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REVIEW ARTICLE

Open developmental science: An overview and annotated reading list

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Abstract

The increasing adoption of open science practices in the last decade has been changing the scientific landscape across fields. However, developmental science has been argued to be relatively slow in adopting open science practices. One of the barriers to applying open science practices might be a lack of knowing 'how to start' among developmental researchers. To address this issue, we followed the format of Crüwell et al. (2019) and created summaries and an annotated list of informative and actionable resources discussing ten topics in developmental science: Open science practices; Issues with reproducibility and replication; Open data, materials and code; Open access; Preregistration; Registered reports; Replication; Incentives; Collaborative developmental science. This article offers researchers in developmental science a starting point for understanding how open science intersects with developmental science. After getting familiarized with this article, developmental scientists should understand the core tenets of open and reproducible developmental science, and feel motivated to start applying open science practices in their workflow.

KEYWORDS
developmental psychology, developmental science, open research, open scholarship, registered reports, special education

[Corrections made on 14 June 2022 after first online publication: Reference to Byers-Heinlein et al. (2021) has been corrected to Byers-Heinlein et al. (2019) in the 'Open developmental science' and 'Collaborative developmental science' sections. Byers-Heinlein et al. (2019) has been removed from the 'Other suggested readings' section and reference details for Byers-Heinlein et al. (2021) has been removed from the References section.]

1 | INTRODUCTION

Robust and actionable knowledge generated by rigorous and reliable developmental science is essential for accumulating knowledge about the development, health, and well-being of humans (Gilmore et al., 2020; SCRD, 2019). However, developmental science shares many of the problematic features identified in other fields, such as lack of transparency (i.e., a lack of sharing methods, code, data, research materials, not being open about biases and conflicts of interests, and about decisions made throughout the research cycle (e.g., Bottema-Beutel & Crowley, 2021; Evans et al., 2021; Parsons et al., 2022; Syed, 2019). A lack of transparency is one important factor that has contributed to the 'reproducibility crisis' in science (Evans et al., 2021; Munafò et al., 2017; see also Baker, 2016 for the discussion about reproducibility and reproducibility crisis). Reproducibility is the ability for researchers to reproduce the same findings with the same data. Accordingly, reproducibility pertains to how well researchers keep records of what they do, so that everything can be reproduced when needed (Syed, 2019; see Parsons et al., 2022 for definitions of reproducibility and other open science-related terms). Developmental science is also heavily impacted by the crisis (see e.g., Davis-Kean & Ellis, 2019; Frank et al., 2017).

Developmental researchers make methodological and analytical choices at every stage of the research process (see Wicherts et al., 2016 for discussion about 'researcher degrees of freedom'). Some of these choices, often made with the best intentions from developmental scientists, are considered research misbehaviours, or Questionable Research Practices (QRPs; Bouter et al., 2016; John et al., 2012). One such practice is *p*-hacking (i.e., favouring the small *p*-values and therefore analyzing data in several ways until a statistically significant result is obtained (Simmons et al., 2011). This behaviour can contribute to publication bias in developmental literature (e.g., by underrepresenting null findings in the scientific literature; Davis-Kean & Ellis, 2019; Silverstein, 2020). The choices considered QRPs are often made by developmental scientists due to challenges related to the recruitment of study participants who are often difficult to cooperate with (Davis-Kean & Ellis, 2019; Frank et al., 2017; Silverstein, 2020). Regardless of the reasons, QRPs undermine research quality (i.e., robustness, reliability, and validity; Nosek et al., 2022).

To address these pervasive problems, challenging established norms within science by adopting open science practices (e.g., preregistration of studies and sharing of study materials) has been suggested (Corker, 2018; Ioannidis, 2005; Munafò et al., 2017; Open Science Collaboration, 2015; Simmons et al., 2011). However, it has been argued—and we also agree with this contention—that developmental science has not incorporated open science practices such as preregistration, data sharing, and replications to the same degree as seen in psychology in general (see Duncan et al., 2014; Frank et al., 2017; Gennetian et al., 2020; Kirtley, 2022). Identifying and addressing the barriers to adopting open scientific practices is vital to improving the value of developmental science and the knowledge it delivers.

We believe that developmental scientists in general strive to conduct robust research, but knowing how to achieve this is not that straightforward and there are many, researcher-centred and systemic, barriers (Nuijten, 2019). In this article, we address just a few barriers to adopting open science practices. Selecting appropriate research practices for particular projects requires awareness and knowledge of different practices by developmental researchers. This awareness and knowledge are not necessarily currently available (e.g., 80% of the child development researchers report that their institutions do not provide guidance for posting and sharing data; Gennetian et al., 2020).

Thus, the purpose of this article is to ease access to knowledge about open science for developmental researchers by providing an annotated list and summaries of open science literature in developmental science. This article targets both researchers who are new to research and/or open science as well as established researchers who are less familiar with open science practices. The article is also written for those who want to stay updated on developments in the field. Our primary goal with this article is to further discussion and showcase how open science practices can be implemented in developmental science.

In what follows, we first present our understanding of open science and then focus on open science in developmental science. We then describe the process of creating our source of the annotated reading list and the summaries before we present the summaries of the selected resources. The article ends with a general discussion of the collated literature and the future open developmental science.

What is open science

Open science (often used interchangeably with 'open scholarship' or 'open research', Parsons et al., 2022) challenges the status quo and bias in science, by aiming to make the whole research lifecycle more transparent, rigorous, accessible and reproducible (Breznau, 2021; Crüwell et al., 2019; Kathawalla et al., 2021; Munafò et al., 2017; Nosek et al., 2022; Parsons et al., 2022; Tennant & Breznau, 2022; Topor et al., 2020). In addition, open science includes championing international and cross-disciplinary collaboration (Brock, 2020; Open Science Collaboration, 2015; Pownall et al., 2022; UNESCO, 2021).

Here, we understand open science as both a philosophical approach to doing science (Fecher & Friesike, 2014) and a set of practices (see Kramer & Bosman (2018) for the rainbow of open science practices: shorturl.at/aijzQ) aiming to improve openness, integrity, diversity, inclusivity and accessibility of science and related academic activities. In line with others (Bergmann, 2018; Corker, 2018; Nuijten, 2019; Spellman et al., 2017; Syed, 2019), we do not view open science as 'all or nothing' and accordingly, we should not expect all researchers to adopt all open science practices in all their projects. Instead, we agree with others who view open science as a buffet (thanks to Christina Bergmann for this metaphor, e.g., shorturl.at/cfhDW, meaning that researchers can 'cherry pick' or select and tailor the suggested solutions to their specific research projects (Nuijten, 2019; Spellman et al., 2017).

Although open science has been changing the way we think and do research across the fields over the last decade (Azevedo et al., 2019; Syed, 2019; Syed & Kathawalla, 2022), uptake of open science practices has been relatively slow and uneven in the subfields of psychology (Norris & O'Connor, 2019; Syed & Kathawalla, 2022; Washburn et al., 2018). The unevenness in awareness, acceptance and implementation of open science practices may result in an asymmetry of rigour and robustness of research across subfields (Syed & Kathawalla, 2022). Therefore, identifying why some subfields are slow in adopting open science practices, and suggesting ways to improve the current practices, is valuable.

Open developmental science

Developmental science is characterized by several challenges such as difficulties in recruiting participants leading to small samples and underpowered studies. This often means that true effects cannot be found (Frank et al., 2017; Nuijten, 2019; Peterson, 2016). Other challenges include limited measurement methods and a general lack of methodological standardization (Frank et al., 2017), as well as incomplete and missing data (Frank et al., 2017). Another challenge that often goes unnoticed in developmental research is related to replications, where the use of participants who do not cooperate well (e.g., babies) means that small procedural differences can lead to substantial differences in outcomes (Gennetian et al., 2020). These challenges can make the field particularly vulnerable concerning QRPs, and research practices that limit replicability in the broader field of psychology may be even exacerbated in developmental research (Davis-Kean & Ellis, 2019; Frank et al., 2017; Silverstein, 2020).

The vulnerability of developmental science makes it obvious that the discipline can benefit from embracing open science practices (Davis-Kean & Ellis, 2019; Gilmore & Qian, 2021; Kirtley, 2022; Silverstein, 2020). There are some prominent examples of rigorous, transparent and collaborative multi-site collaboration and open research practices in developmental science, such as the ManyBabies consortium (https://manybabies.github.io/). ManyBabies is a collaborative project for replication and best practices in developmental psychology research. There is more information about ManyBabies in one of our summarized sources below (Byers-Heinlein et al., 2019).

We agree with others (Gennetian et al., 2020) that more transparency can address at least some of the challenges, such as standardization of procedures and content across labs. Transparency and sharing of study materials will increase the chance for replications through showing which procedural changes researchers had to make in the research because of for example uncooperative participants such as small children (Gennetian et al., 2020).

Not surprisingly therefore, the Society for Research in Child Development (SRCD), the major professional organization for developmental science, considers scientific integrity, transparency and openness, as applied to research, to the teaching of scientific methods, and the translation of science into practice and policy, as core values and strongly endorses them (SRCD, 2019).

However, it has been argued that developmental science generally has not incorporated open science practices, such as preregistration, data sharing and replications to the same degree as we have seen in other areas of psychology (Duncan et al., 2014; Frank et al., 2017). Openness and transparency are not yet norms in developmental psychology and challenges around embracing these values persist (Gennetian et al., 2020).

Lack of information about open science practices has been identified as one of the primary reasons that researchers in psychology are not using open science practices (Crüwell et al., 2019; Washburn et al., 2018). Sometimes, researchers do find relevant resources but feel overwhelmed by their numbers and the difficulty in digesting their content because some of them might be too technical to understand (Crüwell et al., 2019; Parsons et al., 2022). The ambiguity of open science practices might result in researchers not knowing how to start and lead to a sense of paralysis (Kathawalla et al., 2021) or even thinking that learning about open science practices is too time consuming and not feasible. Considering the time constraints of researchers, learning about and integrating open science practices can be seen as an extra burden on top of already busy schedules (Azevedo et al., 2019). Some researchers might feel that they have to adopt all open science practices simultaneously in all their projects to do open science correctly. In addition, although it is certainly ideal to plan on using open science practices at the start of a developmental science project, researchers might not know that it is possible to adopt them at any stage of a project.

To address such barriers, and more that we do not list, that might prevent developmental scientists from applying open science practices, a shared understanding and awareness of these practices and the values they present across fields is essential. To support researchers starting to implement open science practices, Crüwell et al. (2019) created a guide that outlined the best openly accessible resources related to improved practices in (psychological) science. There are also other excellent resources on how to get started applying open science practices or helping others to do so (e.g., Allen & Mehler, 2019; Kowalczyk et al., 2022; Lewis, 2019; Nuijten, 2019). However, tailoring such a guide specifically for researchers in developmental science is needed. Therefore, inspired by the format of an annotated reading list used by Crüwell et al. (2019), here we provide a developmental-focused update of this original article in the form of a collated reading list and summarized resources discussing open science practices in developmental research, including subfields such as infant research and educational psychology.

The aim of this article is twofold. First, it should serve as an introduction to, and a resource for, the emerging topics and current practices in open science for students and researchers at all career stages in developmental science who are new to open science, and also for those with some knowledge of open science. Second, by providing collated resources on open science in this specific field, this article aims to show how open science practices can be applied in developmental science and whether they meet unique barriers or opportunities. The latter is particularly important to avoid the problem of 'reinventing the wheel' because (developmental) researchers may wrongly believe that some challenges are unique to the field. This article and the reading list might also be a useful resource for educators teaching open science to students in developmental psychology, (special) education, educational psychology, and beyond.

2 | CREATING ANNOTATED READING LIST AND SUMMARIES

To create this reading list, we began by collating all relevant resources regardless of type (e.g., articles, tutorials) to identify which open science principles or practices have been discussed in the context of developmental science.

Interestingly, developmental science is a very broad field that lacks a commonly accepted definition. Many researchers agree that developmental science involves trying to understand the process of development; in other words, how and why individuals change. This focus on the process of development infers a method which is then applied to any area of development, including cognitive, affective, social, cultural, physical and biological. Therefore, the specific research field, whether it be education or psychology or another, does not necessarily define developmental science. Relatedly, a study that includes only children does not necessarily make it developmental science. Therefore, drawing the boundaries of what is and what is not developmental science is not simple, and can be idiosyncratic. The included resources fit how we, the authors, define what fits into developmental science, as developmental scientists ourselves.

We grouped our curated reading list into topics. We started with the seven open science topics covered in Crüwell et al. (2019): *understanding open science; open access; open data, materials and code; reproducible analyses; pre-registration and registered reports; replication research; and teaching open science*. We also noticed two other themes emerged from our curated reading list: *incentives* and *collaborative developmental science*.

From this curated reading list, we selected one source per topic which we felt was informative, and was the most general to all of developmental science. For example, when faced with sources that covered a topic for just infant researchers versus all developmental sciences, we selected the latter. However, in the absence of sources discussing the practices in developmental science in general, we were flexible, and summarized sources discussing these topics in specific subfields (e.g., infants). Note that although some readings might be from specific subfields, much of them can be generalized to other subfields of (developmental) science.

During this selection process, we made two changes to the original topics included in Crüwell et al. (2019). We slightly changed 'reproducible analyses' to 'issues with reproducibility and replication', according to the source we summarized. Likewise, our first source is more about open science practices than on open science in general, so we named the topic 'open science practices'. Also, rather than a single source covering both 'preregistration and registered reports', we had two different sources for these topics and decided to split the topic. The final topics the summarized resources cover are: *Open science practices; Issues with reproducibility and replication; Open data, materials and code; Open access; Preregistration; Registered reports; Replication; Incentives; Collaborative developmental science*. There is overlap between these topics and open science practices in general, so some of the discussions within the summaries will overlap (e.g., in the case of preregistrations and Registered Reports).

After selecting the final source for each topic, we wrote an accessible summary of the essential ideas discussed in each source, with our own short introduction of the topic. These summaries are written using the same structure of the original source, and therefore, reflect the source structure. The summaries will allow readers to determine if consulting the source would be useful for them. After each summary we add some recommended literature on the same topic, but this time from developmental science.

The project also has its OSF-page (https://osf.io/z24s3/) containing the supplementary file and the preprint of the article.

3 | SUMMARIES

3.1 | Open science practices

Source: van Dijk, W., Schatschneider, C., & Hart, S. A. (2021). Open Science in Education Sciences. *Journal of Learning Disabilities*, 54(2), 139–152. doi: 10.1177/0022219420945267

Open science practices are presented in the Introduction of our paper and will not be reiterated here. What we would like to add is that just as the field of developmental science is varied, so are the open science practices. They vary in when they are used, as well as the time, resource and expertise intensity of using the practices. In our first paper, van Dijk et al. (2021) summarize five common open science practices: Open Data, Open Analysis, Open Materials, Preregistration and Open Access. Van Dijk et al. focus their review for educational scientists, but we believe that it applies to almost any developmental sciences researcher. We elected to include this general summary paper as it is convenient for those new to open science or who are teaching students to have a single source for the major open science practices. By necessity, the van Dijk et al. review of open science practices is brief for each specific practice. We also include papers that specifically focus on the open science practices (and more) that are highlighted by van Dijk et al., for those readers who wish to have more detail on a specific open science practice.

Van Dijk et al. begin with a review of each of five open science practices, including useful definitions of each and citations. Following this, the authors then review the history of open science. They remind us that although open science practices became part of the common discourse in educational science because of recent high-impact replication failures in psychological sciences, concerns about the scientific practices of developmental science have been around for decades. For example, research in the 1960s discussed the issues of selective outcome reporting and hypothesizing after results are known (*HARK*ing) (Meehl, 1967). Van Dijk et al. also point out that many open science practices are not new, for example, researchers have always regularly made our data open via summary statistics. This also raises the point that data sharing can take many forms and does not need to be only the full final dataset.

Van Dijk et al. then review two benefits of open science practices. The first is that open science practices increase transparency in our science, in particular, increasing our ability to produce scientific evidence that is reproducible. The second benefit is the ability to use open science practices to develop and answer novel research questions. As an example, the authors describe the usefulness of the Child Language Data Exchange System (CHILDES; MacWhinney (2000), an open data repository of child language transcripts. Van Dijk et al. then review resources and provide a 'how to' for each of the five open science practices. The authors include a useful graphic that lays out the key details of how to do each open science practice at different stages of the research process, from project design to after a project is completed.

Finally, van Dijk et al. summarize their recommendations for the field. First, they remind all researchers that they can adopt open science practices. They suggest sharing data and materials from projects which have been completed as a good first step. They also encourage researchers to promote open science practices and to encourage colleagues during collaborative projects or hallway conversations. Van Dijk et al. also suggest that researchers can support open science practices during manuscript and grant reviewing. For example, reviewers of manuscripts can try to reproduce the analysis in the manuscript by requesting and using the data and code, and grant reviewers can check data and material sharing plans and incorporate this into their reviewing criteria.

3.2 | Other suggested readings

Kirtley (2022). Advancing credibility in longitudinal research by implementing open science practices: Opportunities, practical examples, and challenges. *Infant and Child Development*, 31(1), e2302. doi: 0.1002/icd.2302COMMENTARY7of7. [*Provides practical examples of how three open science practices (pre- and post-registration, Registered Reports, and data management) can be implemented in longitudinal research*].

Fleming et al. (2021). Open accessibility in education research: Enhancing the credibility, equity, impact and efficiency of research. *Educational Psychologist*, *56*(2), 110–121. *[A good review of open science practices from the transparency lens]*.

Patall, E.A. (2021) Implications of the open science era for educational psychology research syntheses. *Educational Psychologist*, *56*(2), 142–160, doi: 10.1080/00461520.2021.1897009. [*A good review of open science practices for synthesis papers*] (Patall, 2021).

Cook, B. G., Fleming, J. I., Hart, S. A., Lane, K. L., Therrien, W., van Dijk, W., & Wilson, S. E. (2021). Aow-To Guide for Open-Science Practices in Special Education Research. doi: 10.35542/osf.io/zmebaA. [*A good review of open science practices for special education, including «how-to's»*] (Cook et al., 2021).

3.3 | Issues with reproducibility and replication

Source: Davis-Kean, P. E., & Ellis, A. (2019). An overview of issues in infant and developmental research for the creation of robust and replicable science. *Infant behaviour & development*, 57, 101,339. doi: 10.1016/j.infbeh.2019.101339.

Although open science practices are not new, the genesis for the growing movement of using open science practices in psychology, and subsequently developmental science, is attributed to the 'replication crisis' (e.g., Pashler & Wagenmakers, 2012; Simmons et al., 2011). Stemming from the replication crisis, there was a movement to make psychology more rigorous, and the findings reproducible (i.e., recreate findings in the same dataset) and replicable (i.e., recreate findings in a different dataset). That movement was heavily tied to using open science practices. As discussed prior, developmental science is susceptible to questionable research practices in the same ways other sciences are but there are also field specific issues important to consider (Davis-Kean & Ellis, 2019).

Before we move into different open science practices, we review here a piece that summarizes the QRPs common in developmental science (Davis-Kean & Ellis, 2019). The authors begin their piece with a history of when the replication crisis became apparent in psychology, including citing work that showed how many developmental science papers have *p*-values that are incorrectly reported (i.e., Bakker & Wicherts, 2011). This then sets up their paper, in which the authors review QRPs in developmental science in three categories: statistical power and sample size, protocol flexibility, and analysis flexibility.

Davis-Kean and Ellis begin the statistical power and sample size section with a review of how difficult it is to determine appropriate expected effect sizes for power analysis in developmental science. Small sample sizes in the existing literature mean that published effect sizes are artificially inflated, and in general, effect sizes in developmental science are small meaning rules of thumb, such as Cohen's effect size magnitudes, do not apply well. The authors suggest some strategies to support developmental scientists in their estimation of effect sizes for power analyses. First, they recommend drawing on the literature for the range of effect sizes, but suggest that researchers focus on larger sample studies when doing so. The authors then note that often there is not literature to draw from, and in situations like this, they recommend using an effect size of 0.10 for power analysis, to be conservative. The authors work out an example of what sample size would be required to test the difference between two groups with a low effect size, and the result is sample sizes that pretty much no one lab could do in developmental science (1250 participants per group, for 2500 total participants). This leads to the suggestion that developmental scientists should collaborate across labs or otherwise pool data using existing data repositories.

In the second section, the authors focus on protocol flexibility. In this section, they review one type of what has been called 'researcher degrees of freedom' (Simmons et al., 2011; Wicherts et al., 2016), the researcher decisions made at each stage of the research process that are not noted or often even recognized as important. For example, the authors review how easy it is for developmental scientists to go 'off protocol' when testing children, and that often these changes to the protocol are not written down. If the changes to the protocol are performed systematically, they can lead to bias in the results. The authors suggest that researchers have a method to note any changes to the protocol so that they can be reviewed (e.g., an online lab notebook), or to even videotape all testing sessions so that protocol deviations can be reviewed.

In the third section, Davis-Kean and Ellis focus on analysis flexibility. They review how the difference between confirmatory and exploratory analyses is becoming less distinct. They also review various ways researchers are *p*-hacking, data analysis flexibility that increases the chance of finding a statistically significant finding, as well as *HARK*ing, hypothesizing after the results are known (Kerr, 1998). The authors summarize what they think is the most common instance of analysis flexibility in developmental science, which is multiple analyses conducted without hypotheses to support them, such as looking at large correlation matrices and picking out the statistically significant relations to write up. Davis-Kean and Ellis also review how this can happen during the review process, that reviewers or editors can make authors do extra statistical tests or change variables, a difficult problem to overcome. The authors suggest that researchers can be clear in their manuscript what analyses are exploratory versus confirmatory in cases like this.

The authors then move on to their suggestions for best practices for future developmental science research. They suggest that preregistrations and Registered Reports are the best way to move forward towards a rigorous and reproducible developmental science.

3.4 | Other suggested readings

Gennetian, L. A., Tamis-LeMonda, C. S., & Frank, M. C. (2020). Advancing transparency and openness in child development research: Opportunities. *Child Development Perspectives, 14*(1), 3–8.

Gilmore, R. O., Cole, P. M., Verma, S., Van Aken, M. A., & Worthman, C. M. (2020). Advancing scientific integrity, transparency, and openness in child development research: Challenges and possible solutions. *Child Development Perspectives, 14*(1), 9–14.*[The above two articles represent the two viewpoints of the Society for Research on Child Development (SRCD) Task Force on Scientific Integrity and Openness].*

Bergmann, C., Tsuji, S., Piccinini, P. E., Lewis, M. L., Braginsky, M., Frank, M. C., & Cristia, A. (2018). Promoting replicability in developmental research through meta-analyses: Insights from language acquisition research. *Child Development*, *89*(6), 1996–2009. [*This study uses meta-analytical techniques to explore replication in language studies*]. (Bergmann et al., 2018)

3.5 | Data and material sharing

Source: Gilmore, R. O., & Qian, Y. (2021). An open developmental science will be more rigorous, robust, and impactful. *Infant and Child Development*, e2254. doi:10.1002/icd.2254.

Data sharing, a key open science practice, is the process by which research data is made available for other researchers to examine or use. It may be argued that data sharing is the practice that has the greatest top-down support, in that many major grant funders and journals are now requiring data sharing for grantees and authors. However, in practice data sharing remains a time-intensive practice which requires some specialized skills, resulting in less uptake by researchers than other open science practices (e.g., Makel et al., 2019). There are also issues related to sharing sensitive data that are worth considering in the discussions of data sharing (e.g., Towse et al., 2021). Often linked with data sharing is material sharing, including code sharing, which involves researchers sharing study materials in an online repository. Given the intensity of the data collection (e.g., longitudinal, with infants), developmental science has unique concerns surrounding data sharing. We could only find one paper that discusses data and material sharing from a developmental perspective, Gilmore and Qian (2021), which we will review here.

Gilmore and Qian begin by stating they intend to show why open sharing of data and research procedures and methods will strengthen developmental science. They note that developmental scientists should embrace values of transparency and openness so that we might best understand behaviour rigorously and transparently.

The authors then have two sections, one for data sharing, and one for sharing of methods and materials. To start the data sharing section, Gilmore and Qian note that in the history of science, sharing datasets was common. Although it is not currently common in developmental science, the authors believe that it should be again. Specifically, they believe that the data underlying every published paper should be openly shared so that other analysts can check the rigour of published work. The authors then go on to answer the what, when, where and how of data sharing. For what, they define what data should be shared, which they state should be at the minimum all published data. For when, they suggest that data should be shared as early as possible, but practically shared when a publication is submitted. For where, data should be shared as supplemental material, in a journal specializing in publishing data, or a data repository. For how, data should be shared according to FAIR (findability, accessibility, interoperability, reusability) principles of data management (e.g., Wilkinson et al., 2016) and they should be well-documented to support data verification and reuse.

The authors then go on to describe 'active curation', when data are uploaded into a data repository as soon as they are collected. They give an example using their own data repository, Databrary, which uses a special R package to allow access to data stored in the data repository, allowing for reproducible analytical workflows. The authors conclude the data sharing section with two concerns. First, 'post hoc curation' is difficult. Gilmore and Qian strongly recommend that researchers plan for data sharing at the start of their project to spread the efforts required to share data across the lifecycle of the project. The authors also give some brief recommendations surrounding data management guides. Second, developmental scientists often collect sensitive data, and ethical concerns must be addressed. The authors give some references for practical guidance, as well as a link to templates they have created. For example, they suggest that researchers can store sensitive data in repositories that have restricted access options (i.e., so that research ethics agreements can be determined before full sharing). They also describe how developmental scientists should think about consent when considering data sharing. The authors suggest that broad consent for full data reuse should be attempted.

In the second section, Gilmore and Qian focus on sharing of methods and materials. They begin by noting that it is not easy to reproduce most publications, which is a concern for the field. They encourage researchers to share research protocols openly on the Internet using free and open-source software tools, like Markdown or GitHub. They also encourage sharing of data analysis pipelines, including code and data documentation, for future reuse. In this section, the authors include some links and brief suggestions for how to share materials.

3.6 | Other suggested readings

Logan, J. A., Hart, S. A., & Schatschneider, C. (2021). Data sharing in education science. *AERA Open*, *7*, 23328584211006475. [*A complete guide to data sharing, including «how-to's». Focused on educational science, but broadly applicable*] (Logan et al., 2021).

Mannheimer, S., Pienta, A., Kirilova, D., Elman, C., & Wutich, A. (2019). Qualitative dcata sharing: Data repositories and academic libraries as key partners in ddressing Challenges. *American Behavioural Scientist*, *63*(5), 643–664. doi:10.1177/0002764218784991. [*Good information about data and material sharing for qualitative research*] (Mannheimer et al., 2019).

Meyer, M. N. (2018). Practical tips for ethical data sharing. *Advances in Methods and Practices in Psychological Science*, 131–144. doi:10.1177/2515245917747656. [*A very good guide to tips on data sharing, from the ethical lens*] (Meyer, 2018).

Tsai, A. C., Kohrt, B. A., Matthews, L. T., Betancourt, T. S., Lee, J. K., Papachristos, A. V., Weiser, S. D., & Dworkin, S. L. (2016). Promises and pitfalls of data sharing in qualitative research. *Social Science & Medicine*, *169*, 191–198. doi: 10.1016/j.socscimed.2016.08.004. [*Good information about data and material sharing for qualitative research*] (Tsai et al., 2016).

3.7 | Open access

***Source*:** Roehrig, A. D., Soper, D., Cox, B. E., & Colvin, G. P. (2018). Changing the default to support open access to education research. *Educational Researcher*, *47*(7), 465–473.

Open access is an open science practice rooted in the idea that scientific findings should be easily and freely available to everyone online, not just those who have access to paywalled journals (e.g., see The Budapest Open Access Initiative, 2002; 2012 shorturl.at/jpBWZ). We selected a paper reviewing open access publishing that is written for an educational sciences audience (Roehrig et al., 2018), but is applicable to all developmental sciences. The paper's authors are a unique combination of educational scientists and librarians, and it summarizes the concepts, rationale, and areas of resistance around open access.

Roehrig et al. start with a description of what Open Access (OA) is. They start with some general OA terms. They also note that only approximately a quarter of all recently published scholarly products are available OA, meaning the vast majority of our science is behind a paywall where only certain people can access it. The authors then define ‘Gold OA’ publishing as making a scholarly product freely available at publication by the original publisher, and ‘Green OA’ as when the final scholarly product is not published OA but the authors post their non-typeset scholarly product into an online (preprint) repository or another website, which can be accessed openly separately from the published typeset version. The authors then further differentiate Gold OA options into ‘Diamond OA’, which are publishers that allow for free open access publication, ‘commercial OA’ publishers, which only published OA papers but charge a fee for publication to generate revenue, and ‘Hybrid OA’, which are traditional publishers who allow authors to pay fees to make their paper OA. For Green OA, the authors further discuss some issues around self-archiving, including publisher policies, and slow scientific community uptake.

In the next section of their paper, Roehrig et al. go on to describe why OA has been growing, although growing slowly. They describe various federal mandates for OA policies, as well as institutional policies to support OA adoption. The authors note that many education research journals do not have OA publishing availability, and Green OA has not been widely taken up by the field. The authors spend some time examining why OA has been slow to catch on in educational sciences, suggesting that it is due to the lower journal prestige of newer Gold OA journals coupled with the relative lack of OA journals. The authors believe that OA is not widely supported or encouraged by research-intensive universities, meaning there is not a reward structure in place to change the culture around OA publishing. In addition, the authors describe why they believe that traditional publishers are making their publication contracts purposely restrictive against Green OA.

Roehrig et al. then give their recommendations for how the default negative thoughts towards OA can be changed. First, the authors point to the success other countries outside of the United States have had with top-down mandates from funders and institutions, and they recommend similar mandates in the United States, with accompanying compliance mechanisms. The authors note that OA mandates in other countries have led to more permissive copyright policies from publishers.

The authors note that they continue to see reluctance by researchers to use OA publishing options, and they finish their article by stating common apathy and fears they have heard from researchers about OA (e.g., ‘I don't have time’), and their rationale for how to overcome these. The authors believe that moral arguments will not be enough to sway reluctant authors and that practical arguments are needed. The authors give an anecdote of showing a colleague the large engagement they have had with an OA paper, which could be coupled with the meta-science research showing OA papers have more downloads than paywalled articles (e.g., Davis et al., 2008). The authors also call on senior faculty to support OA publishing, to challenge the current system of blindly signing copyright forms without questioning them, and supporting their pre-tenure colleague's support of OA. Roehrig et al. also call on Editors of journals to look at the copyright forms of their journals and to apply pressure to journals to change their policies if they are restrictive to OA publishing. The authors include a useful table on things stakeholders can do to change from the current default of no OA to allowing OA publishing. The authors conclude with a call to our community to support OA publishing as a service to the academy.

3.8 | Other suggested readings

Fleming, J. I., & Cook, B. G. (2022). Open access in special education: A review of journal and publisher policies. *Remedial and Special Education*, *43*(1), 3–14. [*Empirical study examining the open access levels of special education journals. Interesting example of metescience empirical work that can be done*] (Fleming & Cook, 2022).

https://psyarxiv.com/ or https://edarxiv.org [*Psychology and education-oriented green OA paper repositories. As a note EdArXiv only became available after Roehrig* et al. *was published*].

3.9 | Preregistration

***Source*:** Havron, N., Bergmann, C., & Tsuji, S. (2020). Preregistration in infant research—A primer. *Infancy*, 25(5), 734–754.

Preregistration, a long-standing research practice in clinical trials, and increasingly used in other areas as well, refers to specifying all planned aspects of a study before conducting a study (Nuijten, 2019). Preregistration has been suggested as one way of preventing researchers from unintentionally engaging in QRPs (Nosek et al., 2018), avoiding publication bias and reducing researcher degrees of freedom such as strategic use of flexibility in data analysis (Nuijten, 2019), meaning that researchers can choose from many different possible choices for analysis, exclusion criteria and the like. Preregistration separates clearly exploratory and confirmatory findings (you can read more about preregistration in Nuijten, 2019; Wagenmakers et al., 2012). One form of, or an extension of preregistration is Registered Reports (RRs), which is mentioned in this source, and which you can read more about in the source analysed later (Reich et al., 2020).

In our selected source, Havron et al. (2020) present an in-depth discussion of the issues that might make preregistration of infant research particularly challenging, but discusses also ways to contend these issues. Havron et al. believe that a priori examination of the planned study increases the credibility of single studies and adds value to the field.

Havron et al. describe the problems with transparency and reproducibility in infant studies and explain how preregistration offers a particular advantage to infant researchers. By carefully deciding on the design, analyses, and so on researchers are less likely to conduct a study and discover errors after the completion of data collection.

For an individual researcher, preregistration can have several practical advantages such as avoiding duplicating work and contributing to more efficient workflows. Sharing analysis scripts along with preregistration makes it easier to understand the purpose of these scripts, but they also become reusable for others. Detailed documentation of the research process in preregistration can also prevent mistakes.

Among the challenges with preregistration, Havron et al. highlight the importance of describing deviations from a preregistration. This is important because if undisclosed, deviations do not increase transparency, and are even considered QRP. Another issue with undisclosed deviations is that authors might falsely profit from the credibility that preregistration is associated with, and as such, they can potentially undermine the credibility of preregistration. Another related problem is imprecisely formulated preregistrations, which increase researcher degrees of freedom. The absence of a standard for preregistration makes it difficult to know what the appropriate level of specificity in preregistrations is.

Havron et al. remind us that preregistration does not automatically improve a flawed research question or planned methodology. The value of preregistration depends on whether the preregistration plans are followed when conducting the study, and whether any deviations from the preregistration are reported.

Then Havron et al. mention the current platforms that allow preregistering online such as Open Science Framework and GitHub. Finally, Havron et al. write about how researchers can update their preregistrations, in particular, it is possible to upload an amendment to a preregistration before knowing the results. Doing so is by no means a QRP.

Havron et al. briefly discuss registered reports (RRs), that is submitting a preregistration in the form of the Introduction and Methods section of a journal article which undergoes peer review. Among the advantages of RRs is that acceptance means almost guaranteed publication, which is not based on whether outcomes are significant. Havron et al. note that, like any other format, RRs are not a cure-all solution as expert review is never a guarantee for a sound research design. Despite this, they recommend infant researchers to consider RRs when feasible because improvements made in the peer-review process are beneficial to infant researchers given the resource-intensive nature of their research.

(Readers can consult the next summary to read about RRs).

3.10 | Other suggested readings

Gehlbach, H., & Robinson, C. D. (2018). Mitigating illusory results through preregistration in education. *Journal of Research on Educational Effectiveness*, *11*(2), 296–315. doi:10.1080/19345747.2017.1387950. [*The study examines how preregistration plans can improve scientific integrity of educational science*] (Gehlbach & Robinson, 2018).

Johnson, A. H., & Cook, B. G. (2019). Preregistration in single-case design research. doi:10.35542/osf.io/rmvgc. [*The paper provides a rationale and make specific recommendations for preregistering single-case design research*] (Johnson & Cook, 2019).

Preregistration templates: https://osf.io/zab38/wiki/home/.

3.11 | Registered reports

Source: Reich, J., Gehlbach, H., & Albers, C. J. (2020). 'Like upgrading from a typewriter to a computer': Registered reports in education research. *AERA Open*, *6*(2), 1–6. doi:10.1177/2332858420917640.

RRs is a type of an empirical publication in which study proposals are peer-reviewed and accepted before research is conducted (Chambers et al., 2015; Chambers & Tzavella, 2022), and is an extension of preregistration (Henderson, 2022). In this publication format, decision about which articles to publish are based on the importance of the research question, theory and the rigour of the methods, and not on the results (Henderson, 2022), and as such RRs offer a remedy for a range of reporting and publication biases (Chambers & Tzavella, 2022; Henderson, 2022).

Although one of our summarized sources, Havron et al. (2020) also touched on RRs, it was brief. Therefore, we decided to summarize one source on RRs as applied to education research (Reich et al., 2020). Yet, Reich et al. is relevant for other subfields within developmental science and beyond.

Reich et al. is an introduction to a special issue that includes seven of the first RRs in education research. These articles address diverse topics and uses a variety of methodologies such as lab studies, field experiments and secondary data analysis. After situating these RRs in the context of this special issue, Reich et al. present author and editor perspectives on RRs. They explain that the editors and authors involved in this Special Topic were enthusiastic about the design, writing and review process. Both authors and editors agreed that the peer review process was a friendlier, more productive set of exchanges than it typically is in education research publishing. From the editors' perspective, reviewers appeared less critical and the criticisms were more constructive and generative. Several authors argued that the process of designing a study for a RR was both easier and at the same time more rigorous. Importantly, several authors expressed that the process either took no extra time or saved time compared with traditional publishing. Three studies have graduate students as first authors and authors express the belief that the upcoming generation of education researchers will be champions of new approaches to open science.

Reich et al. continue with discussing challenges and tensions for future Editors of RRs. Many authors noted, and the editors agree, that not all studies are appropriate for a RR. RRs may be more appropriate for confirmatory research. Furthermore, all the studies published in the special issue used quantitative methodologies, and the benefits of RRs for qualitative or design-based work are less clear.

Finally, Reich et al. encourage education researchers to be active in advancing open science in their research through for example writing a proposal to their favourite journal and proposing a special issue on RRs, or planning a registered study and asking their favourite journal to review it as a RR. Finally, authors are encouraged to submit their RR to *AERA Open*.

3.12 | Other suggested readings

The list of journals that accept RRs, which is growing every day (e.g., https://www.cos.io/initiatives/registered-reports).

PCI Registered Reports (https://rr.peercommunityin.org/).

An example of a RR in qualitative research that has Stage 1 acceptance: https://twitter.com/PCI_RegReports/status/1441386222031568904.

Hobson, H., Sedgewick, F., Manning, C., & Fletcher-Watson. S. (2021): Registered reports in autism research—a letter to journals; https://osf.io/pcwbn/ [*The signatories of this letter encourage autism journals to adopt registered reports as a means to publish academic research*] (Hobson et al., 2021).

Shaw, S. R., S. D'Intino, J., & Lysenko, E. (2019). Registered reports, replication, and the Canadian Journal of School Psychology: Improving the evidence in evidence-based school psychology. *Canadian Journal of School Psychology*, *34*(3), 175–187. doi:10.1177/0829573519843027. [*This article outlines the challenges regarding replication, reproducibility, and evidence-based practices, and describes the submission protocol and criteria for acceptance of registered reports*] (Shaw et al., 2019).

3.13 | Replication

***Source*:** Plucker, J. A., & Makel, M. C. (2021). Replication is important for educational psychology: Recent developments and key issues. *Educational Psychologist*, *56*(2), 90–100. doi:10.1080/00461520.2021.1895796.

Replication refers to testing how reliable prior findings are with different data (Nosek et al., 2022) and is considered fundamental to the scientific process (Makel et al., 2016). Whereas no replications are truly exact or 'direct' or 'close' (Nosek & Errington, 2020), there is still a clear distinction between those that use the same methods in the same target population and 'conceptual' replications (Crandall & Sherman, 2016).

Our next source discusses the value and relevance of replication in educational psychology (Plucker & Makel, 2021). They define replication as 'the intentional repetition of previous research to confirm or disconfirm the previous results, serving as a *de facto* reliability check on previous research' (p. 90). The chief value that replications contribute to research and the public is informing stakeholders about which results can be repeated in what circumstances or contexts.

Plucker and Makel explain that replications occur in two forms: direct and conceptual replications. In direct replications, researchers follow the methods of the original study as closely as possible to arrive at similar results. In contrast, researchers doing conceptual replications purposefully alter factors such as demographics, or study context, aiming to examine the theoretical soundness of a particular finding or set of findings. Unfortunately, replications are still uncommon in education, psychology, and educational psychology.

Plucker and Makel summarize researchers' current understandings of replications in the following four areas: *philosophy of replication*, *methodology of replication*, *professional implications of replication* and *utility of replication*.

Regarding the *philosophy of education*, although epistemological questions remain, there has been made a philosophical advance regarding the understanding of the value of replications. Plucker and Makel argue that replication has well-defined, epistemological purposes and that there is a need for increased use of replications in educational psychology. The authors discuss the value of both direct and conceptual replications and call for explicit statements of intent in the papers regarding the type of replications that are conducted.

Under the *methodology of replication*, the authors explain the similarities and differences between meta-analyses and replications (i.e., they both address research quality in different ways, and solve different problems). In particular, meta-analyses help solve the problem of heterogeneous results, whereas replications help assess and address experimental bias. The authors continue arguing that replication is relevant to all forms of research, including qualitative research.

Under the *professional implications* of replication Plucker and Makel argue that replications are good for one's career. They remind us that more emphasis on replications in educational psychology will help make replications more of a key aspect of the educational psychology enterprise. They round out this part by explaining that educational psychology is starting to value and support replication, but the process is slow and uneven.

Regarding the *Utility of replication*, Plucker and Makel remind us that when discussing replications in a field, it is important to discuss whether the most important studies in that field have been replicated, rather than whether a field has replicated a specific percent of studies. Increased use of replications is feasible and there is no way to create an ideal education system that is informed by research evidence without greater use of replications. Plucker and Makel believe that by working together and by using open science practices, educational psychologists will create positive outcomes for both research and practice. Collaboration is the key because it helps to understand existing work better, conduct future research more efficiently and effectively, and provide greater value to practitioners and policymakers.

3.14 | Other suggested readings

Coyne, M. D., Cook, B. G., & Therrien, W. J. (2016). Recommendations for replication research in special education: A framework of systematic, conceptual replications. *Remedial and Special Education*, *37*(4), 244–253. doi:10.1177/0741932516648463. [*This article considers the potential benefits of conceptualizing special education intervention research within a framework of systematic, conceptual replication*] (Coyne et al., 2016).

Duncan, G. J., Engel, M., Claessens, A., & Dowsett, C. J. (2014). Replication and Robustness in Developmental Research. *Developmental Psychology*, Advance online publication. doi: 10.1037/a0037996. [*This article makes the case for prioritizing both explicit replications and, especially, within-study robustness checks in developmental psychology. It also provides recommendations for promoting graduate training in replication and robustness-checking methods and for editorial policies that encourage these practices*].

3.15 | Changing institutional incentives to foster sound scientific practices

Source: Lundwall R. A. (2019). Changing institutional incentives to foster sound scientific practices: One department. *Infant Behaviour & Development*, *55*, 69–76. doi: 10.1016/j.infbeh.2019.03.006

One of the main barriers to the adoption of open science practices can be that an academic reward system does not sufficiently incentivize open science practices (Nosek et al., 2012). For example, despite the importance of replications for the research credibility, the present research culture provides strong incentives for innovation (Nosek et al., 2012), and this emphasis on innovation may undermine practices that support verification (Nosek et al., 2015).

In our next source, Lundwall (2019) reports the changes made in incentives to support open science and replication work at their department. First, Lundwall explains that most universities provide no incentives to adopt best research practices such as replications, rather they tend to favour novel research findings. It is difficult for researchers, especially pretenure or early career researchers, to practice open science practices when their institutions do not consider, for example, replication as innovative enough. The author argues that a lack of institutional incentives to practice open science may be especially problematic for infant researchers who face unique challenges, such as greater developmental variability across younger age groups and difficulty to recruit participants and that some characteristics of infants, like inability to follow instructions and shorter attention spans, mean both that developmental researchers must collect less data from each infant. Then, Lundwall reports on specific rationales for restructuring incentives, explains how their new system works and impacts developmental researchers, and provides suggestions for those interested in changing their institutional incentives.

According to Lundwall, these changes were initiated to support sound scientific practices. At their department, few faculty were applying these practices. Ludwall stresses that this was because researchers felt they needed to focus on institutional expectations for innovation, not because they lacked interest. To remedy this, incentive changes were initiated to support researchers in their efforts. Lundwall provides a table (Table 3 in the article) with examples of activities that increased quality ratings. They believe that providing such a list to faculty early in their careers and prior to annual reviews increases the likelihood that they will be implemented.

Lundwall explains how the creation of this new 'quality' metric provides a formal method for making a case that a particular study is worth more than might be suggested by simply counting publications. Developmental researchers can now provide evidence that their research activities should count as a technique to improve developmental science, while earlier they needed to remind colleagues evaluating a dossier that developmental studies tend to be costlier and take longer. Although not listed in Table 3, Lundwall explains that large-scale collaborative studies should be supported because they provide more confidence in developmental science by both increasing sample sizes and embracing open science. Developmental science is fundamentally individual differences research, requiring larger sample sizes. By collaborating with others, researchers may realize the potential of developmental psychology to address problems of development.

These changes allow Lundwall to be more explicit about methods used and statistical decisions made, and to join large collaboration studies that attempt to replicate key findings in the field. Lundwall provides suggestions for initiating similar changes in other departments and institutions. Table 4 in the article includes a summary of these suggestions (see page 74 in the article).

Lundwall suggests that, before meeting to discuss a specific plan to change incentives, faculty members should read the literature on open science, replication, reproduction and similar scientific practices. Also, a seminar on these topics may be especially helpful for busy researchers. Less formal discussions are also valuable. Lundwall reminds us that in all departments there will be concerns about changes in incentives because they will have various impacts on faculty in different areas. Listening to faculty members concerns and providing a transition period and/or flexibility will likely get more people on board.

Existing incentive structures often put open science and researcher survival in conflict because researchers are expected to provide novel findings. Therefore, institutions should accommodate and incentivize those who want to do replications, given their importance for science. Lundwall expresses hope that some may follow their lead and begin their process of finding balance between novelty and replication in their work.

3.16 | Other suggested readings

Mellor, D. T. (2021). Improving norms in research culture to incentivize transparency and rigour. doi: 10.35542/osf.io/thny5 [*Provides specific recommendations for working towards improved research culture*] (Mellor, 2021).

3.17 | Collaborative developmental science

Source: Heinlein, K., Bergmann, C., Davies, C., Frank, M. C., Hamlin, K., Kline Struhl, M., … Soderstrom, M. (2019). Building a collaborative psychological science: Lessons learned from ManyBabies 1. doi: 10.31234/osf.io/dmhk2

Collaboration is a cornerstone of open science (e.g., Open Science Collaboration, 2015), and open science includes an ideological shift towards championing collaboration (Pownall, Azevedo, et al., 2021; Pownall, Talbot, et al., 2021). Working collaboratively has many benefits including fostering a healthy working environment (Macoun & Miller, 2014; Pownall et al., 2021). UNESCO (2021) defines open science as an inclusive construct that combines various movements and practices aiming to increase scientific collaborations and sharing of information for the benefits of science and society.

In our last source, Byers-Heinlein et al. (2019) share 'lessons emerged' from the first project of ManyBabies—ManyBabies 1—in which 69 labs from 16 countries tested 2845 infants, of which 2329 were included in the final analysis. Byers-Heinlein et al. also include personal narratives of the collaborators.

ManyBabies, a large-scale collaboration on key theoretical questions in developmental science, aims to address the problem of small sample sizes in infancy research, resulting in the ability to test even small effects with enough power and to investigate individual differences robustly. In addition, ManyBabies models open science practices in infant research such as preregistration, open materials and open data. Furthermore, ManyBabies aims to increase growth and diversity both within infancy research and in psychological science in general.

Byers-Heinlein et al. describe some of the discussions the contributors had in the process, the solutions they have found, and the challenges that remain. ManyBabies is an example of a collaborative community of infancy researchers committed to open science best practices, operating within a large-scale collaborative research framework or model. This collaborative framework prioritizes collaboration in all aspects of the project.

Byers-Heinlein et al. outline many of the issues, insights, and processes that have emerged over the first few years of collaboration. By providing a behind-the-scenes view of the steps and challenges they met in the process, the authors hope that other teams of researchers, in infancy and other fields, will embark on a similar journey, and, not least, that they can learn from their mistakes and benefit from their successes. The authors hope to create greater awareness and uptake of open science practices.

Byers-Heinlein et al. emphasize the role of leadership in collaborative projects because the leadership team plays a crucial role in ensuring that diverse views are heard, steering discussions towards a productive resolution, and pushing the project forward by assigning tasks, setting deadlines and so on.

Byers-Heinlein et al. describe the strengths and weaknesses of different communication approaches, such as video conference presentations and meetings, and a Slack group. Byers-Heinlein et al. used a model that has been described as a Contributorship rather than an Authorship model (for more information about contributorship model see https://psyarxiv.com/dt6e8/, Holcombe, 2019; Holcombe et al., 2020). However, they did this towards the end of the project which appeared not to be optimal and it might be better to complete while projects are ongoing.

Byers-Heinlein et al. describe what this project achieved proudly, but at the same time, they describe the ongoing challenges they face such as funding and technical infrastructure for large-scale collaborations. Byers-Heinlein et al. also explain the benefits of contributing to open science collaborations, which are often framed in terms of risks to researchers, particularly early-career researchers. One important benefit of ManyBabies is in providing a model of open science in action, implementing research practices such as preregistration that buffer against the effects of publication bias. In ManyBabies, data are published regardless of the outcome of the data analysis (assuming sound implementation of the experiment). The rich dataset generated by ManyBabies projects allows for secondary analyses.

Participating in a large-scale collaboration provides researchers with direct access to a community of researchers motivated to develop and share new techniques and best practices in the field. This is particularly important for early career researchers and trainees who may not have as many opportunities to expand their research networks.

ManyBabies continues to grow, despite the challenges the team experienced during ManyBabies 1. The guidelines and best practices that were developed will facilitate success for current and future collaborative projects. They continue to develop networks and are working to ensure that core values of equity, diversity and inclusion. Byers-Heinlein et al. encourage any interested graduate student or postdoctoral researchers to raise the possibility of participating in ManyBabies with their advisor, and they encourage every principal investigator to find out if somebody in their lab is interested in contributing. The team hopes to collaborate with and learn from a global network of labs from six continents representing the diversity of human experience. They hope that ManyBabies will help serve as a model of how to create collaborative projects to solve the hardest methodological and theoretical problems in the field.

3.18 | Other suggested readings

Frank, M. C., Bergelson, E., Bergmann, C., Cristia, A., Floccia, C., Gervain, J., Hamlin, J. K., Hannon, E. E., Kline, M., Levelt, C., Lew-Williams, C., Nazzi, T., Panneton, R., Rabagliati, H., Soderstrom, M., Sullivan, J., Waxman, S., & Yurovsky, D. (2017). A collaborative approach to infant research: Promoting reproducibility, best practices, and theory-building. *Infancy*, *22*(4), 421–435. doi: 10.1111/infa.12182. [*Useful description of a proposal for assessing and promoting replicability in infancy research and discuss some of the challenges of collaborative developmental work*].

Makel, M. C., Smith, K. N., McBee, M. T., Peters, S. J., & Miller, E. M. (2019). A path to greater credibility: Large-scale collaborative education research. *AERA Open*. doi: 10.1177/2332858419891963. [*Good discussion of models of large-scale collaborative research practices and how they can be applied to education research*].

4 | GENERAL DISCUSSION AND THE PATH FORWARD

Uptake of open science principles and practices has been uneven and slow across different subfields of psychology (Syed & Kathawalla, 2022; Washburn et al., 2018). A lack of awareness of, and knowledge about, open science practices and their utility are among the many barriers that prevent this uptake (Washburn et al., 2018). To contribute to reducing these barriers within developmental science, in this paper, we present an annotated reading list and the summaries of the selected resources describing various open science practices that have been applied in different areas of developmental science.

Our summarized resources cover the following topics: *Open science practices; Issues with Reproducibility and replication; Open data, materials and code; Open access; Preregistration; Registered reports; Replication; Incentives; Collaborative developmental science.*

Our reading list demonstrates that some practices are discussed more than others within developmental science. For example, we could identify only one white paper (Kim et al., 2020 about teaching open science that also mentions developmental scientists. Therefore, we direct readers interested in reading about teaching open science to the excellent Framework for Open and Reproducible Research Training (FORRT-https://forrt.org/). The FORRT community has recently published a preprint reporting a comprehensive review of literature concerning the impact of teaching open scholarship on students' scientific literacy, engagement and attitudes towards science (Pownall et al., 2022). As well as several subprojects, the FORRT project includes an excellent collection of open and reproducible science literature, some of which is summarized in an accessible manner (https://forrt.org/summaries/). Another useful source is the list of examples of good practice resources across disciplines collated by Farran and colleagues (Farran et al., 2020). This list also contains sources directly relevant for developmental researchers. In addition, our supplementary file contains some important literature. We have also provided reading recommendations related to developmental science after each summary.

Note that although we found several resources on special education and learning disabilities, only one source on our reading list was specifically about neurodevelopmental conditions (Farran & Scerif, 2021). There is a clear need for discussions on how to apply open science practices to fields focused on neurodevelopment and neurodiversity.

We also want to direct readers' attention to grassroots initiatives in open science such as ReproducibiliTea clubs (https://reproducibilitea.org/) and the RIOT Science Club (http://riotscience.co.uk/). One of the authors (TK) of this paper coordinates one of the sites of the RIOT Science Club, while another of the authors (SAH) co-hosts a podcast focused on the methods and metascience of developmental science (Within and Between), which often covers open science topics. In addition, there is a considerable amount of information about open science on the Internet, including discussions that occur frequently on social media, especially on Twitter. For example, we suggest developmental researchers to follow the following Twitter accounts: ManyBabies (shorturl.at/nuJOY), LDbase (shorturl.at/hiACU), Special Education Research Accelerator (shorturl.at/awxDS).

What was obvious after reviewing the identified resources was that collaboration is considered vital for developmental researchers wanting to apply open science practices. Indeed, several barriers to the adoption of these practices can be solved through collaborations and ManyBabies is an excellent example of this. No one researcher can be an expert in all the skills needed to implement all open science practices while keeping up with their field and collecting all the data needed for replicable work. Collaborative science allows the sharing of expertise, time, and resources, making open science more feasible (e.g., Terry et al., 2021). In addition, not all solutions should be the responsibility of the developmental researchers. Instead, top-down incentives also need to be recognized, such as the provision of funding for replication research (Nuijten, 2019).

Our reading list contains sources of other important topics that we encourage readers to learn more about, such as publishing standards and diversity of experimental samples and researchers (see the supplementary file). In addition, we would like to make it clear that while we focused more on open science as a set of practices, open science is also a set of principles, and we recommend readers to get familiar with the historical background and the fundamentals of open science. For this purpose, we want to direct readers another excellent source, FORRT clusters (https://forrt.org/clusters/) where open science literature is sorted according to clusters and subclusters to show which topics they cover and how they are connected to one another.

To researchers writing about and teaching about open science practices, we wish to recommend using positive approaches to encouraging open science practices (e.g., rather than focusing on those who do not as bad scientists in some way). As correctly concluded by Spellman et al. (2017), looking at openness and transparency as a spectrum, and selecting the ideal level might be the best way to practice open science. We also note that there are important discussions on how open science can become better, which is a discussion we must have as a field (e.g., Kessler et al., 2021). For example, some open science practices (e.g., preregistration) or their implementation or what they are supposed to do seem to be more controversial than others (e.g., open access) (see for example, Szollosi et al. (2020) for the critique focusing on the use of preregistration as an attempt to improve scientific reasoning and theory development). We recommend readers get familiar with the relevant literature, including the following: Whitaker and Guest (2020), Pownall, Azevedo, et al. (2021); Pownall, Talbot, et al. (2021), and Kessler et al. (2021).

Finally, to make it clear, this article does not provide a comprehensive literature review based on a systematic literature search. Our goal was to present the topics and practices as a focused but incomplete starting point for a wider, more comprehensive consideration of open science topics and practices in developmental science. While this article addresses a lack of knowledge and awareness of open science practices as barriers to adoption, there might be other difficulties, such as a lack of financial resources, recruiting and retaining babies as participants, that increased knowledge cannot resolve. These barriers should also be discussed in the future. Also, we want to make clear that several aspects discussed in our selected sources, and in the open science literature in general, have been criticized and/or need to be discussed more. Therefore, we encourage developmental scientists to carefully reflect on the included sources and on the open science literature in general, and select what they think is compatible with their work.

Generally, we agree with Syed (2019) that staying up to date on conversations and literature on open science and engaging in debates where possible is important, because this enhances the recognition that we as scientists can always improve our work by making it as open and transparent as possible.

AUTHOR CONTRIBUTIONS

Tamara Kalandadze: Conceptualization; formal analysis; methodology; project administration; visualization; writing – original draft. **Sara Hart:** Conceptualization; formal analysis; methodology; supervision; visualization; writing – original draft.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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SUPPORTING INFORMATION

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