohland et al. 2021; Cooper et al. 2021). **Digital citizen science** (DCS) occurs on platforms such as Zooniverse, iNaturalist, European Citizen Science Platform, CitSci and SciStarter, enabling remote participation. Data from a large-scale 2024 study "Zooniverse Participatory Research Platform As A Neuro-Shared Online Space: A User Survey" (Apreleva et al. 2026, in prep.) suggest that many volunteers participating in DCS projects on Zooniverse self-identify as neurodivergent. Many of the 7,873 respondents described participation in citizen science as an accessible, meaningful way of contributing to society and science. Selected comments, representative of themes reported across the wider dataset, illustrate these experiences:

"*The self paced nature of it lets me feel good about being slower than other folks might be able completing a project*"

"*The projects give me a chance to do something productive yet fun and where I don't need to socialize to do it*"

"*Becoming more and more immobile due to my progressive disease, Zooniverse provides a fantastic opportunity to maintain my self esteem, to remain useful for others and to communicate to others with similar interests*"

However, participants also reported that they sometimes needed additional support, explaining that they have "*difficulty reading long texts*", "*need prompting to take breaks*", are "*colourblind*", can do "*no precise clicking (dyspraxia)*", "*can't cope with making a mistake*", and that sometimes the online environment and research projects' presentation poses a challenge, because "*flashing videos cause headaches*", "*layout can be overwhelming with ADHD*", and they may "*struggle if the instructions aren't specific*".

Although DCS platforms aim to align with globally recognised digital accessibility standards as outlined by WCAG - the Web Content Accessibility Guidelines 2.2 (W3C 2024), the perspectives of neurodivergent participants have rarely been treated as a distinct design lens. Consequently, design choices may unintentionally reflect neurotypical assumptions about cognition, communication and comfort.

Existing literature shows that broadening participation can introduce new perspectives that shape research questions, interpretation and methods, and that engagement with under-represented communities supports co-development of research that reflects lived experience rather than narrow epistemic frames (Downs et al, 2021; Paleco et al., 2021).

In response to this gap, and building directly on insights from the 2024 Zooniverse survey, we established Neuro(Minorities)Science, a working group of 89 adult neurodivergent volunteers and allies from multiple countries, including Brazil, France, Mexico, UK and USA. The group developed actionable neuroinclusive accessibility guidelines for DCS. The group was facilitated by a neurodivergent researcher affiliated with the Zooniverse research group at the University of Oxford. To our knowledge, Neuro(Minorities)Science is the first lived-experience collaboration to focus on accessibility features in DCS for neurodivergent people with or without disabilities.

This publication presents the results of the Neuro(Minorities)Science collaboration, the primary outcome of which is ***The List of Accessibility Features For Neuroinclusive Digital Citizen Science*** (*Supplemental file 1*, hereafter referred to as The List). The List is intended as a practical resource for direct use, reuse and adaptation by platform teams, project owners and science communicators. The Background and Methodology provide the theoretical framing and describe the participatory co-creation process used to develop the List. The Results present and interpret the identified accessibility features, showing how they cluster across stages of participation and functional domains. The Discussion situates these findings within DCS as a socio-technical participation environment, examining the methodological role of neuroinclusive design and its modular implementation under real-world constraints. The Conclusions summarise the framework’s implications for DCS practice and policy.

Background

Neurodiversity in the open scholarship context

Whilst multiple studies of neurodiversity in educational settings (Dawson 2022; Mousa et al. 2024; Waisman et al. 2022) and in the workplace (Doyle 2020; Rollnik-Sadowska & Grabińska 2024) exist, research on neurodiversity within DCS remains extremely limited. Until recently, no peer-reviewed studies explicitly examined the participation of disabled or neurodivergent people in citizen science.

A recent qualitative study by Langhans et al. (2025) provides the first evidence of systemic barriers to participation for racially minoritised, disabled and neurodivergent people in participatory science. Drawing on focus groups with people who engage in nature-based activities but do not currently participate in citizen science, the authors identify accessibility barriers, economic constraints and a pervasive lack of belonging as key factors impeding participation. They further note that, while motivations and barriers to participation in citizen science have been examined for other demographic groups, there remains little empirical evidence addressing disabled and neurodivergent participants.

This scarcity of DCS-specific, neuroinclusive evidence is notable given that DCS has matured over the past two decades into a substantive mode of scientific inquiry, with systematic reviews and large-scale analyses showing that citizen-generated data contribute to peer-reviewed research and discovery across the natural sciences, biomedicine, climate science, ecology and the humanities (Blickhan et al. 2020; Finger et al. 2023; Marshall, Lintott and Fletcher 2015; Yu et al. 2025). Responding to the "societal desire to participate more actively in knowledge production, knowledge assessment and decision-making” (Hecker et al. 2018), citizen science is considered a subtype of open science.

Elsherif et al. (2022) argue that neurodiversity and open scholarship movements share core values of accessibility, equity and transparent knowledge-making by fostering environments that recognise diverse ways of thinking and learning. Neurodivergent researchers contribute perspectives - such as attention to detail, reduced cognitive bias and a strong sense of justice - that directly advance open scholarship’s goals of rigour and integrity. At the same time, open scholarship reduces structural barriers that disproportionately exclude neurodivergent scholars by promoting accessible writing, open materials and flexible participation. Together, these movements are mutually reinforcing: science becomes more ethical and inclusive when neurodivergent perspectives are valued, and open scholarship becomes more “open” when neurodivergent people participate.

Digital citizen science as a neuro-shared space

DCS already removes many of the sensory, social and organisational barriers that prevent neurodivergent individuals from participating in scientific processes by allowing contributors to choose when and how they engage, to process information at their own pace and to communicate through preferred modes such as text, asynchronous discussion, or visual tools rather than real-time social interaction. In the words of a 2024 survey participant: “*I think Zooniverse offers a way for people to contribute free of multiple constraints. You don't have to drive anywhere which saves time and reduces personal carbon footprint. You can work at your own pace and at the times that work for you <...> You can work* *solo...without social pressures from having other people around*" (Apreleva et al. 2026, in prep.).

Therefore, it makes sense to conceptualise DCS as a **neuro-shared space**, extending Rosqvist et al.'s (2013) term for environments in which autistic and non-autistic people coexist without one group being expected to adapt disproportionately to the other. We apply this concept broadly to neurodiversity to emphasise the need for platforms where different cognitive and communicative styles can collaborate on equal terms.

Research by neurodivergent citizen scientists for neurodivergent citizen scientists

Neuroinclusive web design has been addressed in prior research and practitioner guidance, primarily through general accessibility principles applicable across various digital contexts.

A 2025 publication explains how WCAG accessibility standards benefit neurodivergent users (WCAG 2025), citing sensory overload, difficult-to-read text, time constraints for completing tasks and unpredictable navigation as the most common accessibility barriers. The following six WCAG success criteria have a significant impact:

1.4.2 A, Audio Control: users have the ability to pause, stop, or control audio that plays automatically for more than three seconds;

2.2.1 A, Timing Adjustable: Users are free to change or extend time limits, providing individuals with the flexibility they need to finish tasks;

2.2.2 A, Pause, Stop, Hide moving, blinking, or scrolling content after five seconds;

3.2.2 A, On Input: changes on a webpage should not occur automatically when a user inputs data, e.g. selecting a checkbox shouldn't trigger an unexpected action like submitting a form.

3.2.3 AA, Consistent Navigation helps users understand where to find key elements like menus, search bars, and links;

3.2.4 AA, Consistent Identification: buttons, links, and icons with the same functionality should be labeled consistently across a website, ensuring clarity and reducing confusion.

Elsewhere, AbilityNet (n.d.) provides a list of digital accessibility resources, including disability-specific resources for dyslexia, hearing loss, Parkinson's disease, dementia and multiple sclerosis.

Both sources provide an essential baseline for inclusive digital design, but are not specific to the needs of neurodivergent people participating in DCS. DCS platforms involve a distinct interaction context characterised by sustained cognitive effort, learning new concepts, repeated task execution and ongoing social interaction between citizen scientists, research teams and platform maintainers. Design choices related to task structure, feedback, pacing and interface customisation therefore play a central role in shaping participation, retention and research quality.

Dehn (2017) argues, based on a detailed analysis of user interface design for DCS, that the heterogeneity of citizen science projects makes the development of a fully generalisable platform design model inherently challenging. Liu et al. (2021) conceptualise citizen science platforms as “instruments” for citizen science, identifying usability and design as the main challenges for platform builders. Drawing on a review of prior literature, they highlight several design considerations, including the need for more human-centred platform conceptions and relative openness of the platform. Highly guided, low-autonomy interfaces can be experienced as frustrating by participants, whereas simpler, more repetitive interfaces that allow greater user autonomy tend to support sustained engagement.

The Neuro(Minorities)Science collaboration contributes to this line of research by producing the first actionable set of accessibility guidelines specifically developed for neuroinclusive DCS. The primary stakeholders of this work are teams maintaining DCS platforms, project owners and managers, and science communicators. Each recommended accessibility feature was emphasised by working group participants as essential for supporting genuinely neurodivergent-friendly participation.

Grounded in neurodivergent lived experience, this inquiry also responds directly to the gap identified by Phillips et al. (2019), who note that few studies have qualitatively characterised citizen science engagement across multiple projects from the perspective of participants.

Although this study is affiliated with Zooniverse - a long-established and most popular DCS platform offering projects in a variety of disciplines - the working group consisted of citizen scientists who contribute to various platforms and projects, and the study did not focus specifically on Zooniverse. The group was mindful to propose guidelines that are universal for all types of DCS projects and platforms.

Methodology, Aims and Process

Working group recruitment

This study employed a participatory, collaborative qualitative design. Adult people (18 years or older) self-identifying as neurodivergent, and as allies, who have experience of contributing to DCS on platforms like Zooniverse, iNaturalist, CisSci and SciStarter, were invited to join the **Neuro(Minorities)Science** working group. Invitations were extended in May and June 2025 via direct group emails to the existing neurodiversity networks like Zooniverse Neurodiversity Task Force and NASA's Neurodiversity Network; and professional organisations dedicated to citizen science such as the Association for Advancing Participatory Sciences, European Citizen Science. Participants were also invited via Zooniverse platforms' pages; a dedicated web page, a conference presentation and social media.

Although this project was facilitated by the lead author, Alisa Apreleva, who is a researcher from the Zooniverse group at the University of Oxford, with professional clinical training and extensive international experience supporting neurodivergent communities, the study did not position working group members as research subjects. All 89 individuals who took part were contributors and co-researchers. The group actively participated in the study, from the ideation stage to the final write-up. The facilitator's role was primarily organisational and supportive, ensuring accessibility, safety and methodological coherence, while the substantive intellectual work was co-produced by the group. The group collaborated asynchronously, in writing, by using online collaborative tools like Miro, Jisc Surveys and Google Workplace. Participation was voluntary, uncompensated except for small incentives, and conducted entirely remotely.

Research aims

The aims of the Neuro(Minorities)Science collaboration were to:

1) identify accessibility challenges in DCS faced by neurodivergent people;

2) raise awareness of these barriers among platform developers, project owners and the wider citizen-science community; and

3) produce an actionable set of accessibility guidelines for neuroinclusive digital citizen-science projects and platforms.

Methodology and process

Phase 1: Data collection and preparation

During the first stage, working group members were invited to share their views, experiences and domain knowledge regarding the accessibility of DCS for neurodivergent people. Contributors responded in writing to the prompt: *"What accessibility features must citizen science projects and platforms have to enable neurodivergent people to participate more actively and more comfortably in online citizen science?"*

Participants also shared relevant resources, reading materials and examples of good practice in digital accessibility. These contributions formed a rich lived-experience **Dataset 1** (*Supplemental file 2*) of 84 entries that became the foundation for subsequent phases of analysis and the development.

To strengthen the robustness and representativeness of the findings, the study also incorporated secondary data from the large-scale 2024 Zooniverse Neurodiversity Survey (Apreleva et al. 2026, in prep.). The facilitator prepared a pre-filtered, fully de-identified subset of 1,669 free-text responses to the question: *"Do you think Zooniverse research experience could be improved for people with neurodivergent conditions? If so, how?"* This subset was designated as **Dataset 2** (*Supplemental file 3*) and made available to the working group for use in subsequent stages of the collaborative qualitative analysis.

Whilst the smaller Dataset 1 produced by the working group was open for analysis by all participants, Dataset 2 was assigned in segments of 100 responses individually to the 17 citizen scientists who expressed their interest in this work upon completing analysis of Dataset 1.

Phase 2: Thematic text analysis

We employed the **thematic text analysis (TTA)** method to identify and interpret patterns across both datasets. TTA is a qualitative analytic method used to identify, organise and interpret patterned meanings across a body of textual data. It focuses on themes understood as recurring configurations of meaning that capture how participants experience a phenomenon (Braun & Clarke 2006; Nowell et al. 2017). This method is well-suited to community-led research because it is epistemologically non-prescriptive (and, as such, open to community meaning-making), transparent in procedure and able to integrate large volumes of heterogeneous qualitative material.

All participants received guidance on the steps of TA and were introduced to the use of shared online Miro board tools for coding and organising data. Citizen scientists were also offered an option to email the results to the facilitator in text form. The facilitator took part in all stages of the analysis alongside the participants. This process established a shared methodological foundation and ensured that contributors with diverse backgrounds were able to participate confidently and consistently in the analytic process.

The analysis followed the six phases outlined by Braun and Clarke (2006) and happened separately for Dataset 1 and Dataset 2 during phases 1 - 4, to accommodate the work process for the two different analyst groups, after which the data were merged for phases 5 and 6. Each phase lasted several weeks to accommodate the asynchronous group process.

1. **Familiarisation**. Citizen scientists read and re-read the data with the purpose of noticing the recurring ideas.
2. **Generating initial codes**. Citizen scientists found text segments relevant to neuroinclusion, accessibility, barriers, needs, and formulated a "code" (short description, sometimes in the form of a quote) for each idea they encountered. Each code was added to a separate "sticky note" on a common Miro board.
3. **Searching for themes**. The facilitator grouped the codes with similar or adjacent meanings into the initial set of "themes" (e.g. Colour-blind features, Cross-Device Accessibility, Support, Integrity, Community). Each theme was visually represented by a separate

surface on the collaborative Miro board, which contained the "sticky notes" with relevant codes suggested by citizen scientists.

4. **Reviewing themes**: This process of matching codes to themes happened in multiple iterations for each dataset. Any citizen scientist in the group could create or rename a theme and add or move codes across themes until no further changes were suggested. The facilitator did not make any changes to the boards at this point.
5. **Defining and naming themes**: Final themes resulting from both datasets were reviewed by the facilitator, transferred to an Excel spreadsheet as a list and structured into 11 functional domains corresponding to practical areas of accessibility. Changes were made to the list, based on comments from citizen scientists, until no further changes were suggested.
6. **Producing the report**: Citizen scientists worked together in a Google Document to draft and refine the article text and create the accessibility guidelines with commentary and examples.

Collaborative, cyclic review was used to strengthen credibility and reduce interpretive blind spots. Group analysis does not remove subjectivity but improves rigour through reflexive triangulation - multiple perspectives interrogating the same data (Nowell et al. 2017). Across iterations, participants identified common patterns, challenged ambiguous or inconsistent interpretations, refined theme boundaries, compared findings across the datasets and cross-checked themes against existing sources on digital accessibility.

Results

Main empirical outcome

The Neuro(Minorities)Science collaboration produced a structured set of accessibility guidelines for neuroinclusive DCS, supported by qualitative analysis of two datasets. **The primary empirical outcome of this study is *The List of Accessibility Features for Neuroinclusive Digital Citizen Science*, which captures 91 features identified by neurodivergent citizen scientists as essential for comfortable and successful participation**. It is intended for direct use by DCS platform teams, project owners and science communicators when making decisions about neuroinclusion practices.

Interpreting neuroinclusion requirements

Our research demonstrates that neurodivergent needs are often cognitive, sensory, or social in nature and therefore largely invisible within conventional web design and evaluation processes. As a result, accessibility barriers may go unrecognised until they appear as disengagement or volunteer withdrawal. The foundational elements of neuroinclusive accessibility therefore require interpretation grounded in neurodivergent expertise to be actionable in practice. The accessibility guidelines presented in this study function not only as recommendations but as translational work, bridging lived neurodivergent experience and DCS design practice.

The 91 recommended features spanned both technical user-facing features (e.g., display customisation, interaction modes, break reminders) **and social-organisational practices** (e.g., communication style, moderation, feedback framing, transparency about research processes). All features were further organised into **11 functional domains to** reflect recurring patterns in how accessibility barriers arise across the lifecycle of participation in DCS, from first contact with a project through sustained contribution and community interaction:

- Onboarding
- Project Instructions
- Task Presentation
- Integrity
- Co-design
- Project Management
- Safety
- Human Value
- Web Interface (Technical Functionality): General
- Web Interface (Technical Functionality): Opt-in Features
- Outreach

Together, the 11 domains constitute a structured accessibility framework for neuroinclusive DCS, addressing technical, communicative and organisational dimensions of participation.

Social-organisational practices for neuroinclusive digital citizen science

Onboarding

Features from the **Onboarding** domain support the first contact with the multi-project platform or a standalone project web page, including how information is presented, how expectations are communicated and how volunteers assess whether participation is appropriate and safe for them.

As an essential first step toward neuroinclusivity, DCS projects and platforms should be explicitly neurodiversity-welcoming. The group agreed that early signals of acceptance and safety strongly influence whether neurodivergent individuals perceive participation as possible. Visible indicators of inclusion help reduce uncertainty and communicate that neurodivergent differences are expected rather than exceptional, for example through visual symbols such as the sunflower for invisible disabilities (Hidden Disabilities Sunflower Scheme n.d.), the rainbow infinity sign commonly associated with neurodiversity (Xu et al. 2025), or clear written affirmations such as *"We Celebrate Neurodiversity"*.

This finding is consistent with evidence from participatory science focus groups showing that a lack of visible belonging and cultural welcome can discourage participation even when projects align with participants' interests and skills (Langhans et al. 2025).

Visible acceptance and dedicated accessibility support help shift participation from conditional tolerance to genuine inclusion and reduce the need for "masking" in DCS environments. Masking - suppressing authentic behaviours to appear neurotypical – has been described by the group as cognitively and emotionally exhausting, leading to burnout, anxiety and identity fragmentation. As one contributor to our group explained, *"Masking is how we manage in public... it's truly exhausting and not always successful"*. Although research has focused primarily on autistic masking (Pearson and Rose 2021), participants in this study indicated that masking pressures extend across neurodivergent conditions.

Project instructions and task presentation

Features from the **Project Instructions** and **Task Presentation** domains offer practical recommendations for the project design stage and address how scientific tasks are explained, structured and experienced during active participation, including clarity, pacing and error tolerance.

Integrity and human value

The **Integrity** domain focuses on transparency, honesty and trust in research processes, including explanations of purpose, data use and outcomes, and the **Human Value** domain captures practices that recognise and affirm volunteer contributions, linking individual effort to collective scientific impact.

Co-design

The **Co-design** approach aligns with the fourth principle of citizen science, which emphasises that "citizen scientists may, if they wish, participate in multiple stages of the scientific process" (Robinson et al. 2018). Because neuroinclusive accessibility needs are highly heterogeneous and context-dependent, they cannot be fully anticipated from any single design perspective, regardless of a designer's neurotype. While accessibility guidelines, such as WCAG 2.2 (W3C 2024), provide an essential foundation, effective implementation requires engagement with neurodivergent testers who bring diverse lived experience. Involving neurodivergent citizen scientists throughout the project lifecycle, particularly during early stages of developing instructions, tutorials and task interfaces, improves clarity and usability, enables early identification of participation risks and complements guideline-based design. Where possible, those participating in such efforts should be compensated or otherwise recognised for their expertise.

Project management

The **Project Management** domain captures organisational and relational practices that shape how volunteers experience participation over time. This domain includes the provision of responsive help and question-and-answer spaces, moderated community environments, clear codes of conduct and private communication channels between volunteers and research teams. Participants emphasised that project coordinators and moderators play a critical role in sustaining neuroinclusive participation, particularly when they are mindful of diverse communication styles, uncertainty and support needs among neurodivergent and disabled contributors. Training and ongoing awareness among project staff were therefore identified as central to creating predictable, respectful and supportive participation environments.

Safety

The **Safety** domain highlights the social, sensory, cognitive and emotional risks that may arise during participation and identifies features that support psychological and physical wellbeing in online research environments. Safety is a foundational requirement for neuroinclusive participation. It extends beyond basic online safety norms and directly influences sustained engagement. Yet many safety risks in DCS are not immediately apparent to project owners without lived neurodivergent experience.

Social safety requires clear moderation protocols and data security policies to address hateful, intimidating, or inappropriate behaviour. Forums may become exclusionary when contributors criticise others' tone, communication style, or perceived expertise. Volunteers should have accessible, private mechanisms for reporting concerns, which must be handled consistently and transparently, as the absence of clear safeguards can exacerbate anxiety and discourage participation.

Neurodiversity-aware moderation is essential to support respectful interaction across diverse communication styles. Support should be empathetic and focused not only on solving a technical issue but also on ensuring volunteers feel safe and understood. Moderators should recognise that neurodivergent and neurotypical communication styles can differ in tone and expression. Direct language, common among some autistic people, may sometimes be perceived by neurotypical participants as abrupt or sarcastic, while differences in phrasing or formality can lead to misunderstanding on both sides. Messages from volunteers with limited mobility or dyspraxia may contain frequent typos or inconsistent spelling. These variations do not reflect a lack of intelligence or respect. Neurotypical participants, moderators and project teams alike can benefit from learning about neurodivergent communication styles and barriers, fostering an atmosphere where everyone can express themselves authentically and feel valued as contributors.

Sensory safety is equally critical. Participants reported that sudden exposure to disturbing content, such as injured animals, unexpected audio, or flashing patterns, could lead to shutdown or heightened anxiety. Optional content warnings, the ability to disable autoplay and options to skip distressing material reduce risk by allowing volunteers to prepare and retain control over their engagement.

Cognitive and emotional safety are also shaped by task structure and feedback. Repetitive tasks may encourage hyperfocus, particularly among neurodivergent volunteers with ADHD, enhancing performance while obscuring fatigue and increasing the risk of exhaustion or abrupt withdrawal (Ashinoff and Abu-Akel 2021). Optional, user-controlled break reminders and small task segments with visible progress indicators can support pacing and consistent contribution. Feedback and error messages should reduce error anxiety and repeatedly reassure volunteers that occasional mistakes do not compromise research quality.

Customisation as the technical foundation of neuroinclusion

Consistent with prior work by Dehn (2017) and Liu et al. (2021), we have found that it is not possible to recommend one generalised web design model across DCS projects with different goals, task structures and audiences, and universal design alone may not be useful to improve accessibility for neurominorities. We recommend that multi-project DCS platforms offer highly customisable interfaces allowing individuals to tailor the environment to their cognitive and sensory preferences.

To aid practical implementation, we divided the functional web interface recommendations into two domains. The **Web interface (technical functionality): General recommendations** domain outlines the features useful for most volunteers regardless of device, ability or neurotype. The **Web interface (technical functionality): Opt-in features** domain focuses on personalisation for different neurotypes.

Web interface (technical functionality): General recommendations

We recommend that DCS interfaces maintain a clean, logical and consistent layout that minimises cognitive effort and supports intuitive navigation. Predictable structure and clear labelling help volunteers focus on research tasks rather than interface mechanics.

A highly visible accessibility statement should outline available assistive technology support and explain compatibility with standard built-in browser accessibility features and adaptive tools such as screen readers, high-contrast modes, text-to-speech, voice-activated commands and alternative input devices.

Platforms should allow multiple data entry techniques, including keyboard, mouse, touch and speech recognition, to accommodate diverse physical and sensory needs and include an option to display passwords in plain text when logging in.

Interfaces must function reliably across different devices, browsers and operating systems, with particular attention to mobile optimisation. Layouts should adapt seamlessly to various screen sizes, ensuring that essential controls remain visible and accessible. Visual accessibility is enhanced by user-controlled zoom that operates gradually and smoothly, avoiding abrupt transitions which may disorient users.

Finding a DCS project that aligns with one's skills and interests can be challenging for neurodivergent volunteers, and excessive choice can become overwhelming. To support volunteers in navigating this landscape, we suggest that multi-project platforms develop recommendation tools informed by past activity, configurable interest lists or brief quizzes. These tools should also allow filtering by task complexity, type of task, expected time per classification and required skills.

Web interface (technical functionality): Opt-in features

Opt-in accessibility features enable volunteers to tailor the digital environment to their sensory, cognitive and motor preferences, for example through a checkbox-based settings panel and, where possible, predefined templates reflecting common neurotype profiles.The group emphasised that customisation should be balanced to ensure that environments remain comfortable and usable for neurotypical volunteers as well.

For example, to help reduce distraction and sensory overload, platforms should offer options to increase button size, hide non-essential components such as toolbars or guides, choose a pre-set minimalist layout or turn on a “screen mask” which allows volunteers to focus on a small, highlighted area and while darkening the surrounding content.

A dyslexic user should be able to choose font style and size, including dyslexia-friendly or sans-serif options (Braille Institute n.d.; Barstow 2021; Staake 2022) and modify colour schemes through custom or dark-mode palettes. As one of the group participants explained, *“The task of classifying data based on reading in a standard high-contrast interface (black text on a white background) can be unbearable for a volunteer with dyslexia or Irlen Syndrome, causing eye strain and headaches”*. The group agreed that no single font or background works for everyone, including within the dyslexic community, and thus providing a choice is essential. Other dyslexia-specific tools include word prediction and audible clues.

Features supporting colour-blind users should include adjustable foreground/background contrast ratios (WebAIM n.d.) and clear warnings when colour-dependent projects are unsuitable.

To support volunteers with attention differences, platforms should offer options to set custom participation limits based on time or number of classifications, helping to prevent overwork and burnout. Positive reinforcement features, such as pop-up congratulations, real-time milestone notifications, or messages highlighting collective project progress, can help sustain attention and motivation. By contrast, gamification elements such as leaderboards or points remain controversial: while they may be motivating for some users, competitive settings can cause stress and may reduce motivation for others. Gamified features should therefore be optional rather than default. We recommend that DCS teams draw on existing empirical and theoretical research when considering the use of gamification in project design (Sailer et al. 2017; Greenhill et al. 2016; Satrio et al. 2025).

DCS developers seeking to further understand neurominority needs can refer to open-access resources such as Rusakova (2020), the ADHD-Friendly design guide (Bureau of Internet Accessibility 2021) and disability-specific resources offered by (AbilityNet n.d.).

The level of fine-grained customisation beneficial for neurodivergent users may sometimes be achieved through using web accessibility overlays - technologies that aim to improve the accessibility of a website. For example, the National Autistic Society website uses the Recite Me accessibility toolbar. This feature allows users to customise colour contrast, text size, fonts and spacing, and to use screen-reading or translation tools according to their individual preferences. However, experts have raised concerns that third-party accessibility overlays may not always meet accessibility standards and can introduce new barriers including risks to data protection and conflicts with assistive technologies (Overlay Fact Sheet n.d.).

In the context of the European Accessibility Act (Online ADA 2024) and the Americans with Disabilities Act (U.S. Department of Justice 2022), WCAG compliance is increasingly becoming a legal requirement. Most operating systems already offer settings to adjust font size, colour contrast and interaction modes, yet research and user feedback show that volunteers value having these adjustments surfaced clearly in an easy-to-access settings panel, as discussed earlier in this section. If an overlay is itself accessible, easy to use, does not interfere with assistive technologies, and the base platform is WCAG compliant, it can be an empowering tool, and our research suggests it is worth considering.

Neuroinclusive pathways to digital citizen science engagement

Outreach

The **Outreach** domain addresses how projects are framed and communicated beyond existing communities. Participants emphasised that outreach materials strongly influence who feels invited and able to participate, particularly for neurodivergent and disabled individuals who may self-exclude in the absence of clear accessibility cues. In the words of one working group participant: *"Targeted advertising should be done with extreme care and sensitivity, using empowering and positive language (e.g., 'Your detailed focus or interest is a strength'). I suggest prioritising partnerships with advocacy organisations led by neurodivergent people, rather than relying solely on broad digital ads. This is an important topic, as the internet is currently full of misinformation about neurodivergence"*.

Thoughtful outreach was therefore identified as a key mechanism through which projects can broaden participation and reduce barriers before engagement begins.

Discussion

Neuroinclusive accessibility as a methodological framework

DCS platforms are complex socio-technical systems with a distinct form of online participation, characterised by sustained cognitive effort, repeated task execution, rule learning and uncertainty management within a collective research context. When these features intersect with neurodivergent differences, such as sensory processing, attention regulation, language processing and tolerance of ambiguity, accessibility adjustments that extend beyond baseline web standards are required.

Prior work has shown that project design, interface usability and participation structures influence volunteer engagement, retention and data quality in citizen science (Phillips et al. 2019; Liu et al. 2021; Downs et al. 2021). When accessibility barriers are present, volunteers may disengage, contribute inconsistently or self-select out of projects altogether, with implications for data completeness and research timelines. Neuroinclusive design and management in DCS should thus be understood not simply as matters of inclusivity or social justice, but as part of the DCS methodological framework that shapes who participates, how they contribute, as well as the reliability and quality of the scientific knowledge produced.

Implementing neuroinclusive design: a modular approach

Our results suggest that neuroinclusive DCS practice depends on balancing two interconnected dimensions of participation. First, features that support autonomy, including clear onboarding, structured instructions, predictable task presentation, interface customisation and the ability to work in a user-controlled environment, enable volunteers to participate independently and comfortably. Second, features that support collaboration, such as transparent communication, inclusive project management, ethical recognition practices and safe neuro-shared spaces, help volunteers understand the value of their contributions and remain connected to the wider research effort. Together, these dimensions contribute to what Elsherif et al. (2022) describe as "an environment that benefits all and is crucial to some".

While customisable technical design is central to supporting volunteer autonomy, DCS is inherently a collective endeavour. Participation therefore depends not only on interface-level accessibility, but also on how projects are organised, supported and managed over time. Translating technical accessibility requirements into meaningful participation thus requires implementation across multiple layers of project design and operation.

Prior research indicates that citizen science project managers often view engagement as something that develops organically, while simultaneously reporting limited time, resources and institutional support to engage with volunteers in sustained ways (Collins et al. 2022). In recognition of these constraints, the accessibility guidelines proposed here are intentionally adaptable rather than prescriptive, supporting staged implementation based on impact and feasibility. Within this approach, accessibility is understood as a modular, poly-level process operating across communication practices, interface design and technical infrastructure. Some features form a baseline for participation, while others can be implemented at more advanced stages or offered through configuration, allowing projects to respond to the heterogeneous needs of neurodiverse audiences.

Importantly, many neuroinclusive accessibility measures can be implemented through low-cost, intentional adjustments to communication and project management practices, such as clear project descriptions, transparent expectations and consistent recognition of volunteer contributions. Langhans et al. (2025) provide a valuable initial set of considerations for project managers and moderators seeking to make participatory science more inclusive, particularly through organisational practices that support accessibility and belonging. Other measures, particularly those involving advanced customisation, require technical expertise and dedicated funding. Recognising this variation allows projects to move incrementally toward neuroinclusive practice rather than treating accessibility as an all-or-nothing undertaking.

For further guidance, we refer readers to ***The List Of Accessibility Features For Neuroinclusive Digital Citizen Science***, alongside established open-access resources on digital accessibility practice, including (AbilityNet n.d.; WCAG 2025). Together, these resources offer practical support for DCS project teams and platform developers seeking to strengthen neuroinclusive participation over time.

Conclusions

Neuroinclusive design in DCS can be understood as a methodological framework that expands the range of viable participation styles and, in doing so, strengthens research robustness, data continuity and long-term volunteer engagement.

The accessibility guidelines developed in this study are intended to be actionable across multiple levels of practice. At the platform level, they support the integration of neuroinclusive accessibility into interface design, moderation systems and governance structures. At the project level, they offer practical guidance for task design, onboarding, communication and participation management. For funders and research institutions, the guidelines provide a framework for evaluating accessibility not only in terms of compliance, but in relation to participation quality, retention and research outcomes.

Consistent with Elsherif et al. (2022), building genuinely participatory and neuroinclusive research environments is central to open, equitable and socially grounded scientific discovery. Many of the recommendations identified here are likely to benefit a broader range of contributors beyond neurodivergent participants, including younger volunteers, older adults, English language learners and neurotypical participants. This reflects the principle that design choices supporting marginalised participants often improve participation conditions more broadly (Cooper et al. 2021). Written from a neurodivergent perspective, this work offers a practical reference for ongoing efforts to align digital citizen science with inclusive and responsible research practices.

Supplemental Materials

Supplemental file 1: The List of Accessibility Features for Neuroinclusive Digital Citizen Science.

DOI: https://doi.org/10.5281/zenodo.18594965

Supplemental file 2: Dataset 1.

DOI: https://doi.org/10.5281/zenodo.18609915

Supplemental file 3: Dataset 2.

DOI: https://doi.org/10.5281/zenodo.18612669

Data Availability

All qualitative datasets and the accessibility framework are openly available via Zenodo at the DOIs listed above. Files are publicly accessible without restriction.

Competing Interests

The authors have no competing interests to declare.

Ethics

The study received research ethics approval (R94294/RE001) from the Central University Research Ethics Committee at the University of Oxford.

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Authors' Contributions

AA led conceptualisation, analysis of Datasets 1 and 2, review, writing, supervision. AMHA, RA, JC, GF, AMG, IH, FH, CH, CK, HHFdM, IT, CAT contributed to conceptualisation, analysis of Datasets 1 and 2, review, writing. MC, ACG, RFJ, MLK contributed to conceptualisation, analysis of Dataset 1, review, writing. RG, MKJ contributed to conceptualisation, analysis of Dataset 1, review. EEG, EPP, SZ contributed to conceptualisation, analysis of Dataset 1. KL contributed to conceptualisation, analysis of Datasets 1 and 2, writing. AAA, MTG contributed to conceptualisation. BN contributed to analysis of Datasets 1 and 2, review, writing. MR contributed to review and writing. SS contributed to review. CL, LT, SB contributed to conceptualisation, review, writing, supervision. Not all participants in the Neuro(Minorities)Science working group elected to be listed as authors.

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