A systematic scoping review of the ethics of Contributor Role Ontologies and Taxonomies

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Abstract

Contributor Role Ontologies and Taxonomies (CROTs) provide a standard list of roles to specify individual contributions to research. CROTs most common application has been their inclusion alongside author bylines in scholarly publications. With the recent uptake of CROTs among publishers—particularly the Contributor Role Taxonomy (CRediT)—some have anticipated a positive impact on ethical issues regarding the attribution of credit and responsibilities, but others have voiced concerns about CROTs shortcomings and ways they could be misunderstood or have unintended consequences. Since these discussions have never been consolidated, this review collated and explored published viewpoints about the ethics of CROTs. After searching Ovid Medline, Scopus, Web of Science, and Google Scholar, 30 papers met the inclusion criteria and were analyzed. We identified eight themes and 20 specific issues related to the ethics of CROTs and provided four recommendations for CROT developers, custodians, or others seeking to use CROTs in their workflows, policy and practice: 1) Compile comprehensive instructions that explain how CROTs should be used; 2) Improve the coherence of used terms, 3) Translate roles in languages other than English, 4) Communicate a clear vision about future development plans and be transparent about CROTs’ strengths and weaknesses. We conclude that CROTs are not the panacea for unethical attributions and should be complemented with initiatives that support social and infrastructural transformation of scholarly publications.

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Introduction
Contributor Role Ontologies and Taxonomies (CROTs) are recent innovations developed to address a range of ethical issues associated with the attribution of credit and responsibilities and practical use cases in scholarly publications. By providing a standard list of roles to specify individual contributions to publications, CROTs aim to enhance transparency and consistency about reporting diverse research tasks and contributions to the work leading to a publication or published research output, thereby improving the attribution of credit and contributions (Brand et al. 2015). The uptake of CROTs has not been limited to journals. CROTs have also been adopted by repositories (e.g., DARIAH-DE, Zenodo) and universities (e.g., University of Glasgow), and are among recommended solutions to improve research assessment, promotion, and funding processes (Hosseini et al. 2022a). Accordingly, CROTs are becoming a pivotal part of scholarly publications and associated workflows, as they are beneficial not only to researchers (e.g., to receive the deserved credit for their contributions) but also for publishers and their editorial teams (e.g., to enhance understanding about who did what in relation to a publication and who is responsible for each task and accountable for assertions or associated research outputs), funding organizations (e.g., to clarify who benefitted from provided funds), universities’ administration and research offices (e.g., to improve tenure and assessment processes) and libraries (e.g., to enable indexing publications based on involved contributions) (Hosseini et al. 2022b). Currently, the Contributor Role Taxonomy (CRediT) is widely adopted (by journals) and used (by the academic community), has been formalized as an ANSI standard under the custodianship of the National Information Standards Organization (NISO), which is a community-led organization (National Information Standards Organization (NISO) 2022a, 2022b); and has started to be linked to individual ORCID identifiers and associated with specific research outputs, thereby allowing ORCIDs to be directly linked to the roles (Demain 2021).

Thus far, no published review has systematically analyzed CROTs from an ethical perspective (Hosseini and Gordijn 2020), which given their growing significance and uptake in scholarly publishing workflows is both timely and important. Indeed, with the steady increase of collaborative and international research (National Science Board, 2018), and a continuous rise of the number of diverse roles required in research projects, exploring the ethics of CROTs (i.e., the relevant obligations, values, and virtues in relation to CROTs) increases the likelihood of their ethical development and deployment (Hosseini and Gordijn 2020). Having ethical issues categorized under specific themes will be useful for future implementations and the development of CROTs. Furthermore, as will be discussed in the discussion section, there are various misunderstandings in the literature about CROTs and the implications of their use and impact, necessitating further scrutiny and clarification.

The first iteration of this review was conducted in 2020 as an exploratory search of the literature about CROTs and was presented in M.H.’s PhD thesis, which was supervised...
by B.G. and concluded in May 2021 at Dublin City University, Ireland (Hosseini 2021). However, this effort was unsystematic, limited in scope (only Google Scholar and Web of Science were searched), and lacked input and validation of a librarian and a digital infrastructure expert. To address these limitations and extend the analysis and provide a more holistic and multi-dimensional perspective on the development and implementation of CROTs, a librarian (Q.E.W.) and a digital infrastructure expert (K.L.H) were invited to collaborate in this scoping review, which endeavors to answer the following questions:

- What ethical issues of CROTs are discussed in the literature?
- What ethical themes can be identified in the current debate about CROTs?

Methods

We conducted a scoping review in accordance with the reporting guidelines suggested by Tricco et al. (2018), the Preferred Reporting Items for Systematic reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR) and an established protocol (Hosseini et al. 2022). We worked with a research librarian (Q.E.W.) to develop a comprehensive search strategy that incorporated keywords and controlled vocabulary terms describing “contribution,” “attribution” and “authorship,” and CROTs. Terms for CROTs included both descriptive terminology and specific CROT models. We performed the search in Medline (Ovid), Scopus (Elsevier), and Web of Science (Thomson Reuters) on 27 January 2022. No limitations were placed on document type or publication date. We also searched Google Scholar for additional studies. (Full search strategies are available in Appendix 1 and the PRISMA-ScR checklist is available in Appendix 2).

The bibliographic database searches identified 979 records. Upon de-duplication, 576 documents qualified for screening. Titles and abstracts were screened, resulting in the removal of 428 documents based on the following exclusion criteria:

- Non-English sources
- The application of ontologies and taxonomies in areas other than specification of contributions in scholarly collaborations
- CROTs intended for non-scholarly collaborations
- Publication types without a full text (e.g., slides from conference presentations)

Consequently, 148 documents were deemed eligible for full-text reading. After reading the selected full-text articles, 118 documents were excluded because they did not meet all three inclusion criteria:

- Must mention CROTs that are used to specify contributions to scholarly output (e.g., CReditT, TaDiRAH, CRO, DataCite contributorType).
- Must mention the application of CROTs in reporting contributions made to different scholarly outputs (e.g., manuscripts, research protocols, software).
- Ethical issues (i.e., obligations, values, or virtues) in relation to CROTs should be discussed to a significant extent as determined by an ethics expert (M.H.).

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Subsequently, 30 documents that met all three inclusion criteria were deemed eligible for content analysis (Figure 1).

To analyze the sample, five randomly selected (via computer-generated numbers) documents were examined using an inductive approach, which entails labeling sections that describe an ethical issue followed by subsuming labels under ethical themes, and finally, tagging respective documents with relevant themes (Thomas 2006). Choosing this method was motivated by the fact that documents that discussed CROTs, reflected views and perspectives of their authors about how CROTs should be used and were not always exploring the ethics of CROTs in a systematic or structured manner. After reading the first five documents, thirteen initial labels were created [M.H.] and improved by coauthors (B.G. and K.H.). Using these labels, the rest of the sample (consisting of 25 documents) was read and labeled, and where necessary, new labels were created. After charting the data in Microsoft Excel, a draft report was developed [M.H.] and shared with coauthors for debate (B.G. and K.H.). This resulted in creating eleven new labels, merging three labels, and reducing overlap, bringing the total number of labels to 20. These labels were then subsumed under eight ethical themes. Upon rereading the entire sample, the titles of some issues were changed, but no new themes or issues were created. Eventually, all documents were tagged with one or more themes (Figure 2).

Results

Characteristics of the sample

Document types—Of the 30 documents eligible for full text analysis, 22 were peer-reviewed research articles and the rest were commentary, book chapters and conference papers (Figure 3).

Publication trend over time—The 30 selected articles had been published between 2014 and 2021, and included 10 published in 2021 (Figure 4).

Most common ethical issues and the associated themes—Analyzing the sample resulted in identifying eight ethical themes (Figure 5), which encompassed 20 specific ethical issues (Table 1).

A temporal analysis of discussed themes shows that recently, not only ethics of CROTs are discussed more frequently, but also a more diverse range of ethical themes are discussed (Figure 6). In what follows, ethical issues related to each theme are described.

Attribution.: Attribution issues are about improving CROTs’ lists of roles and definitions, extending output types that should be captured by CROTs and using CROTs in specific contexts, all of which directly impact the scope of credit attributions and the extent to which specific disciplinary nuances are captured by CROTs. Ensuring that the range of roles included in CROTs remain inclusive and representative of the diversity of common roles help CROTs to remain relevant and useful.
**Issue 1) Improving CROTs’ lists of roles and definitions.** CROTs’ list of roles should evolve “as science and the types of contributions that may become less or more important change” (Allen, O’Connell, and Kiermer 2019, 73). Indeed, keeping lists current to meet evolving user needs is paramount and among factors that promote the use of CROTs (Vasilevsky et al., 2021). Although Ding et al. (2021, 7578) asserted that CRediT roles “cover almost the whole process of scientific research of most disciplines,” several publications mentioned specific roles that should be added to CRediT, perhaps because as its developers noted, “CRediT was initially developed and tested as a taxonomy for life and physical sciences” and thus, may not fit all other disciplines (Allen, O’Connell, and Kiermer 2019, 73). Some authors provided specific suggestions for CRediT. For instance, Alpi and Akers (2021, 362) noted that “CRediT does not currently describe all roles that librarians play.” Steele et al. (2021) examined the ability of CRediT to capture the contribution of medical writers to reports of Randomized Controlled Trials (RCTs) in dermatology. They found that in only 1% of published RCTs a distinction is made between copyediting and preparing the first draft (Ibid.).

While Dappert et al. (2017) made a general suggestion to define roles more clearly, others made more specific suggestions. For instance, Matarese and Shashok (2019, 6) claimed that CRediT “ignores” some non-author contributions including technical support, translation and editing the manuscript. They provided specific suggestions to improve three of CRediT’s current roles (Investigation; Writing – Original Draft; Writing – Review & Editing) and add two new roles (Technical support; Translating or editing the manuscript, as non-author). Zhang et al. (2019, 6) noted that some important roles in RCTs such as “randomization, patient enrollment, and follow-up are not clearly defined” by CRediT, and suggested Contributor Roles Taxonomy for Randomized Controlled Trials (CRediT-RCT) that includes ten roles for conducting an RCT (Conceptualization, Funding Acquisition, Project Administration, Site Principal Investigator, Statistical Analysis Plan, Investigation, Data Curation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing). The role of software development for research and CRediT’s shortcomings in capturing involved nuances is highlighted by Alliez et al. (2020). They argued that since software development in research involves “significant innovations,” qualified human intervention and qualitative information are necessary to ensure accurate reporting of contributions (Ibid., p. 48). Accordingly, they suggested nine finer categories for better representation of involved tasks (Design, Debugging, Maintenance, Coding, Architecture, Documentation, Testing, Support, Management).

**Issue 2) Extending output types.** Dappert et al. (2017) noted that CROTs’ scope should be extended beyond peer-reviewed journal articles. While supporting this suggestion, Vasilevsky et al. (2021, 35) highlighted that since output types such as datasets, software, and research protocols “have less well-established workflows to collect and present structured metadata,” this is not easily achieved. Similarly, although two papers specifically noted that capturing contributions to datasets should be improved (McNutt et al. 2018; Mongeon et al. 2017), others highlighted the lack of a robust link between datasets and all their contributors as a factor that “inhibits re-use, verification of research, and detection of scientific fraud” in datasets (Fenner et al. 2015, 309). The absence of robust links between...
contributors and datasets could be explained by the wide range of contributors to datasets (e.g., governments, non-research organization, companies, and other professionals), which often include groups and teams as authors in addition to individual authors. Since there is no ORCID equivalent for groups and teams, such practices reduce consistency and machine-readability of attributions (Mongeon et al. 2017; Dudek, Mongeon, and Bergmans 2019). Although adding groups and teams to the authorship list is also common in peer-reviewed papers, none of the explored documents in the sample mentioned this issue as a challenge.

**Issue 3) The use of CROTs in specific contexts.:** Extending the application of CROTs to other object types could be particularly challenging in some contexts. According to Bliss et al. (2020, 2), in creating digital outputs such as online dictionaries, oral story databases or linguistic atlases, some contributors might only be “involved for a very short time, as short even as just one recording session or consultation,” but others’ contributions might extend to years. This dynamic justifies devising macro-credits and micro-credits to account for discrepancies in terms of the time contributors were engaged in a project. Bliss and colleagues further noted that in their evolving project, which constantly attracts new contributors and contribution types, macro and micro credits are needed. While macro-credits are high-level “general contributor roles such as editor, director, web design, data processing, and funding,” micro-credits are attached to individual items such as dictionary entry and audio files, and “include more specific contributor roles such as speaker, storyteller” (Ibid., p. 13).

Alliez et al. (2020, 47) highlighted the complexities of capturing contributions made to software and questioned the accuracy of taxonomies that flatten out all involved contributions “on the simple role of software developer.” McLaren and Dent (2021, 53) noted that some outputs such as “design protypes, experimental data sets, or methodologies designed to test a hypothesis” are not captured in a digital format during research workflows and sometimes emerge from intangible and immeasurable contributions (e.g., experience), thereby making them complicated to capture by CROTs.

**Impact on authorship.:** Since CROTs are currently used in parallel with authorship bylines, they are discussed within debates about ethics of authorship and sometimes promoted as a solution to resolve known ethical issues of authorship (Although none of the analyzed papers in our sample provided empirical evidence in support of these claims, it seems as though CROTs are expected to resolve issues that are almost outside of their scope. Authorship disputes, honorary authorships, and challenges of defining authorship order or employing authorship definitions are among the side effects of using a whole different attribution paradigm (i.e., authorship), and, as mentioned by some of the cited documents, are impossible to resolve only with the existing CROTs).

**Issue 4) Authorship disputes.:** Some publications suggest that using CROTs (and CRediT in particular) minimizes the likelihood of specific ethical issues of authorship. Using CRediT is intended to not only reduce authorship disputes (Brand et al. 2015), but also “support research institutions and authors to resolve author disputes by providing more transparency around individual author roles and responsibility” (emphasis added) (Allen, O’Connell, and Kiermer 2019, 72). Holcombe (2019) anticipates that since CRediT is implemented with
checkboxes to choose contributions (as opposed to authorship criteria that requires reading large amounts of text and complicated inferences), it is likely to induce better engagement from researchers because navigating checkboxes is easier than reading authorship criteria. However, Matarese and Shashok (2019) noted that checkboxes induce authors to choose more roles than they would declare in a free-text form, thereby suggesting that although CROTs might be easier to use, but they might contribute to other ethical issues.

**Issue 5) Honorary authorship.** Teixeira da Silva (2021) and Holcombe (2019) suggested that using CRediT can reduce honorary authorship because it reduces ambiguity about contribution types. However, this view is challenged by Larivière, Pontille, and Sugimoto (2021, 124) who argued that researchers could also adopt practices like ghost, guest, and gift authorship when using CROTs. They further concluded that CROTs “systematic description of work does not, therefore, preclude invisibility, but only displaces it elsewhere. Consequently, it leaves ghostwriting of articles and potential honorary contributorship in the backrooms of scientific research” (Ibid.).

**Issue 6) Authorship order.** Using CRediT is believed to reduce ethical challenges regarding authorship order as well. Without alluding to how using CROTs will influence author order across disciplines (where order is strongly guided by specific norms), McNutt et al. (2018, 2559) claimed that adopting CRediT would “help alleviate some of the confusion across disciplines and cultures regarding the meaning of author order.” Using CRediT is also considered as a reasonable strategy to “minimize interpretation of [authorship] order and variability in perceptions of roles” (Poirier, Keys, and Ferguson 2021, 226).

**Issue 7) Authorship standards.** Although McNutt et al. (2018) and Holcombe (2019) explicitly noted that CRediT improves current authorship standards from an ethical perspective, some explained why this claim might not be true. For example, Bliss et al. (2020) argued that CRediT does not help distinguishing those who should be listed in the author byline from those who should be acknowledged. Matarese and Shashok (2019, 6) stressed a similar point, highlighting that CRediT is “only applicable to byline authors.” This could, in part, be because CRediT (as a model) does not resolve questions “about the quantity and quality of contribution that qualify for authorship” (Larivière, Pontille, and Sugimoto 2021, 124), and while some of its roles overlap with elements of authorship, they “do not fully encapsulate in any single role, the concept of authorship” (McLaren and Dent 2021, 53). Furthermore, CRediT does not provide clarity on one of the most challenging aspects of defining authorship, namely the notion of “substantial contribution” (Smith and Master 2017, 253).

**CROTs’ design.** Ethical issues about CROTs’ design pertain to the overall architecture and design of CROTs, which ultimately affect an ethical attribution of credit and responsibilities.

**Issue 8) Open or controlled vocabularies.** Open-ended lists allow the addition of new roles and thus, essentially accommodate the recognition of any task deemed relevant in a project, but controlled lists only entail a certain number of tasks and unless updated, only allow recognizing these tasks. In their introduction of the CRediT taxonomy, Brand et al. (2015, 154) stressed that “a controlled vocabulary of contributor roles” is needed within
the scholarly ecosystem. Craig’s (2018, 46) citation of suggestions provided by the UK Academy of Medical Sciences explained the rationale for this need: “So that individuals encounter the same system in all work, whether as a researcher or an appraiser.” Those in favor of open vocabularies, however, advocated for “fast changing” fields in terms of used techniques and objects, e.g., digital humanities (Dombrowski and Perkins 2014, para. 2) or projects that involve a “continuously evolving” set of roles both at the project and item level, as well as the preference to prioritize “the wishes of the contributors of each project over perceived consistency” (Bliss et al. 2020, 13).

Although both Larivière, Pontille, and Sugimoto (2021) and Borek et al. (2021, 325) noted that a CROT’s list of roles can never be complete, the latter added that they do not have to be complete but instead should be “open for extensions without the need to revise existing definitions.” The open-endedness of list of vocabularies is also implied in design requirements suggested by Sauermann and Haeussler (2017, 9) who stressed that CROTs should be flexible to accommodate nuances across projects and fields and, also, “anticipate changes to scientific activity, such as growing team size and specialization, automation and commoditization of certain research activities, as well as broader participation by nonprofessional scientists.”

**Issue 9) Strategies for selecting terms for a vocabulary.** Strategies used for choosing terms for a vocabulary, affect how vocabularies are understood and used in practice, thereby affecting the attribution of credit and responsibilities. While specific terms support precision, broad terms support “consistent application, collocation and recall” (Borek et al. 2014, 182). Furthermore, selected terms should be reconciled with existing taxonomies (e.g., tags currently used by repositories and libraries) and strike a balance between theoretical correctness and commonly used terms “(visualization + geospatial coordinates object vs. mapping)” (Ibid.). Selecting terms for vocabularies also affects the evolution of CROTs, because sometimes decisions must be made about whether a role is “distinct enough to stand on its own as a separate category (e.g., storage vs. storage and dissemination)” or it can be subsumed under existing categories (Borek et al. 2016, 5).

Selecting terms for roles that are inherently related and/or roles that are conducted by the same person are discussed as well. For instance, Zhang et al. (2019, 6) suggested that in RCTs, roles such as formal analysis and software (both among CRedit roles) cannot always be described with unique terms because “statisticians need to use software to perform formal analysis.” Challenges of updating terms in CROTs are briefly discussed in relation to TaDiRAH, whose developers suggested using “the property skos:closeMatch” to create a mapping between old and new terms (Borek et al. 2021, 328).

**Impact on reporting scholarly contributions.** These ethical issues are concerned with the impact of using CROTs on reported contributions to scholarly work.

**Issue 10) Strategic and opportunistic use of CROTs.** Larivière, Pontille, and Sugimoto (2021, 124) noted that since contributions and gained credit are inevitably tied to the reward system of science and the *symbolic capital* in academia, goal displacement (i.e., behavioral modification to “meet certain requirements, norms or incentives”) might happen...
upon wider adoption of CROTs (2021, p. 124). As an example, they suggested that the disproportionately high number of PLOS Medicine authors assigned with CRediT’s roles of “Writing – Original Draft” and “Writing – Review & Editing” may be explained by authors’ attempt to demonstrate adherence to the ICMJE authorship criteria (as the ICMJE’s second criterion explicitly requires a contribution to the writing process). Furthermore, they noted the risk of financial conflict of interests being disguised when CROTs are in publications that report industry-academia collaborations. From an industry-partner perspective, authorship implies intellectual intervention whereas contribution to tasks might help “avoid allegations of conflicts of interest” (Ibid.).

Three publications mentioned the impact of CROTs on inaccurate reporting of contributions. Matarese and Shashok (2019, 8) noted that since CRediT is only used to describe authors’ contributions (thereby omitting non-author contributors), it could induce authors to “unintentionally yet misleadingly shift credit for certain tasks from the people who did the work to people named in the byline as authors.” Larivière, Pontille, and Sugimoto (2021, 124) expressed concerns about disciplinary differences in terms of interpreting contributions, and the presumed link between the actual labor and its indicators, speculating that the discrepancy between the two could be further obscured by researchers’ strategic behavior, e.g., favoring “good working relationships.” Sauermann and Haeussler (2017) highlighted that using CROTs may encourage researchers to crowd into tasks that are considered more valuable and dissociate themselves with tasks considered less important or those with a greater potential for risk of error.

**Issue 11) Responsibility and accountability.** A survey to investigate contributions made by undergraduate assistants to research projects suggested that since collaborators with different levels of seniority might have dissimilar assumptions about the “level” as well as “range of responsibilities over time,” mentors and students may sometimes have different impressions of individual responsibilities (Honoré et al. 2020, 42). For example, when conducting Data curation and Investigation tasks (often involving “repetitive work guided by structured procedures and protocols”), both mentors and student researchers assume high levels of responsibility for students. However, when it comes to tasks such as Validation or Writing, a discrepancy is reported between assumed responsibilities (Ibid.).

Two publications mentioned CRediT and the ICMJE criteria in the context of responsibilities. McLaren and Dent (2021, 53) noted that while authorship credit “carries additional layers of rights, responsibilities, and ultimate accountability for the work” and is also subject to stringent tests such as the ICMJE criteria, CRediT is only concerned with acknowledging (some of the) contributions. Teixeira da Silva (2021, 1118) noted that CRediT is an improvement to the ICMJE recommendations “increasing the transparency of author contributions and stating with greater clarity the contribution of each author, potentially fortifying accountability.”

**Issue 12) Significance and extent of contributions.** Two publications highlighted CRediT’s inability to rate different tasks based on their significance for a project, which results in ambiguities about the overall significance of individual contributions. While Ding et al. (2021) noted that knowing each role’s significance in relation to the whole work helps
differentiate their importance, the argument provided by Smith and Master (2017)—i.e., that the importance or value of roles varies per project and context—implies that this clarification cannot be a default assumption built into CROTs (2017). Furthermore, Smith and Master (2017, 253) provided an analogy to the notion of substantial contribution in using authorship definitions and suggest that when using CRediT, “it remains unclear how much an individual must contribute” to qualify as a contributor. They noted that since being fully inclusive results in lengthy lists of names “including those individuals who provide minor contributions,” some form of quantification “is, and will always be, necessary” (Ibid.). Nevertheless, Alliez et al. (2020) claimed that attempts to quantify contributions, even if automated (e.g., to capture contributions to software development), could be gamed to inflate contributions to an individual’s benefit.

Assessment: The attributed credit for conducting research-related tasks is ultimately reflected in resumes and used for assessing researchers in academic hiring and promotion processes. Ethical issues discussed in this section are concerned with the implications of using CROTs in academic assessments.

Issue 13) Improving academic assessment and evaluation.: While Smith and Master (2017) noted that CROTs are unlikely to be used as metrics of performance without authorship, others argued that they may facilitate “the development of contribution-based indices to complement authorship-based indices” (Sauermann and Haeussler 2017, 9) or allow developing altogether “new metrics of individual research productivity and impact” (Alpi and Akers 2021, 362). Whether as standalone or in combination with authorship, these changes require the development of infrastructure to integrate CROTs into funding agencies’ submissions and progress reports and institutional hiring and assessment workflows (Vasilevsky et al. 2021). Another aspect where CROTs can benefit research assessment pertains to the peer review process. Integrating CROTs into review processes could improve efficiency by means of connecting reviewers to specific contributions based on proficiency and expertise (Ilik et al. 2018; McNutt et al. 2018; McLaren and Dent 2021).

Issue 14) Improving equity and diversity in academic work and evaluation.: Two publications claimed that since using CROTs improves Meta Science (i.e., the science of science), their wide adoption could provide new insights about the distribution of labor in academia and help addressing gender and diversity challenges (Alpi and Akers 2021; Allen, O’Connell, and Kiermer 2019). In fact, Larivière et al. (2021) use of the CRediT roles of articles published in PLOS journals between 2017 and 2018 is an example of how CROTs could be used in Meta Science (these authors note that the quality of such studies is highly dependent on the accuracy of reported contributions). Among other conclusions, Larivière and colleagues(2021, 119) noted that “men are more likely to conduct tasks associated with seniority, such as funding acquisition and supervision (30% more likely than women), contributing resources, software, conceptualization, and project administration.”

Availability: CROTs’ availability pertains to their accessibility for different members of the academic community and discoverability for reuse, both of which affect how credit is distributed among different cohorts.
**Issue 15) Accessibility.** Since inaccessible or partially accessible contribution information might negatively impact different user groups such as researchers and institutions, conformity of CROTs and contributors’ data to FAIR principles (Findable, Accessible, Interoperable and Reusable) is essential. This could be demonstrated, for example, by using unique resource identifiers “to uniquely identify the concepts,” “using W3C Standard SKOS and the usage of CC0 1.0 license [Public Domain Dedication]” (Borek et al. 2021, 330). Furthermore, different forms of accessibility of contributions were mentioned in two papers. Although Craig (2018) emphasized the electronic accessibility of contributor information (e.g., in journals’ websites), Das and Das noted that such developments cannot be implemented “in the print copy” of journals (2020, p. 29).

Availability has also been discussed in terms of translating CROTs’ roles and their definitions into languages other than English. For instance, TaDiRAH’s translation into German, French, Spanish, Portuguese, Serbian, Italian and Norwegian will not only “ensure technical and professional mentoring for the use and reuse” (Borek et al. 2021, 330), it will also make it more accessible to more users across the globe (Borek et al. 2016). Indeed, increasing the visibility of contribution statements requires reducing access barriers and processing costs, and could be further facilitated by editors, funding agencies, administrators, and database providers (Sauermann and Haeussler 2017).

**Issue 16) Machine-readability.** Machine-readable contributions are readily discoverable and reusable (Vasilevsky et al. 2021; Craig 2018), thereby improving the availability of CROTs to more users and extend their application into a “variety of contexts” (Borek et al. 2016, para. 38). This issue is further discussed by McNutt et al. (2018, 2559) who noted that the availability of contributor information in both machine- and human-readable forms facilitates the “transparency of author contributions in different contexts, via syndication, indexing, and abstracting services, and possibly future applications across journals.” When contributor information is available in a machine-readable and consistent format, “contributions will transition from hearsay to quantifiable evidence” (Ibid.) [assuming, of course, that the data are accurate].

**Usability.:** Ethical issues about usability include suggestions that affect how CROTs are used by the academic community, thereby impacting the attribution/presentation of attributed credit and responsibilities.

**Issue 17) Improving usability.** Some suggestions to improve usability require technical development, such as linking CRediT roles to ORCID records (Craig 2018; Vasilevsky et al. 2021) and creating free web-based tools that allow journals to keep additional information in “acknowledgments, footnotes, or by other means” (McNutt et al. 2018, 2560). McLaren and Dent (2021, 53) noted that CRediT is not consistently understood and applied across the board and highlighted supplementary approaches that could complement the CRediT model, e.g., the “Technician Commitment” initiative in the UK. Another suggestion to improve usability is to develop and promote guidelines that describe how contributions should be allocated (Craig 2018). In line with this suggestion, Larivière and colleagues (2021, 124) observed that only 55% of explored articles in a sample of 30,054 included CRediT’s role of Validation, and accordingly suggested that since lack of direct oversight might increase...
chances of potential misconduct, mistake, or fraud, “journals could require validation as a mandatory contribution type for empirical work.”

**Issue 18) Role assignment.** Three papers discussed role assignment in different CROTs and the involved process and parties. Brand et al. (2015) recommended corresponding authors to assign CRedit roles, and to provide the review and confirmation opportunity to other contributors. However, in describing how to use the Contributor Role Ontology (CRO), Ilik et al. (2018, 7) proposed a different workflow for role assignment, calling it the “claim process.” In this process, which is part of the paper production stage, authors, non-authors, editors and others report their own contributions using the list of roles (instead of assignment by the corresponding author and then having contributors confirm). Once contributions are reported, all contributors need to confirm reported roles. Another discussed approach is adopted by the Algonquian Language Digital Resources Credit System wherein an additional free-text box allows contributors to describe roles in their own words to ensure more transparency (Bliss et al. 2020).

**Managing CROT.** Since contribution types in various research fields change over time, CROTs should evolve and reflect new roles to ensure an ethical attribution of credit and responsibilities across the board. This requires a CROT’s administrators and management board to engage with the academic community.

**Issue 19) Transparency.** The transparency of involved process in the development and revision of CROT is discussed in two publications. The CRedit developers described the 2012 collaborative workshop held at Harvard University as an event that engaged experts and as a defining moment in the development of the taxonomy (Brand et al. 2015). In contrast, Matarese and Shashok (2019, 5) questioned the openness and transparency of this process, noting that this was “an invitation-only meeting,” and that data from the subsequent survey of life science researchers who provided “positive feedback” about the initially suggested taxa were never made available.

**Issue 20) Engagement.** Two papers introduced open community-developed resources and mechanisms to collect user feedback as useful tools for engagement with the academic community, which also promote collaborative approaches in managing activities related to CRO and CRedit (Ilik et al. 2018; Vasilevsky et al. 2021). Borek et al. (2016) highlighted using similar strategies for maintenance of TaDiRAH and note that versioning and issue tracking features of GitHub have been conducive to their efforts. However, they also highlighted that one challenge of open engagement pertains to receiving contradictory feedback from the community. Borek et al. (2021, 330) also introduced the “TaDiRAH board,” which will be responsible for managing activities related to the development of TaDiRAH: “The board consists of the original core team, new developers and other contributors.” Furthermore, this group openly shared their strategy for expanding TaDiRAH to “revise and harmonize the structure and semantics of the model, as well as the concept terms and definitions” based on how it is used by the community (Ibid.).
Discussion

Confusion around CRediT’s application and impact

While CRediT is the most widely used among the CROTs (and discussed more frequently, as shown in this review), its correct application and possible impact on current ethical issues are not always fully clear to those who discuss it. Reviewing the literature showed a discrepancy between what CRediT developers advise and what the community understands in terms of CRediT’s scope and application – some papers in our sample have misread or misunderstood key details about CRediT (e.g., (Alpi and Akers 2021; Honoré et al. 2020; McNutt et al. 2018)).

CRediT developers have published several journal articles to create awareness about CRediT and its intended use (Allen, O’Connell, and Kiermer 2019; Brand et al. 2015) but misinterpretations in the published literature suggest that these instructions have not always been effectively communicated and well-received or perhaps journal articles were misread.

For instance, in an editorial published in Journal of the Medical Library Association, Alpi and Akers (2021, 109) noted: “Together with ICMJE guidelines, CRediT can be used to facilitate conversations and help determine who merits authorship within collaborative teams (emphasis added).” In a different example, Honoré et al. (2020, 42) claimed that CRediT was “originally conceived and designed with authorship roles in mind.” However, Brand et al. (2015, 154) have refuted both claims when they described the taxonomy’s scope, and specifically highlighted that CRediT’s parallel use with authorship definitions also caused confusion when CRediT was piloted for the first time:

“Most of the questions that arose concerned confusion over whether the taxonomy was explicitly intended to specify which types of contribution qualify for authorship status, when in fact that was never the intention. As stated in the taxonomy header: The classification includes, but is not limited to, traditional authorship roles. That is, these roles are not intended to define what constitutes authorship. Rather, the roles are intended to apply to all those who contribute to research that results in scholarly published works, and it is recommended that all tagged contributors be listed, whether they are formally listed as authors or named in acknowledgments.”

Other examples of misunderstanding pertain to CRediT’s impact on reducing ethical issues related to authorship order. When promoting CRediT, Brand and colleagues briefly mentioned authorship order following a hypothetical situation in a non-existing infrastructure, and stipulated that assessing researchers in such a scenario would no longer depend on authorship order:

Imagine publishers collecting structured information about contribution in a standard format. Imagine, further, that this information is associated with the article DOI via CrossRef, and with ORCID author identifiers. We would then have the infrastructure in place to track not only who authored which publications, but also who contributed what to each publication that names the individual as a contributor. With this infrastructure in place, it would eventually be possible to devise more
precise, author-centric credit and impact tracking tools, on which the byline order of author names would have no bearing

(Brand et al. 2015, 154).

This statement does not imply that using CRediT would resolve disputes about authorship order or affect decisions related to authorship order. However, McNutt et al. (2018, 2559), -cited by 40 and 229 articles as per December 2022 according to PubMed and Google Scholar, respectively, noted: “Adopting the CRediT taxonomy would also help alleviate some of the confusion across disciplines and cultures regarding the meaning of author order.” To back this claim, authors cited Sauermann and Haeussler’s (2017) paper, which did not make such a claim either.

In a different misunderstanding about CRediT’s impact on reducing ethical issues related to authorship order, while citing Brand et al. (2015), Poirier, Keys, and Ferguson (2021, 225–226) noted: “Adhering to the recommendations from Project Credits [CRediT] by clearly listing contributions of each author may be a reasonable strategy for acknowledging order. This approach would create transparency and minimize interpretation of order and variability in perceptions of roles.”

Examples like these or instances wherein journal instructions suggest using CRediT contrary to what is prescribed by its developers (see Hosseini et al. 2022a for an example about the PLOS Biology journal) show that communicating information about CROTs by means of peer-reviewed publications is not always effective. CROTs such as CRediT could be misused and misunderstood in many ways, and researchers will not always have the knowledge necessary to identify, read and understand the instructions embedded in peer-reviewed publications. One way of minimizing these misunderstandings, is for CROTs’ developers/custodians to compile reasonably comprehensive and straightforward instructions for users (similar to those developed by the ICMJE) and store them in public repositories (e.g., Zenodo, OSF).

**Issues relating to CRediT’s current list of terms**

Some CRediT roles describe tasks at the project-level while others describe tasks at the paper-level. While one of the identified ethical issues related to CROTs’ design pertains to strategies for selecting terms for a vocabulary, none of the explored papers mentioned certain irregularities in CRediT’s current list of terms. Here we discuss two such issues, 1) using both performative and non-performative terms, 2) confounding paper and project-level contributions.

1. While TaDiRAH developers use a coherent and consistent set of terms for activities, arguing that these terms should be “gerundiva [i.e., verbal adjective] to represent the performativity of the activities” (Borek et al. 2021, 325), such considerations have not been observed in developing CRediT terms. Consequently, some CRediT terms are non-performative nouns (e.g., resources, software) that strictly speaking, do not represent a specific activity.

2. CRediT currently dovetails roles that describe specific work on a paper (e.g., writing, methodology, validation) with roles that mainly occur at a project...
level, and that could affect (and be reflected in) several papers (e.g., funding acquisition, project administration). This inconsistency could result in project-level roles being more coveted (and preferred by senior researchers) because they can potentially yield better return on invested time: Suppose project X has eight contributors involved in investigation, data curation and writing, two contributors involved in funding acquisition and one in project administration. If project X results in five papers, those involved in roles such as investigation, data curation and writing would have to make unique contributions in relation to each paper to be listed as a contributor, but those who acquired funding and performed administrative tasks for the project would be automatically listed on all papers.

Given CRediT’s quick uptake and a recent study that found that CRediT roles show an unequal distribution of labor and gender differences in terms of conducting specific tasks in academia (Larivière, Pontille, and Sugimoto 2021), it is reasonable to expect CRediT developers/custodians to improve these irregularities in future iterations.

**CROT status: Complementary or stand-alone?**

Are CROTs complementary to existing authorship bylines or would they ultimately become stand-alone solutions? Papers that discuss CROTs are not always clear about whether, and how, CROTs should be employed in tandem with authorship lists. Given 1) legal and 2) ethical challenges of doing away with authorship lists, currently, it seems unlikely (if not impossible) to envision scholarly publications without author lists:

1. **Authorship has a legal significance** – authors can readily engage in litigation in relation to a publication, whereas non-authors first have to prove that they have a legitimate claim to authorship. Employing CROTs without authorship lists affects “copyrights, intellectual property rights and the process via which these rights are assigned/challenged” (Hosseini 2021, 260).

2. **Authors’ names are used for (non-numerical) citations and in reference lists.** Without author names, publishers and/or the scientific community must develop and adopt completely new systems of citation and referencing based on contributors’ names. In such a system, ethical issues might occur with regard to the selection of the contributor(s) whose name(s) should appear (at all/first) on in-text citations or in the reference lists. Furthermore, while using authorship lists (except those ordered alphabetically), for the most part, it is possible to implicitly infer those who made the highest degree of contribution relative to others (i.e., first author) and those responsible for the overall integrity of the work (i.e., last author). However, CROTs cannot currently address these issues on their own (Ibid., p. 264). Even using the Supervision role cannot always help because projects might have numerous supervisors.

Accordingly, in the foreseeable future, CRediT (and other taxonomies) must be used in parallel with author bylines. Nevertheless, the scope of this parallel use is currently vague and visions to improve or end it are not openly communicated. Specifically, since its developers suggest that CRediT should not be used to define authorship, and CRediT does not capture the full range of scholarly contributions –even in life and physical sciences for
which it was initially intended; it is unclear how the CRediT roles and authorship definitions should be employed beside each other. Answering questions like these would facilitate developing a clearer vision about the function which CRediT and other CROTs could serve in the future of scholarly publications.

**CROTs are not the panacea**

When looking at the ethical issues of CROTs, similarities with ethical issues of authorship are noticeable. For example, ethical issues about the attribution of credit and responsibilities when using CROTs are similar to ethical issues about the attribution of authorship credit and associated responsibilities, and ethical issues about CROTs’ design and usability have similar components to ethical issues about the definitions of authorship and their application in different contexts. Given these similarities, one can argue that in discussing scholarly attributions, improving the used model (e.g., authorship definitions, CROTs) and the development of technical workflows or even the creation of a perfect CROT schema and workflow may address technical (or syntax) problems but not the infrastructure (e.g., links to ORCID/Crossref) or the social component of the problem and incentive structures around scholarly publications and contributions (arguably much more urgent and challenging to address). Exploring the similarities between ethical issues of authorship and CROTs in future research could lead to new insights about unethical human behavior in attributions as well as challenges of recognizing scholarly work.

This review is limited by the small sample size and does not include debates that took place on the blog-sphere, online forums or in print-only material. Exploring these spaces could be useful for future research. In addition, this review only used and considered English publications about CROTs, and therefore, exploring viewpoints published in other languages could be among possible directions for future research. Conducting empirical research to explore the views of researchers from different disciplinary backgrounds could be another focus area for future research.

**Conclusions and recommendations**

While our review of the debate about CROTs demonstrates a growing interest in CROTs in recent years, the academic community should be mindful about inaccurate published views about them, especially regarding how they should be used and the implications of their adoption. We believe that CROTs should be continuously improved to create better systems of attribution, but overemphasizing CROTs shortcomings could potentially be used to excuse unethical behavior of researchers or perverse institutional incentives, both of which continue to be urgent to address. In what follows we provide four recommendations for CROTs’ developers and those seeking to implement and use CROTs in their workflows, policy and practice:

1. **Compile and promote comprehensive instructions that explain how CROTs should be used and that note common pitfalls of employing them in practice.** Given the mentioned ethical issues in terms of CROTs’ impact on authorship and reporting of scholarly contributions, as well as the highlighted inaccuracies in the literature, extensive and specific guidance is needed to orient scholars about the
concept of CROTs and guide their responsible use. In particular, communicating the scope and limitations of using CROTs in parallel to authorship bylines seems essential. These efforts can be coordinated by community-led organizations like NISO or the TaDiRAH Board, allowing users to find definitive information about CROTs from trusted sources. However, enforcing instructions and guidelines for CROTs requires the endorsement and cooperation of other involved user groups like academic institutions, publishers, and funders.

2. **Improve the coherence of existing roles.** Our analysis of existing CRediT roles shows that some roles describe tasks at the project-level while others describe tasks at the paper-level. In the long run, these incoherencies might create hierarchies among roles and result in an unfair attribution of credit. While it is up to the research community to highlight such irregularities and report specific challenges of employing CROTs in different contexts, developers/custodians of CRediT and other CROTs should strive to continuously improve existing roles and ensure that they are coherent.

3. **Provide translations of roles in languages other than English.** Currently, only one of the CROTs has roles translated into languages other English (e.g., TaDiRAH). Given the wide international use of CROTs, translation of roles into non-English languages (and in case of TaDiRAH, increasing available languages) with the support of native academic speakers of different languages improves availability and inclusiveness of CROTs. These efforts could be coordinated by community-led organizations like NISO and the TaDiRAH Board.

4. **Communicate a clear vision and strategy about future development plans.** Developers/custodians of CROTs need to present regular updates and explain how they plan to work with the academic community. Timely communication of future plans and transparency regarding intended use, strengths and weaknesses could facilitate input and engagement from the community and democratize the process of improving CROTs.

**Supplementary Material**

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
The selection process deemed 30 documents eligible for content analysis.
Figure 2.
Summary of the tagging process.
Figure 3.
Document types of the eligible items.
Figure 4.
Publication year of the eligible items.
Figure 5.
Ethical themes ranked based on their occurrence in the literature. Some documents are tagged with more than one theme.
Figure 6.
Temporal analysis of discussed ethical themes in the literature.
Table 1.

List of ethical themes and associated issues.

| Ethical theme         | Issue                                                                 |
|-----------------------|----------------------------------------------------------------------|
| Attribution           | (1) Improving CROTs' lists of roles and definitions                  |
|                       | (2) Extending output types                                           |
|                       | (3) The use of CROTs in specific contexts                           |
| Impact on authorship  | (4) Authorship disputes                                              |
|                       | (5) Honorary authorship                                              |
|                       | (6) Authorship order                                                 |
|                       | (7) Authorship standards                                             |
| CROTs' design         | (8) Open or controlled vocabularies                                  |
|                       | (9) Strategies for selecting terms for a vocabulary                  |
| Impact on reporting scholarly contributions | (10) Strategic and opportunistic use of CROTs               |
|                       | (11) Responsibility and accountability                              |
|                       | (12) Significance and extent of contributions                        |
| Assessment            | (13) Improving academic assessment and evaluation                    |
|                       | (14) Improving equity and diversity in academic work and evaluation  |
| Availability          | (15) Accessibility                                                   |
|                       | (16) Machine-readability                                             |
| Usability             | (17) Improving usability                                             |
|                       | (18) Role assignment                                                 |
| Managing CROTs        | (19) Transparency                                                    |
|                       | (20) Engagement                                                      |