

Recommendations for handling image integrity issues

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*STM Working Group on Image Alteration and Duplication Detection*¹

These best-practice recommendations outline a structured approach to support editors and others applying image integrity screening as part of pre-publication quality control checks or post-publication investigation of image integrity issues at scholarly journals (and when applicable, these recommendations may also be relevant for books, preprint servers, or data repositories). It provides principles and a three-tier classification for different types of image aberrations commonly detected in image integrity screens of figures in research papers and for a consideration of impact on the scholarly study; it also recommends actions journal editors may take to protect the scholarly record. The guidance covers figures in research papers or preprints, including source data underlying these figures, where available. It does not include the reanalysis or forensic screening of raw data and large datasets (for example for statistical reporting).

Since the seminal Journal of Cell Biology editorial in 2004 [1], many journals have developed image integrity guidelines and processes. The recommended actions are based on the collective experience of members of an STM working group of publishing and image integrity experts, with some policies posted previously in the publications of group members, in particular [2-3]. The recommendations apply to a range of image anomalies and are consistent with and complement recommendations made by the Committee on Publication Ethics (COPE) [4]. This guidance is intended to supplement journal editorial policy and aid editors in these complex decisions but does not supersede any existing policy that a journal may have.

This document will be periodically reviewed and updated by the Working Group based on further comments from the community, and as new issues arise and best practices in image integrity evolve.

Limitations:

- This document is based on the group's experience, which is largely with images in biomedical research (e.g. electrophoretic gels and blots, cell-based image analysis, spectra and graphs) and therefore may not be fully comprehensive to all image types. Additional ethical considerations may be required for other image types, e.g. privacy issues in patient photographs. However, the overall principles and other aspects of this document should be useful to editors considering integrity issues in a broad range of disciplines.
- These recommendations are not intended to comprehensively address the entire

¹ The following individuals served on the [working group](#): Bernd Pulverer (EMBO Press), Catriona Fennell (Elsevier), IJsbrand Jan Aalbersberg (Elsevier), Jacob Kendall-Taylor (JAMA), Jon Slinn (Wiley), Joris van Rossum (STM), SJ MacRae (Aries Systems), Sarah Robbie (Taylor & Francis), Sowmya Swaminathan (Springer Nature), Teodoro Pulvirenti (American Chemical Society), Tim Spencer (Rockefeller University Press). All these individuals acknowledge that their participation and contribution does not commit their organization to endorse these recommendations.

complexity of research institution-journal cooperation. For more detailed guidance, we recommend the COPE and CLUE guidelines [5,7].

- These recommendations are primarily focused on addressing image integrity issues for the published record, rather than on assessing whether individuals have engaged in research misconduct [5].
- This document does not include suggestions for specific techniques or software to perform image integrity checking. The Working Group will separately outline requirements and recommendations for assessing and implementing potential detection tools.

A. Principles

The recommendations presented in this document are based on two sets of principles, which are summarized below. First there are principles for researchers about the integrity of images. These address how images should be handled during experiments, in preparation of using them as underlying evidence for the scholarly record (including research article, preprint, or dataset). And second, there are principles on how editors should handle image integrity issues, especially related to their responsibility in the context of journals, authors, readers, and institutions, and also to how they should deal with, for example, underlying source and replicate data in image integrity checks.

A.1 Image integrity principles for researchers

Below we provide a number of general integrity principles on how images should be prepared for use as underlying evidence for reporting in the scholarly record.

- Researchers are responsible for proper data acquisition, accurate data labelling, retention of raw data, clear research records and adherence to FAIR data management [6].
- Researchers are responsible for ensuring that the results displayed in images accurately and objectively represent the data acquired, and are not displayed in a misleading manner.
- Researchers are responsible for properly describing the underlying methods used to generate the data to render the experiment reproducible by others.
- Researchers are responsible for a proper alignment and provenance between raw data and the text and images provided in the article to support the claims made.
- Images should accurately reflect the circumstances and conditions of data collection.
- Images should be minimally processed as non-essential modification could have unintended side-effects. For example, modifying for brightness or contrast is acceptable only when applied equally across the whole image and applied equally to controls but must not obfuscate any original data [1,3]. Processing should not be used to emphasize one region in the image at the expense of others or to emphasize experimental data relative to the control [3]. Cropping of patient photographs to remove non-clinically essential features that make the patient recognizable is appropriate, but should not obfuscate (clinically) relevant information.
- Images should not be altered to idealize or caricature results (aka 'beautification').
- Any image alteration or processing should not be misleading or change the

interpretation of the original data.

- Any substantive image alteration or processing should be described in the caption, legend, or associated article text in a way that allows accurate, unbiased interpretation of the experimental data. For example, vertically sliced images from within the same gel must have a clear separation/line delineating the boundary and must be described in the figure legend. If one experiment using the same samples was run across multiple gels, this must be made clear in the legend and figure panel: two different gels should not be spliced together to look like one.
- For image duplication or image re-use from other publications, the original source and context, as well as the reason for the re-use should be provided. Any license needed for reuse must be obtained.

For images and image alterations, transparency is key. This includes transparency on:

- The experimental method, including the data and image capturing process.
- The results, as represented through the data and images provided.
- The alterations (what, why, and how) made on the data and images.

A.2 Image handling principles for editors

The following principles relate to editor actions around image integrity issues, and deal with their responsibility in the context of journals, authors, readers, and institutions, and in dealing with e.g. underlying source and replicate data.

(1) Scope of journal integrity assessments

Editors of scholarly journals aim to ensure the reliability of the scholarly literature and the integrity of the scholarly record. Journal editors and publishers cannot undertake formal investigations for research misconduct, which may include review of lab books and primary data feeds, or formal interviews with authors. The scope of a journal integrity assessment (whether led by journal editors or a publisher's research integrity group) is therefore limited to the implications for the evidence and claims presented in the published research article and the need for any corrections to the record. Other considerations, including the assessment of research misconduct by individual researchers and disciplinary actions are referred to the corresponding authors' institutions and potentially funding organizations as recommended by CLUE and COPE guidance [5,7]

Journals may apply image integrity checks at any stage in the publication process (submission, before publication or after publication). The possibility of such checks should be made transparent to authors before submission. Image integrity screening cannot be expected to uncover all image aberrations, especially in cases with severe misconduct based on an intent to obfuscate information. Conversely, not all image anomalies identified in image screening imply intent to deceive.

(2) Editor responsibilities and transparency

Journal editors should analyze submitted figures and source data in good faith and without

prejudice. Editors may, at their discretion, consult with subject experts and peer reviewers where appropriate, taking care to ensure a confidential process.

Editors should inform the corresponding authors of a research paper confidentially with the aim of resolving image integrity issues and give them an opportunity to respond. Corresponding authors have a duty to respond fully and promptly to journal editor inquiries related to image integrity issues at any time after manuscript submission or publication. Editors may also choose to communicate with all authors.

As outlined in CLUE, authors should generally be informed in advance if the editors plan to approach the corresponding authors' institution. However, to avoid unintentionally aiding authors in destroying evidence of malpractice, Editors should contact institutions at the same time as/before they contact authors "in exceptional cases when journals have evidence of substantive or significant falsification or fabrication of data." [5].

Based on the strength of the evidence and outcome of their assessment, Editors should take appropriate action to protect the integrity of the scholarly record in a timely manner, where necessary independently of institutional investigations. Actions may include rejecting a manuscript, posting an Expression of Concern (or similar), or correcting or retracting the study.² Authors should be informed in advance of any corrections to the published record.

Published Corrections, Expressions of concern or Retraction-notes should contain sufficient detail to understand the issues and, where appropriate, reference the nature of the aberrations. In some cases, journals may wish to include an explanation by the authors and provide further context from the journal (for example, in an editorial or other statement).

A due diligence research integrity assessment involving authors and research institutions can take considerable time. In cases where resolution with authors is delayed or research institutions are contacted, it is recommended that editorial notes or expressions of concern should be posted alongside the paper. These notes are superseded when a case is resolved and either updated, rescinded or replaced by a notice detailing the corrective action applied.

Journals with a transparent editorial process policy which involves routinely publishing editor-author correspondence may include non-confidential communication related to image integrity in the transparent process documentation, where appropriate.

(3) Source data

Source data in this context is defined as minimally processed "raw" data underlying a figure. It is distinct from replicate data (see below) or data from orthogonal experimentation leading to the same conclusions. Journal editors may request source data or raw, unprocessed image data for any figure in a manuscript before or after publication, being considerate of data retention policies of the research institution or funder of the work.

The absence of compelling source data may undermine confidence in a figure. Journal editors can refuse to publish a manuscript in the absence of source data (for example if source data is systematically lacking across the paper or missing for key figures), even if there is no definitive proof of data falsification or fabrication. In the absence of source data after

publication, editors should assess the need for a correction to the record based on the available evidence, including replicate data where appropriate (see Replicate data section for specific guidance). The absence of source data within the timeframe for data retention required by the authors' employers may undermine the trust in the reliability of the published work, and may lead to an Expression of Concern or retraction of the paper.

(4) Replicate data

Under certain circumstances *before publication* and at their discretion, editors may request replicate data (ie., data from a replication of the experiment displayed in the manuscript) to replace the data and figure in question, provided that it is consistent with the conclusions shown in the original figure. This course of action is not recommended if there is clear cut evidence of image or data falsification or fabrication, unless there is explicit and definitive support for this course of action from an institutional investigation.

In exceptional circumstances, when issues are discovered after publication, replicate data may be used to support the veracity of the conclusions made, at the editor's discretion even if the specific source data for a figure is not available for documentable reasons (for example, data is no longer archived as it is beyond time frame required by institution or funder). In such cases, the replicate data should be documented as having been generated at the time of the original experimentation; it may then be used to correct the published record in a fully traceable and transparent manner (for example, to replace questionable data in a published paper, or to include it as part of a correction notice, depending on journal policy).

Replicate or orthogonal data that was generated after publication of the paper should not be used to replace published questionable data. It cannot replace the original figure *post hoc*, as that would imply that a research paper merely states claims that are then later supported by compelling experimental evidence. However, under exceptional circumstances, such as when source data are no longer available, replicate data may be used to support the contention that the conclusions of a paper stand, and editors may offer to link to such data posted elsewhere in a correction notice.

(5) Interactions between journals and institutions

Editors should consult COPE guidance [7] and the CLUE recommendations [5] for details regarding best practice on cooperation between journals and institutions on research integrity cases. Journal editors should inform the appropriate research integrity or supervisory authorities at a research institution in cases of serious suspected image manipulation or other data aberrations that cannot be resolved to the editors' satisfaction. Journal editors commit to working with the corresponding authors' research institutions or, where appropriate, funders to exchange their findings (within the limits of their own institutional policies on confidentiality).

Editors aim to act in a manner that is consistent with the results of formal, independent research misconduct investigations, where these are made available to editors (institutional investigations may be made available to editors under a non-disclosure agreement or in redacted form) and consistent with the evidence available to the journal and its findings. If editors disagree with the findings of an investigation based on documentable evidence, they

should act first and foremost to protect the integrity of the scholarly record. In cases where an institutional investigation is unduly delayed or not made available to the editors, they can act independently on the strength of their findings to take appropriate action to protect the integrity of the scholarly record in a timely manner (see principle 2).

(6) Interactions between journals

Consistent with COPE guidance, journal editors from different journals may communicate on specific cases where image aberrations affect multiple journals, with the aim of exchanging information relevant to ongoing research integrity cases, in order to ensure a consistent and informed response [8]. For example, if a manuscript with image integrity issues was declined and this data is published elsewhere, the original journal should carefully consider whether to inform the editors of the publishing journal and share any relevant evidence so that the publishing journal can, at their sole discretion, decide whether to correct the scholarly record. Due diligence shall be applied to ensure no confidential information is exchanged without appropriate safeguards and permission/ good cause.

(7) Considering comments from third parties (readers, whistleblowers)

Journal editors should consider meritorious comments on images, both before or after publication in a journal, even if they are communicated or posted anonymously. Comments need to clearly show that there are image integrity issues. Editors may decide not to pursue non-definitive and minor concerns that would not affect the main conclusions in a published research paper. Authors should be encouraged by editors to address compelling issues raised in post-publication comments. Editors may choose to provide a public response to comments at their discretion. A journal may post updates on commenting platforms or respond to comments directly submitted at its sole discretion. If requested, journals will unequivocally protect the identities of commentators or whistle-blowers.

(8) Legal considerations

In some cases, seeking legal advice, including from the publisher's in-house legal advisors, may be advisable. For example, to advise on avoiding defamation when drafting retraction notices [9].

B. Classification of image aberrations

The classification in Table 1 refers to aberrations in specific image panels, rather than a whole manuscript. These issues may occur in a figure panel and/or the source data underlying a figure panel. A given manuscript may include various aberrations that fall into different categories, and the whole research manuscript or published paper can usefully be classified according to a similar scheme by taking into account the severity and frequency of all individual aberrations in aggregate. Thus, a manuscript can be classed as level II even if it contains a large number of level I issues. This may be appropriate if the editors, after careful consideration, decide the trust in a dataset has been put in question. Individual panel classifications may remain level I based on the absence of substantive evidence, but the lack of compelling author cooperation or source data may compel the editors to increase the

severity of the issue overall.

As shown in Table 1, the classification includes three levels based on: the type and severity of the aberrations, any confirmation of image processing error, any evidence of intent to manipulate, and the impact of the affected images to the main conclusions of the research paper (as a guide, that is typically conclusions highlighted in the title, abstract or the discussion section of a paper). The consequences of each classification level are notably different. Note that the classification refers to the editor's conclusion regarding an aberration based on all evidence available to them, rather than to the aberration itself. That conclusion may change as further information becomes available.

Image aberrations encompass unintentional mistakes and intentional manipulation. Manipulated images may be based on actual data (and this data may even be compelling in unmanipulated form), or it may point to a lack of compelling underlying data. Image aberrations can include, but not be limited to, cloning/duplication of parts of an image or a whole image within a figure, between figures or between papers, splicing, insertion or selective deletion, non-linear or excessive contrast enhancements. Duplications may be at the image level (i.e. within a figure, between figures in the same paper or between papers) or experiments may have been set up inappropriately or intentionally to falsify or fabricate data with duplicate samples.

Statements of Interests

BP is responsible for image integrity screening, research integrity and publication policies at EMBO Press and co-author of the CLUE recommendations.

CF has responsibility for Elsevier Journals' overall policies and processes for image integrity, including testing of potential image-checking software and advising Editors on the handling of image integrity allegations.

IJJA is responsible for research integrity in Elsevier-branded web products, advises on research integrity matters across the company, and is co-author of the FAIR Guiding Principles.

JKT is employed by the JAMA Network (The Journal of the American Medical Association), where he works with the submission and peer review system and assists with editorial matters.

JS works for Wiley and is responsible for delivery of Data/Analytics/AI solutions for Wiley Research, working closely with the Wiley Research Integrity team looking at potential solutions.

JvR works for STM and oversees projects around Research Integrity.

SJM works for Aries Systems Corporation, and is responsible for product design across their commercially available submission, peer review and production management systems.

SR is employed by Taylor & Francis Group (T&F) and supports T&F journal editors and editorial teams in addressing publication ethics and integrity issues, and develops editorial

policies.

SS is responsible for editorial policy and research integrity for Nature Portfolio journals including matters related to image integrity and she serves on the advisory board for Research Square, a multidisciplinary preprint server.

TP oversees the Publishing Integrity Office in the Publication Division of the American Chemical Society (ACS) and is involved in advising ACS Journals on the handling of violations of publication ethics.

TS works for Rockefeller University Press where he serves as the Executive Editor of Journal of Cell Biology and advises editorial and production teams at the Press on issues related to publication ethics and image/data integrity.

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- [8] COPE guidelines Sharing of information among editors-in-chief regarding possible misconduct DOI: <https://doi.org/10.24318/cope.2019.1.7>

[9] COPE retraction guidelines version 2.0 <https://doi.org/10.24318/cope.2019.1.4>

Table 1: Classification of image aberrations [2]

	Description	Examples	Action Pre-publication	Action Post-publication
Level I	Image aberrations include substantive or possible aberrations restricted to a subset of image panels or the source data provided. Image irregularities can in principle be due to inadvertent mistakes in data processing or cosmetic image processing ('beautification') that nonetheless potentially affects the proper interpretation of the data by the reader. There is no evidence for intent to mislead. Source data is readily available and explains the aberrations or possible aberrations. Once analysed, if such aberrations are found to have no material impact on the overall reliability or interpretation of the data or the conclusions made, they can be rectified by supplying properly processed versions of the same data or alternate data.	<ul style="list-style-type: none"> (i) duplication of a complete or part of images (within the same figure, in different figures, in different papers). (ii) vertical splicing of gel/blot lanes (merging comparable data from the same blot/gel or merging non-comparable data from different blots/gels). (iii) loading controls for gels/blots not run on the same blot/gel. 	If the corresponding author(s) provide a satisfactory explanation for the aberrations, compelling source data for the aberrant images and reverse the image processing underlying the aberrations, the revised figure may be accepted for publication without reporting to the institution. The co-authors of the research paper will be informed by the corresponding author(s) or the editor and may be asked to agree to the changes. For journals that routinely publish pre-publication author-editor correspondence, non-confidential communication related to the issue may be noted in the transparent review process documentation in a manner that does not lead to undue exposure of the authors.	If the corresponding author(s) can provide a satisfactory explanation for the aberrations, compelling source data for the aberrant images and reverse the image processing underlying the aberrations, the revised figure may be published in place of the aberrant figure in a fully traceable and transparent manner, typically in form of a written corrigendum. The co-authors of the research paper will be informed by the corresponding author(s) or the editor and will be asked if they agree to any changes and this will be documented in any correction notice. If the interpretation of the published paper is not affected in a significant way, the editors may decide that a correction is not warranted. Authors are encouraged to address compelling issues raised on post-publication commenting sites.
Level II	Significant data "beautification" or undeclared image/data manipulations, which undermine objective data presentation, which are at odds with accepted scholarly practice, and which change the scientific conclusions for key data in a research paper. Intent to mislead cannot be excluded without formal further investigation.	<ul style="list-style-type: none"> (i) extreme contrast adjustments that affect quantitative information of critical features or obscure data. If this quantitative information is crucial to the central conclusions of the paper this can border on "falsification". (ii) reusing control lanes or control panels (potentially "falsification/fabrication"). 	Depending on the author's explanation, the availability of authenticated source data and the severity of the manipulations, a revision may be allowed. All the co-authors will be notified. The corresponding author(s) institution(s) may be notified and the findings of an institutional investigation may be considered as part of the editorial process. Journals that routinely publish pre-publication author/editor communications should publish non-confidential correspondence related to the image aberrations. If the authors cannot provide satisfactory information, the paper should be rejected.	If the corresponding author(s) can provide a fully satisfactory explanation and depending on the availability of authenticated source data and the severity and extent of the manipulations, a corrigendum or retract and republish may be allowed [9]. If the information provided by authors does not satisfy the editor's concerns about the veracity of the images but intent to mislead remains unclear and the aberrations do not undermine the central conclusions of the paper, editors may consider an Expression of Concern. If figures show level II aberrations that undermine the central conclusions of the paper, the editors may, after careful consideration, decide that the confidence in the paper is undermined to a level that requires retraction of the whole study. A Retraction may also be initiated by the authors. All the co-authors should be notified and may be given the opportunity to publicly agree or disagree with any corrective measures. The corresponding author(s) institution(s) may be notified and the findings of an institutional investigation may be considered to inform any corrective measures.

<p>Level III</p>	<p>Severe image manipulation, with substantive evidence of obfuscation or fabrication and an intent to mislead, typically in more than one image panel, with a lack of compelling, authenticated source data. A level III paper will typically have multiple individual figures panels with level II or III aberrations.</p>	<ul style="list-style-type: none"> (i) splicing of separate experiments, cloning, insertion, deletion of parts of an image (signal or background) or graph, repositioning, inverting, flipping elements within panels or graphs; synthetic data. (ii) mislabelling and duplication of a different part of an image. (iii) unequal application of processing within an image or set of images such that data are misinterpreted. (iv) selective reporting or cropping of images such that they are not representative of the data collected. 	<p>If authors do not provide a compelling explanation or source data with compelling provenance, the manuscript should be rejected; all the co-authors and their research institutions should be notified. The editorial decision will include consideration of institutional investigations wherever appropriate. If the journal becomes aware of subsequent publication of the affected data in another journal, the affected journal should be notified (see A.2 Principle 5).</p>	<p>If authors do not provide a compelling explanation, and source data with compelling provenance, the research paper should be retracted pending notification of all the co-authors and their research institutions. Corrective measures will be informed by institutional investigations when appropriate. In the case of delays, editorial notes or Expressions of Concern should be posted. If the journal becomes aware of subsequent publication of the affected data in another journal, the affected journal should be notified (see A.2 Principle 5).</p>
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