

Author response to reviews of

To be FAIR: Theory Specification Needs an Update

Caspar van Lissa on behalf of co-authors
submitted to *Perspectives on Psychological Science*

[RC] Reviewer comment

Manuscript text

Dear Dr Vrieze,

Thank you for considering our manuscript for publication at *Perspectives on Psychological Science*. We appreciate the feedback that you and the reviewers have provided. In the following itemised list we respond to each comment point by point.

[RC 0.1.] Editor's Comments

RC: COMMENT 1

Thank you for submitting Manuscript ID PPS-25-140 entitled "To be FAIR: Theory Specification Needs an Update" to *Perspectives on Psychological Science*. It now has been reviewed. The comments of the reviewer(s) are included at the bottom of this letter.

The reviewer(s) have recommended publication, but also suggest some revisions to your manuscript. I have some further comments, which I hope also will be helpful to you in making a revision. Therefore, I invite you to respond to the reviewer(s)' and my comments and to revise your manuscript.

[x] Headings should not be numbered. [x] Tables and Figures should be uploaded separately and not positioned in the text (although it is fine to indicate where they should be inserted). [] Figures should be uploaded in their native format (the program they were created in) at 300 dpi. Acceptable figure file formats include MS Office files (DOC, PPT, XLS), Adobe Illustrator (AI), JPG, EPS, and PDF. [x] References should be done with hanging indents using APA style. [] If you want to add the doi that is good. But do not put in the search criteria for retrieving a document that has been published in a book or journal. WHAT??

AR: Upload tables separately: tab_meehl.csv Upload figures separately: ec_visio.pdf, git_branches.png, git_compare_short.png

RC: COMMENT 2

a) You have a balancing act to strike between providing technical tools (e.g., version control workflows) that can assist scientists in implementing your proposals on the one hand, against a readership and a scientific discipline that likely largely cannot effectively implement such tools. I will give a simple example. The very first thing I read after the title page was "This is a preprint paper, generated from Git Commit # 7b710ba5." I wager that most readers of *Perspectives* do not know what a git commit is, at least not in any meaningful way. This is a minor example, but illustrates the larger point. Reviewer 2 (Turkheimer) makes this point in his review.

AR: This does not directly ask for a change, but summarize relevant changes here.

1. I agree that striking the balance between the conceptual and technical details is the very challenge of this paper. I think we should go a route in the revision in which we try to explain technical details in even simpler language. For example, the github reference to our code could read like this: “Our manuscript is reproducible given the code provided in our Github repository identified by the snapshot with the unique commit id #XXXXXX.” And maybe there is a way to move the more technical details to a section that can be skipped without compromising the conceptual/opinion aspects. M. D. Wilkinson et al. (2016)

RC: COMMENT 3

b) My interpretation of this manuscript is that it is proposing policies, procedures, and documentation as an important path forward to improve psychology and related soft sciences. One reason I find such proposals interesting is because I don't see them in my other area of expertise, human genetics. No doubt strong conventions develop in genetics, but they seem to develop because scientists writ large working in those fields recognize that those conventions (e.g., publicly available genomic maps organized in a certain way; analytical workflows based on accepted genetic theories) will immediately benefit their own area of research by making new avenues of work feasible, or more efficient. The payoff is obvious. They are "no-brainers" that organically arise. Some conventions in psychology, like registration or even data sharing, do not seem to arise or take hold in quite the same way, and instead rely on top-down requirements by grant funding agencies, journals, etc.

I can definitely see the advantage to policies, procedures, and documentation, if the goal is to identify fraudulent work, because it creates a paper trail to audit. I am more skeptical that these things are crucial to scientific advance in psychology, and there are no empirical results in this paper to the contrary. I believe this echoes Reviewer 3's suggestion to take seriously in your discussion, and I would suggest elsewhere in the paper, the limitations of policies, procedures, and documentation, versus other aspects of the scientific enterprise including culture, norms, and perhaps even the tractability of the subject matter, as in my human genetics example.

AR: ->

We appreciate the Editor's meta-scientific comparison of the emergence of conventions in human genetics to the (current wave of) more top-down nature of open science reforms in psychology, which by-and-large also originated in grass-roots initiatives.

As methodologists, our focus in this paper is on “procedures”, rather than policies or documentation. Our goal is to position FAIR theory as a communication protocol: a set of standards, grounded in philosophy of science and implemented in existing infrastructure, that facilitates theory specification, reuse, and collaborative refinement.

We agree with the Editor that there is no guarantee that “*these things are crucial to scientific advance in psychology*”. We have, however, provided reasoned arguments to support the “affordances” of FAIR theory: *it makes possible* particular scientific advancements, even if it does not guarantee them.

Compare FAIR theory to preregistration: it, too, was introduced first as a good idea; now - a decade later - empirical studies are being conducted to investigate its effects.

To address this comment, in the Revision:

- We explicitly state that we describe the affordances of FAIR theory and argue for its potential impact by comparing it to other open science methods
- We acknowledge in the Limitations section that empirical evidence for these potential benefits remains to be evaluated.

[RC 0.2.] **Reviewer: 1**

RC: COMMENT 4

In this manuscript, the authors introduce a framework for FAIR theory specification while outlining what makes a theory FAIR, which is accompanied by practical guidance on how to implement this in one's own work. In my opinion, the paper is relevant for the journal and presents research that is significant for the field of psychology but also adjacent fields that rely on theories similar in nature to ours. FAIR theory is a promising idea that could significantly advance psychological research, especially in terms of transparency and replicability.

AR: We thank the Reviewer for their thoughtful and encouraging review. We appreciate the Reviewer's recognition of the relevance and potential impact of FAIR theory—not only within psychology, but also in related disciplines. We have sought to address all comments, and feel that doing so has improved the quality of the manuscript.

RC: COMMENT 5

The abstract provides a (mostly) comprehensive overview of the paper that can be easily followed and understood. I personally felt that the introduction of the theorytools R-package was an important aspect of the paper and should thus briefly be mentioned in the abstract.

AR: As suggested, we now briefly mention the R-package in the abstract:

This paper adapts the FAIR principles for theory, reflects on FAIR practices in contemporary psychology, introduces a workflow for FAIRifying theory, which is largely automated by the `theorytools` R-package

RC: COMMENT 6

In the abstract, the authors mention the discussion of “FAIR theories’ potential impact in terms of reducing research waste,” which I couldn’t really find at any point in the manuscript.

AR: We thank the Reviewer for pointing this out; we have included the reference to the paper making this argument in the following section:

Testing ad-hoc hypotheses not grounded in theory, or grounded in misinterpreted- or multi-interpretable theory, does not advance our principled understanding of psychological phenomena, and consequently contributes to research waste ([nakagawaPoorHypothesesResearch2024?](#)).

RC: COMMENT 7

Lines 48–50: I would have benefited from a few more words on the FAIR guiding principles (what they are, where/how they originated, and how they are used).

AR: As requested, we have added a few more words - but we also want to avoid redundancy, as the FAIR principles are fairly (pun intended) common sense, and well-documented in other publications which are all cited in the

opening paragraph. In the body of the text, we explicitly engage with each of the FAIR (sub-) principles, so all information is already contained within the paper.

To address the comment, we have rewritten the opening paragraph as follows:

The FAIR Guiding Principles (hereafter: FAIR principles) were established by a diverse consortium of stakeholders to improve the reusability of research data and other resources produced during the course of scholarly work by making them Findable, Accessible, Interoperable and Reusable (M. D. Wilkinson et al., 2016)^a. Since the FAIR principles' inception, they have become a widely adopted standard for archival of academic output, representing an estimated tens of billions of dollars in reuse value (Vogt et al., 2024). Scholars have demonstrated their relevance for making other digital objects more open, such as research software (Lamprecht et al., 2019) and computational workflows (S. R. Wilkinson et al., 2024).

^aAs the colloquial use of these terms differs from their definition according to the FAIR principles, we capitalize these terms when referring to specific FAIR principles.

RC: COMMENT 8

Line 101: In Figure 1a, it would be helpful to see the two phases (currently, those are not clear to me). Also, even though Figure 1c is addressed at a much later point in the manuscript, it would be helpful to briefly mention it here as well, so it doesn't seem forgotten.

~~RC:~~ COMMENT 9

Line 102: The corresponding year should be added to "Wagenmakers and colleagues."

AR: Done.

RC: COMMENT 10

Line 147: In the case of "Lamprecht and colleagues," the year should also be added.

AR: Done.

RC: COMMENT 11

In general, I'd move this section up, as the word "theory" has been used a lot already at this point, and readers might benefit from an earlier explanation/definition (for example, directly after the section "The Need for FAIR Theory").

AR: We have done as requested, and additionally, include a sentence in the first paragraph to pre-emptively address readers' concerns that FAIR theory may only be relevant for those who have adopted a specific paradigm:

Definitions of theory are abundant and hotly debated, but many of them are compatible with the FAIR principles.

RC: COMMENT 12

Line 163: Following APA 7 standards, no "cf." is added. In the case of three or more authors, it is shortened to "et al."

AR: We removed "cf." here, although we couldn't find mention of it in the APA7 style guide. We use "cf." to indicate when a specific reference *contradicts* a point; e.g. "all theories should be formal (Smaldino, 2017;

cf. Oude-Maatman, 2024)”: Oude-Maatman disagrees with this statement. We have also updated the citation scheme to APA7, so three or more authors will be shortened to “et al.”. Note that some journals prescribe citation styles that (partly) conflict with APA7; we defer to the Editor on how to handle such cases.

RC: COMMENT 13

Line 207: It could be helpful to add a very brief description of the phonological loop in case some readers are not familiar with it and its parameters.

~~RC:~~ COMMENT 14

Line 350: I think that this was supposed to be displayed as a link: <www.theorymaps.org>

AR: Thank you for pointing this out; we have fixed the formatting.

RC: COMMENT 15

Line 390: In the case of a direct quotation, a page number should be added if possible.

AR: We have added the page numbers to all direct quotations.

RC: COMMENT 16

Line 688: I’d add the year for Van Lissa’s specification.

AR: Done.

RC: COMMENT 17

Line 776 onwards: The proposed system of modular publishing seems to have been around for quite some time (since 1998 at least) but is not widely used, which could briefly be addressed as a limitation.

AR: We respectfully disagree; open data - one example of modular publishing - has increased dramatically in recent decades, up from ~7% of articles in 2000–2009 to ~50% of psychological articles in 2010–2019, and more (~80%) in other disciplines. Given this, we don’t see a reason to note this as a limitation, but we have added a reference that indicates that data sharing has become widely adopted in psychology:

Data sharing is an example of modular publishing that is already widely adopted, becoming the de-facto standard in psychology (Tedersoo et al., 2021).

RC: COMMENT 18

Line 800: To make the strengths understandable to all readers, I’d encourage the authors to briefly explain the “open empirical cycle.” Overall, this is a very “strong” section indeed!

AR: We have rewritten this section slightly, including a brief explanation of the “open empirical cycle” and how the present work relates to it:

Recently, the “open empirical cycle” was introduced, arguing that each phase in De Groot’s model of cumulative knowledge generation via scientific research can be supported by specific open science practices to increase the transparency, quality, trustworthiness, and replicability of research (Hoijsink et al., 2023). As we identified, however, most existing open science methods focus on rigor in testing (phases 2–4 of the cycle), but few provide guidance on how to derive hypotheses from theory (phase 1), or how to relate empirical findings back to theory (phase 5), leaving a gap in the cycle. By instantiating theory as a FAIR digital object, we provide much-needed open science infrastructure for transparently

deriving hypotheses and modifying theory, thus contributing to closing the “open empirical cycle”.

RC: COMMENT 19

In my opinion, it is very important that the learning curve is mentioned; even though I am a big fan of the proposed framework in general, I do feel like it would take some practice and getting used to.

AR: We had mentioned the learning curve in the Limitations section, and have expanded this discussion to address the present comment:

Another limitation is the learning curve associated with tools like Git and Zenodo. The `theorytools` R-package mitigates this limitation for R-users by automating key steps in the process. Moreover, the initial investment in time can be offset by long-term productivity gains and increased impact of FAIR theory. One final way to address the learning curve is via specialization and collaboration, or team science (Van Lissa et al., 2024): as scientific workflows increase in sophistication, it is increasingly difficult for any one scholar to master all skills involved. In relation to FAIR theory, we see unique opportunities for intergenerational collaboration and knowledge exchange, as theoreticians tend to be seasoned experts, whereas open science literacy is more commonly found among early career scholars.

RC: COMMENT 20

Line 852: I’d add a reference for the jingle-jangle fallacy.

AR: We have done as requested; this section now reads:

FAIR theories can also help address “jingle- and jangle fallacies” in psychology, which are ambiguities that arise from using the same term for different constructs, or conversely, using different terms for the same construct (Song, Watson, & Zhao, 2021). By explicitly referencing operational definitions in FAIR theories, such jingle-jangle fallacies would come to light and could ultimately be resolved.

RC: COMMENT 21

The affiliations could be changed to follow a common system.

AR: We have tried to make this requested change, although there is some residual heterogeneity because our institutions have different preferred / mandated ways to write the affiliation.

RC: COMMENT 22

I do understand why the words Findable, Accessible, Interoperable, and Reusable are always written with a majuscule, but it did confuse me a bit during reading at times.

AR: Since all of these words have a colloquial meaning in everyday language, as well as a more restrictive operationalization in the literature on the FAIR principles, we think its important to signal the distinction between the formal and colloquial use of the terms. We now clarify this in a footnote, the first time the capitalized terms are introduced:

As the colloquial use of these terms differs from their definition according to the FAIR principles, we capitalize these terms when referring to specific FAIR principles.

RC: COMMENT 23

The references should use sentence case following APA 7 (e.g., Back to Basics: The Importance of Conceptual Clarification in Psychological Science → Back to basics: The importance of conceptual clarification in psychological science).

AR: We've updated the reference style to APA7, but note that some journals have fixed the case of specific words in titles (e.g., "FAIR" is fixed to capital letters). These remain unchanged. We defer to the Editor to indicate whether we should change this, or whether it will be addressed in the typesetting process.

RC: COMMENT 24

I've mentioned these two already for specific examples, but I'd check them in the whole manuscript again: In the case of more than two authors, use of et al. and the mention of page numbers for direct quotations.

AR: Done.

RC: COMMENT 25

Two of the links did not work for me: Line 490 (FAIR metadata example), Line 606 (example of metadata).

AR: TO DO

[RC 0.3.] **Reviewer: 2**

RC: COMMENT 26

I submit this review signed as Eric Turkheimer.

Editors generally prefer that reviewers not preface their reviews with declarations of their lack of expertise in the relevant subjects, but I am going to allow myself to do so here, because I already said as much to the editor when I was asked to review the paper. I have no particular expertise in meta-science; I have never (I am somewhat embarrassed to admit) so much as pre-registered an analysis. I am 71, and open science procedures are the blinking 12:00 on my VCR.

I am here as a practitioner of theory, not as a meta-theorist. I have written a few "theoretical" papers over the years, of different kinds that I will get to in a minute. I want to consider how adopting a FAIR framework would change, improve, or inhibit what I do.

I can think of two kinds of theoretical papers I have written, or perhaps better, two theoretical research programs I have participated in. One of them is closely tied to empirical results. I am thinking of the Scarr-Rowe hypothesis, something that was developed by Sandra Scarr and David Rowe, and then turned into something resembling a theory by our 2003 paper. Since then it has been much investigated and argued about.

In this case, I think the FAIR framework would be very helpful. The S-R hypothesis makes a number of empirical claims with respect to theory. These claims have changed in response to empirical results and theoretical disputes over the years. I have often been frustrated by the difficulty of maintaining meaningful boundaries on the theory and the predictions it makes.

Here are two examples. In the months after our paper was published, someone (Nagoshi, C. T., & Johnson, R. C. (2005). Socioeconomic status does not moderate the familiarity of cognitive abilities in the Hawaii Family Study of Cognition. Journal of Biosocial Science, 37(6), 773-781.) shot out a "failure to replicate." But it wasn't— their analysis studied parent-child correlations, not twins, and

the S-R hypothesis makes no predictions about them. But despite 20 years of trying to make this clear in the published literature, the study is still cited. An even worse example happened recently, when a group of "race scientists" (Pesta, B. J., Kirkegaard, E. O., te Nijenhuis, J., Lasker, J., & Fuerst, J. G. (2020). Racial and ethnic group differences in the heritability of intelligence: A systematic review and meta-analysis. *Intelligence*, 78, 101408.) used the S-R hypothesis as a platform for a bunch of unrelated claims about race differences.

To be clear, it cuts both ways. It has turned out over the years that the S-R interaction does not occur in Europe, and I have revised the theory to fit the new facts, but I have done so on a strictly ad hoc basis. It would be easy to suggest that I am adding epicycles to it, and having a formalized structure for the theoretic revisions would help keep me honest. Similarly, when conducting new analyses, I am often confronted with investigator degrees of freedom (should we use parental education or income as an SES indicator) that are very difficult to resolve in the privacy of the lab. Having a structured platform for doing so would help.

AR: Dear prof. Turkheimer,

on behalf of all co-authors, I would like to express our sincere appreciation for your thoughtful comments. This is my (Caspar's) favorite review to date, and I especially value your perspective as a seasoned scholar/theoretician. All authors unanimously agreed that it would be a pity to deprive our readers of an opportunity to view FAIR theory through the lens of your lived experience - but we were not sure how to incorporate it. One author proposed to invite you as a co-author, others were concerned that this might constitute a conflict of interest.

We took the initiative to draft a paragraph that summarizes your comments on FAIR theory from the review, and mention your contribution in the Acknowledgements. We would be equally happy to credit your contribution with a co-authorship, depending on your - and the Editor's - preferences.

Our draft paragraph now reads:

We invite the reader to ask the rhetorical question raised by our reviewer, prof. Turkheimer, who - reflecting on a long career as a practitioner of theory in psychology - considered "how adopting a FAIR framework would change, improve, or inhibit what I do". We paraphrase his answer here^a, because his lived experience complements our youthful "techno-enthusiasm". Prof. Turkheimer remarked that a FAIR framework would have been very helpful in maintaining meaningful boundaries between a theory and the predictions it makes, in tracking how empirical findings result in changes to empirical claims made by a theory, and in resolving theoretical disputes. *"FAIR theory provides a structured, machine- and human-readable framework that distills and formalizes the core components of a theory. Everything published about a theory can continue to exist in its original form, while a FAIR representation supplements that literature by explicitly outlining the theory's assumptions, logical structure, and testable implications. Importantly, FAIR theory can evolve semi-independently from individual papers, offering a persistent and collaborative object that others can reuse, cite, and refine. Contributing to the development of a FAIR theory thus becomes a new way of contributing to the theoretical literature - much like writing a high-quality review article, but with the added benefit of interoperability, versioning, and reusability."*

^aEdited for brevity.

The Acknowledgement now reads:

We are particularly indebted to our Reviewer, Dr. Eric Turkheimer, whose thoughtful reflections on FAIR theory were incorporated into the Discussion.

RC: COMMENT 27

(This sounds like pre-registration. I don't think there is a bright line between FAIR theorizing and preregistering.)

AR: We think that this comment signals a need to better explain the important distinctions between these two practices. To address this comment, we have included the following section in the revision:

One important future direction is embedding FAIR theories within existing open science methodologies. For example, consider how FAIR theory relates to preregistration. These practices are distinct but complementary. The purpose of FAIR theory is to communicate general principles and expectations about a given phenomenon, and to provide infrastructure for explicitly deriving hypotheses from specific theories and revising those theories in light of empirical results. The purpose of preregistration, by contrast, is to eliminate inductive bias from hypothesis tests and increase trust in the outcomes of a specific empirical study (Peikert, Ernst, & Brandmaier, 2023). FAIR theories are specified at a level of abstraction that transcends individual studies. FAIR theories can inform - and be informed by - both quantitative and qualitative research. Preregistrations, by contrast, are specific implementations of quantitative hypothesis tests, within the context of a specific study design, analysis plan, and - optionally - a fully reproducible analysis pipeline. These practices complement each other: authors can make the derivation chain from theory to hypothesis more explicit by citing a specific FAIR theory in their preregistration. Moreover, it is possible to preregister an inferential procedure that would require revising the theory after observing data, or even to have proponents and detractors of a theory review a registered report of such a test. In short, combining FAIR theory with preregistration and other existing open science practices has the potential to strengthen the epistemic cycle of prediction, testing, and revision, moving us closer to a cumulative science.

RC: COMMENT 28

The second kind of theorizing I have done is more philosophical, along the lines of my "Three Laws" paper and related work. Here, I think applying the FAIR framework would be a little more problematic. At times, the current manuscript sounds as though it is trying to make scientific theory machine readable, an idea that has some good points that the authors make clear, but would also eliminate a lot of interesting papers that have been written by human beings from a subjective point of view. What would happen to Meehl's great Sir Karl Sir Ronald paper within FAIR? How much of the importance of that paper would remain if you took Meehl's voice out of it? Is all narrative philosophy "theorizing" that could be augmented or replaced by FAIR? See also: Meehl on "Cliometric metatheory".

These considerations lead me to some recommendations for strengthening the manuscript. The first is to clarify the relationship between FAIR theory and traditional paper-writing. Is the former meant to replace or enhance the latter? It seems to me that using FAIR to enhance the environment created by traditional theoretical papers is much the better option. That is, everything that currently exists about the S-R hypothesis could continue to exist, and be supplemented by a FAIR framework outlining the theory and its implications. Development of the FAIR model could exist almost independently of the individual papers, analyses, reviews and meta-analyses (see below). Someone could contribute to the literature on a subject by developing a FAIR framework, much as a good review paper does.

AR: We agree, this is exactly how we envision the role of FAIR theory. We think this comment can be concisely

addressed by emphasizing that modular publishing does not replace the traditional paper, but adds value to resources created in the process of its writing:

The primary unit of scientific communication has long been the academic paper. In the process of writing papers, scholars often produce many valuable resources, including instruments, materials, data, code, and theory. These resources are often merely described in papers (if at all), and not made available for reuse. Modular publishing is the practice of making each of these resources available as independent *digital objects*, facilitating their reuse and making them citable (Van De Sompel, Payette, Erickson, Lagoze, & Warner, 2004).

And:

Modular publishing of resources, including theories, increases their reuse potential and makes them citable without detracting from the conventional academic paper as a unit of academic communication which allows for greater nuance and the author's voice. Theories published in traditional papers can be supplemented by FAIR versions that live independently, evolve collaboratively, and feed into reproducible workflows.

RC: COMMENT 29

Second, and speaking of Meehl, many of the ideas incorporated here have a relationship to construct validity. Many of our "theories" of behavior take the form of hypothetical constructs, like intelligence or for that matter the S-R interaction. Much of what is described here seems like a formalization of Meehl's idea of a nomological net— a network of theoretical connections among abstract entities and empirical observations.

AR: We partly agree; we recognize two distinct lines of thought in this comment.

The first is that FAIR theory relates to construct validity. To address this point, we have rewritten the section on FAIR theory and the "measurement crisis":

Another future direction is the intersection between the aforementioned "theory crisis" and the related "measurement crisis" pertaining to the lack of clarity, consistency, and validity in the operationalization of theoretical constructs (Bringmann, Elmer, & Eronen, 2022). Since FAIR theories can reference other theories and resources, it is possible to attach references to specific measurement instruments (or even theories of measurement) to constructs named in a theory.

The second is that much of what we describe looks like Meehl's nomological nets. This is definitely true for the way that *we* are using FAIR theory (e.g., in the online examples), as we are inspired by Meehl, but it's not necessarily true of FAIR theory in general. We're not sure if further changes need to be made to address this.

RC: COMMENT 30

Finally, and this is the only concern about the paper as a publishable manuscript, the last third of the paper where the authors get into the technical aspects of how one would go about building a FAIR theory, is difficult to read. This is where the manuscript reads more like a software manual than a perspectives paper. It would seem out of place in this journal, and frankly it left me discouraged about the prospect of trying this on my own. In its place, I would recommend working an example for an actual theory, with as much of the specific detail as possible removed from the main text.

AR: To address this comment, we have removed as much of the specific detail as possible from the main text, and instead refer to the package vignettes (we have created an additional vignette to make this change possible, and extended several other vignettes). There are already two worked examples for actual theories in the package vignettes, which we now reference in the text.

The resulting shortened section reads as follows:

We propose a practical, software-agnostic workflow for making theory FAIR. While these steps can be implemented using a variety of tools, R users can streamline the process using the `theorytools` package, which automates most steps. We will illustrate the workflow using De Groot's *empirical cycle*, a meta-theory of theory construction, as a running example for this tutorial. The resulting FAIR implementation of this theory is available at <https://doi.org/10.5281/zenodo.14552329>.

The R-package includes further examples for FAIR theory creation in tutorial form, including a worked example for implementing this workflow. Two other vignettes apply the workflow to substantive theories: Decy and Ryan's *Self-Determination Theory* (Ryan & Deci, 2000), and Morris' *Tripartite Model* of parental socialization of children's emotions (Morris, Silk, Steinberg, Myers, & Robinson, 2007).

Our workflow builds upon existing open science infrastructures to the greatest possible extent. At the time of writing (2025), the integration of GitHub and Zenodo makes for a particularly user-friendly approach that meets *all* FAIR principles. Zenodo and GitHub are both integrated with the Open Science Framework (OSF), a popular platform in psychology. Thus, it is possible to create a project page on the OSF to increase the visibility of a FAIR theory among users of that platform, while the integration of the OSF with Zenodo and GitHub removes the need for maintaining the same information on multiple platforms. Note that open science infrastructure is an area of active development, and as such, workflows might change as new tools or databases are developed or existing tools and database change over time.

1. Implement the Theory

Begin by creating an empty folder to hold all files associated with the theory - this folder will become the theory archive. The first file to create is the theory itself. This could be a plain-text file containing natural language statements, or a more formal representation, such as a directed graph. For example, the empirical cycle was originally described as a series of natural language statements (De Groot & Spiekerman, 1969, p. 28):

Phase 1: 'Observation': collection and grouping of empirical materials; (tentative) formation of hypotheses.

Phase 2: 'Induction': formulation of hypotheses.

Phase 3: 'Deduction': derivation of specific consequences from the hypotheses, in the form of testable predictions.

Phase 4: 'Testing': of the hypotheses against new empirical materials, by way of checking whether or not the predictions are fulfilled.

Phase 5: 'Evaluation': of the outcome of the testing procedure with respect to the hypotheses or theories stated, as well as with a view to subsequent, continued or related, investigations.

Implementing the theory as a digital object can be as simple as isolating these statements from the paper, and saving them to a plain text file.

Optionally, we can formalize the theory further. According to a taxonomy of different levels of theory

formalization, the empirical cycle is presently defined at either the “theory” or “specification” level (Guest & Martin, 2021). To fulfill criterion II of the FAIR principles: using a formal language for knowledge representation see Supplemental Table S1), we can further formalize it to the “implementation” level by specifying it in the DOT language for describing directed graphs^a. Given the cyclical nature of the conceptual model, such an implementation might look like this:

“ induction; deduction; observation; test; evaluation;

observation -> induction; induction -> deduction; deduction -> test; test -> evaluation; evaluation -> observation; “

Note that the first part of the implementation constitutes an ontology - it specifies the entities comprised in the theory. The second part of the implementation describes the flow of information from phase to phase. Figure 1a) shows what this implementation looks like when plotted. Regardless of which implementation we prefer, we can save it to a plain text file - this is the “digital object” containing our theory.

2. Document the Theory

To meet the Interoperability and Reusability criteria, it is important to properly document the theory file. Firstly, add a README.md file with instructions for future users of your theory. The `theorytools` package contains a vignette on writing README files for theory. Secondly, add a LICENSE file with the legal conditions for reuse. We recommend explicitly waiving copyright with the CC0 license, but other options are available, see <https://choosealicense.com>.

3. Version Control the Theory Archive

To track all changes to our theory, the theory archive can be version controlled. Git is well-suited for this purpose. Hosting a backup in the cloud on a platform like GitHub additionally makes the theory publicly accessible and facilitates community engagement.

4. Archive the Theory on Zenodo

Archiving major versions of a theory in a FAIR-compliant repository that issues a persistent identifier (DOI) improves their Findability and allows them to be referenced in perpetuity. Zenodo is a FAIR compliant repository with GitHub- and OSF integration.

5. Entering Meta-Data

When archiving a FAIR theory, documenting it with relevant metadata improves its Findability. We recommend using a standardized metadata schema like DataCite (DataCite Metadata Working Group, 2024). See here for an example of the metadata associated with our FAIR empirical cycle. Within this schema,

- Set the *resource type* to the category `Model`,
- Add the words `FAIR theory`: to the title so that sentient readers will recognize the work as a FAIR theory (just as meta-analyses are encouraged to use the words `meta-analysis` in the title),
- Add `fairtheory` to the keywords to aid search engine indexation.
- Optionally, submit the theory to the “FAIR Theory Community” to contribute to community

building; communities on Zenodo are shared spaces to manage and curate research outputs.

^aPresented here in a simplified form; see the tutorial for technical details

[RC 0.4.] Reviewer: 3

RC: COMMENT 31

I have read through the manuscript on FAIR theories in psychology. I am extremely sympathetic with the arguments in the paper and believe it will make a valuable contribution.

Drawing on previous work on FAIR principles, the authors of this manuscript argue that psychological theories should be findable, accessible, interoperable, and reusable. These principles are clearly part of a broad movement toward improved and open science in disciplines like psychology.

The authors point out that, despite many reforms since the identification of the "replication crisis" meant to improve scientific rigor (e.g. per-registration), the problems lie with deeper root causes, including a problem with theory development. I could not agree more. For example, there is often little connection between theory and hypotheses. In addition, theories are often so ambiguous as to be unfalsifiable. The key issue, according to the authors, lies in where we should focus reform efforts. To date, reform efforts have focused on improving deductive methods, while overlooking the process of theory construction and improvement. I completely agree.

In the rest of the paper, the authors lay out specific aspects of their argument (e.g. what is a theory? what is the role of formalization in theory development? what is modular publishing? what role should version control play in theory development? etc.). They then discuss a specific example of how to implement the FAIR principles in theory construction and development.

As should be obvious, I am a fan of this paper.

AR: We are grateful for this thoughtful and supportive review. The Reviewer's clear articulation of the central goals of our paper, and their agreement with the need to (re)focus reform efforts on theory development, is affirming and encouraging.

RC: COMMENT 32

That said, I wonder if the paper could be improved with a more probing discussion section. If I had one criticism of the paper, I would say that it lets scientists off the hook too easily. An uncritical reader might conclude that the issue is merely one of creating the right set of norms (e.g. version control through Git and archiving through Zenodo). I am doubtful. The sciences (especially physics) have not run into the same problems as psychology and yet they have not always nor always currently practice anything like these FAIR practices. Sure, physics tends to use formal theory, which limits some of the most egregious issues associated with the replication crisis. But that is not true of most theory in biology — and yet biology has done a better job of good theory development. I wonder if the authors would be willing to talk more in the discussion about the role of values? We live in a world that is dominated by the logic of incentives: If we just get the incentives right, then we can solve all of our problem. Perhaps. This logic suggests scientists are motivated by mere self-interest (why else would we need the incentives?) and operate in a world of ignorance (e.g. scientists are not aware that their theories are vague and why that is bad for science). I accept that both of these are true, to a large degree. If so, I worry that creating new incentives may only exacerbate problems. It seems to me that we need a change in values. For example, scientists should be embarrassed by publishing vague and

ambiguous theories—at least after that has been pointed out to them. I am not trying to be a scold here, but I wonder if there's value in talking about how we might better cultivate norms and values in scientists without requiring more procedures and incentives. After all, why have the problems in the social sciences not so badly infected the sciences? The authors address these issues to some degree (e.g. they mention that they are often asked "who owns a theory?" during seminars. This is precisely the problem! That that question would be asked suggests a deeper problem than incentives—the problem lies in not really understanding what science is or how it works.

Sorry for the rant! I really loved the paper and think it is fine as is. I would love to see a bit more of a discussion about issues like values, but I don't need to see that.

AR: We appreciate this thought-provoking comment, which explores the broader sociological and cultural dimensions of scientific reform. We are sympathetic to the reviewer's view that the challenges facing psychology are not solely technical or procedural, but likely also reflect deeper issues of norms and values.

That said, we are not sure that we are best positioned to engage with these issues, nor that the present paper would be the best place for such an argument. As methodologists, our primary aim in this paper is to articulate the affordances of FAIR theory: a framework that supports better theory specification, sharing, and reuse. We believe our contribution will be most effective if it remains sharply focused on the practical infrastructure and its scientific use cases.

We do not mean to suggest that infrastructure alone is sufficient, nor do we discount the importance of cultivating scientific values. However, we believe that meta-scientists and sociologists of science would be better positioned to engage with the topics of norms and values, and that these topics are better suited to empirical enquiry - i.e., establishing what the most widely held norms and values are, and how these relate to endorsements of academic practices.

We share the Reviewer's interest in the meta-scientific perspective, and we hope that the Reviewer will agree that - while there is clearly a need for enquiry into norms and values - the present paper might not be the best avenue for it.

We did make one minor change to address this comment, and “punched up” the section on Theory and Scientific Progress, with a reference to scientific norms as documented in ethical guidelines:

Collecting significance statements about ad-hoc hypotheses is much like trying to write novels by collecting sentences from randomly generated letter strings (van Rooij & Baggio, 2021); inefficient at best, and more likely, futile. As the Declaration of Helsinki prescribes that ethical (medical) research with human participants must “avoid research waste”, our field should take seriously its ethical responsibility to develop procedures to reduce it.

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