Nudging Open Science

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Abstract

In this article, we provide a toolbox of resources and nudges for those who are interested in advancing open scientific practice. Open Science encompasses a range of behaviours that aim to include the transparency of scientific research and how widely it is communicated. The paper is divided into seven sections, each dealing with a different stakeholder in the world of research (researchers, students, departments and faculties, universities, academic libraries, journals, and funders). With two frameworks in mind — EAST and the Pyramid of Culture Change — we describe the influences and incentives that sway behaviour for each of these stakeholders, we outline changes that can foster Open Science, and suggest actions and resources for individuals to nudge these changes. In isolation, a small shift in one person's behaviour may appear to make little difference, but when combined, these small shifts can lead to radical changes in culture. We offer this toolbox to assist individuals and institutions in cultivating a more open research culture.

Key words. Open Science, behavioural change, nudging

Nudging Open Science

A spotlight on replication failures spanning many scientific fields has given rise to what has been called a 'reproducibility crisis'. Psychology, economics and medicine are just a few disciplines where the reproducibility of findings have been criticised (Duvendack et al., 2017; Open Science Collaboration, 2015; Prinz et al., 2011); Questionable research and publication practices (QRPPs) are partly to blame for this crisis; a norm or bias toward publishing positive results (the 'file-drawer problem'; Rosenthal, 1979) incentivises researchers to be especially liberal when analysing their data (e.g., 'p-hacking'; Simmons et al., 2011) and generate hypotheses after the results of an experiment are known as if they were expected from the outset ('HARKing'; Kerr, 1998). More than half of researchers in psychology, for instance, have reportedly peeked at their study's results before subsequently deciding whether to collect more data and more than one third also claimed to have reported *unexpected* findings as though they were expected from the outset (John et al., 2012). QRPPs provide fertile ground for further irreproducibility and result in part from the culture and incentive structures in academia (Edwards & Roy, 2017; Munafò et al., 2017; Nosek et al., 2012).

A movement of Open Science has arisen in response to these issues (Vazire, 2018). The umbrella term 'Open Science' encompasses a range of behaviours that aim to increase the transparency of scientific research and how widely it is communicated (Fecher & Friesike, 2014). Reforms such as preregistration, publicly sharing data, open review processes, and open-access publication are designed to make research easier to use, evaluate and reproduce (Corker, 2018; Pontika et al., 2015; Spellman et al., 2018). However, some individuals are not yet committed to change because they may be unaware of Open Science or its benefits. Individuals and institutions may be dissuaded by a perception that more transparent science is too laborious or may not know how to change the way they currently do things. Additionally, the incentive structures and publication practices are problematic because they tend to reward positive findings more than negative or null findings. If certain kinds of findings are demanded, then Open Science can be perceived as a barrier to these goals.

Whether or not researchers and institutions decide to adopt Open Science practices is largely a behavioural question (Norris & O'Connor, 2019). Insights from psychology and other behavioural sciences suggest that humans are far from purely rational decision makers. Instead, people routinely make decisions through automatic, impulsive, and emotional processes — often

driven by social pressures and immediate cues in their environment (Kahneman, 2011; Tversky & Kahneman, 1974). Everyday decisions are often shaped by surprisingly incidental or opportunistic factors. When a person chooses what toothpaste to buy, they rarely make a fully rational choice by weighing up the costs and benefits, or foreseeable utility. Instead, they tend to opt for the toothpaste presented at eye level (Thaler & Sunstein, 2008), or the one that is the most familiar or regularly advertised (Pliner, 1982; Zajonc, 1968).

The influence of psycho-social factors, however, is not limited to consumer decision-making. It extends to decisions that researchers and institutions make when deciding how to conduct, report, evaluate, publish or fund research. For example, 'bad' scientific practices include QRPPs (e.g., p-hacking, HARKing, or selective reporting) whereas Open Science includes behaviours such as preregistration, posting preprints, or publicly sharing data. Human psychology is at the centre of every decision, whether it be buying toothpaste, running a scientific study, or evaluating a research project.

Theories and findings from across the behavioural sciences can inform practically any situation where a human decision-maker is involved. There are many examples where simple and inexpensive changes in choice architecture (i.e., the way that choices are presented to consumers) have significant impacts on behaviour. When confronted with a decision, for instance, people tend to choose the option that requires the least effort. In most cases, the status quo — how things currently are — is preferred over a more effortful change. Sweden, for example, enjoys far higher rates of organ donation than Denmark not because the Swedes are more compassionate or because organ donation is a core value of their nationhood, but simply because Sweden requires people to opt-out of donating their organs whereas in people in Denmark must opt-in (Johnson & Goldstein, 2003; Davidai et al., 2012).

Highlighting a social norm — the accepted standard of behaviour of most people in group that one cares about — can also greatly influence how people act. For example, if people discover that 90% of fellow group members (rather than 10%) put their rubbish in the bin, they are more likely to do the same. Social norms messaging is a cost-effective strategy for a range of behaviours, including conserving energy (Benartzi et al., 2017; Nolan et al., 2008), reducing over-prescription of antibiotics among general practitioners (Hallsworth et al., 2016) and increasing tax compliance (Hallsworth, 2014).

These are all examples of ‘nudging’ (Thaler & Sunstein, 2008). They are small, easy-to-avoid changes to a person’s decision-making environment that alter behaviour in a predictable way without forbidding any options or using economic incentives. Though we have only outlined a fraction of the possible interventions that behavioural research can offer, the field has a great deal of potential to help improve the uptake and maintenance of positive, open scientific practices. There are at least two key frameworks for effective behaviour change (see Figure 1). The first framework is the Pyramid of Culture Change (Nosek, 2019) and the second is the EAST (Easy, Attractive, Social, and Timely) framework (UK Behavioural Insights Team, 2014). Many of the underlying principles from the Pyramid of Culture Change and EAST are similar, and both converge with well-established findings from the behavioural change and nudging literature.

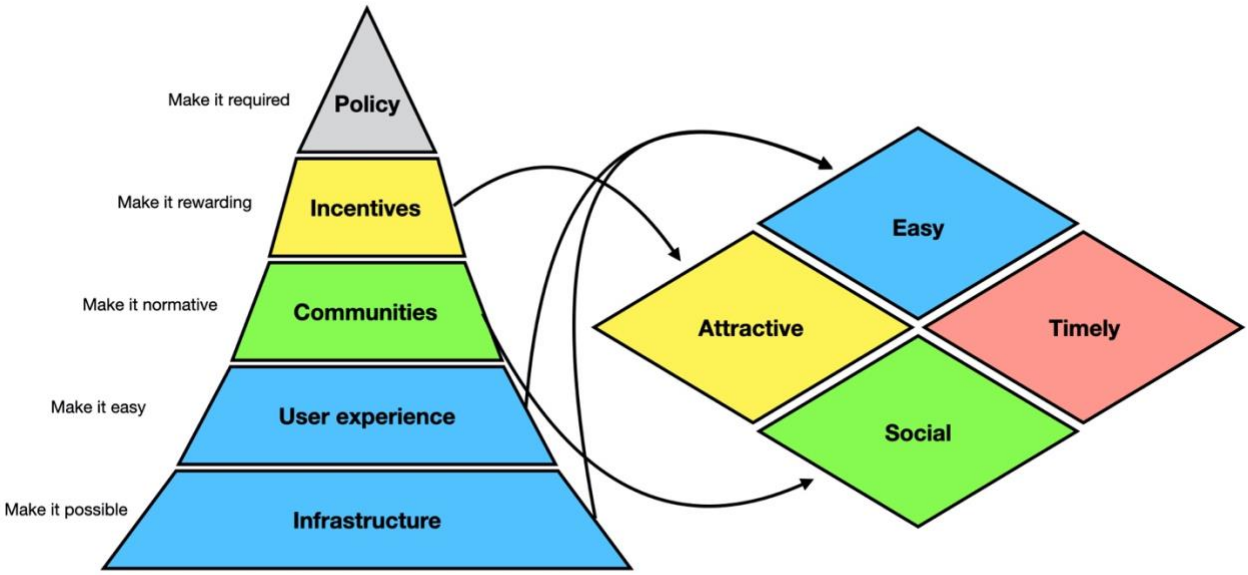

Figure 1. *An illustration of the Pyramid of Culture Change and the EAST framework, and how the components of each model relate to one another.*

The first rung on the Pyramid of Culture Change prescribes that desired behaviours be made possible by providing the necessary infrastructure, while the second rung highlights a need for desired behaviours to be simple for people to engage in. These two rungs broadly resemble the first principle of the EAST framework: desired behaviours ought to be made easy. The third rung on the Pyramid endorses the power of communities in shaping normative behaviour and

instilling social connection. Similarly, the EAST framework emphasises the utility of social norms, social commitments, and the power of networks to change behaviour. The fourth rung underscores incentivised reward systems. In other words, desired behaviours ought to be attractive, as per the 'A' in EAST. We will ignore the top rung of the pyramid because 'requiring' any behaviour runs counter to the nature of nudging. However, many nudges would be effective if presented regularly or when people are most receptive (i.e., timely, as per the 'T' in EAST).

Inspired by these two frameworks, we offer concrete ways for individuals to nudge a more open research culture. Each section in this paper is devoted to nudging a different node in the research ecosystem: researchers, students, departments and faculties, universities, libraries, journals, and funders. In doing so, we map the psychology of the target audience, outline their role in the scientific community and suggest actions they can take to improve scientific research. We then offer ways to bridge the intention-action gap — the void between what people say they would like to do and what they actually do — using the principles outlined in the Pyramid of Culture Change and EAST frameworks. We believe that incremental behavioural shifts across the research ecosystem will greatly improve the way scientific research is conducted, promoted and disseminated, and that action at each node is essential for bringing about these shifts. In Table 1, we also provide a list of resources that readers can use to promote Open Science.

Table 1.

Open Science Resources for Nudging Various Stakeholders in the Research Ecosystem.

Resource	URL
Researchers	
Grassroots movements	https://www.cos.io/blog/how-build-open-science-network-your-community
Preregistrations servers	https://osf.io https://aspredicted.org https://clinicaltrials.gov
Preregistration and templates	https://how-to-open.science/ https://cos.io/prereg/ https://osf.io/zab38/wiki/home/?_ga=2.131598031.1140806084.1569228081-2063469120.1563260321&view

	https://osf.io/t6m9v/ https://dunn.psych.ubc.ca/resources/
Preprint guides and templates	https://osf.io/preprints/ https://help.osf.io/hc/en-us/articles/360019930533-Upload-a-Preprint
Registered reports guides and templates	https://cos.io/rr/ https://osf.io/3wct2/
Preprint servers	https://arxiv.org/ https://psyarxiv.com/ https://www.biorxiv.org/ https://peerj.com/preprints
Annotated preprints	https://web.hypothes.is
Tutorial for the OSF and other Open Science topics	https://www.youtube.com/channel/UCGPlVf8FsQ23BehDLFrQa-g https://www.youtube.com/watch?v=kzUtpDBo8wk https://www.youtube.com/watch?v=EnKkGO3OM9c
Is your journal open access?	http://sherpa.ac.uk/romeo/index.php
ReproducibiliTEA guide	https://reproducibilitea.org/online.html
Community outreach tools	https://osf.io/hnp6x/wiki/home/
Data repositories	http://www.nature.com/sdata/policies/repositories https://osf.io/ http://oad.simmons.edu/oadwiki/Data_repositories https://zenodo.org https://www.psycharchives.org
Guides for evaluating researchers	http://www.leidenmanifesto.org/ https://wcrif.org/guidance/hong-kong-principles
General Open Science resources	https://www.sub.uni-goettingen.de/en/electronic-publishing/open-science/ https://open-science.sites.uu.nl/

Students

Student Initiative for Open Science	https://studentinitiativeopenscience.wordpress.com/
Open scholarship knowledge base (OSKB)	https://www.oercommons.org/hubs/OSKB
Master's course on Open Science template	https://osf.io/v3z7q/
Course materials for open a reproducible research methods	https://osf.io/zbwr4/wiki/home/ https://osf.io/vkhbt/ http://www.projecttier.org/tier-classroom/course-materials/
Courses for learning statistics with open-source software	https://psyteachr.github.io/ https://learningstatisticswithr.com/ https://r4ds.had.co.nz/
Free coding software and websites	https://github.com/ https://www.r-project.org/ https://jasp-stats.org/
Departments/Faculties	
Example Open Science declarations	https://www.smu.edu/-/media/Site/Dedman/Academics/Departments/Psychology/2018/Policy-on-Open-Science-032218.pdf
Universities	
Research Excellence Framework's (2021) research integrity metric	https://www.ref.ac.uk/
Example surveys of adherence to Open Science	https://osf.io/bk8y7/ https://osf.io/d6pu5/
Starting an Open Science Community tutorial	https://docs.google.com/document/d/112B-OCArTI-zdDZ6S67BPVHSn6gPL9GgmluoQ35zG40/edit
Open data map	opendataimpactmap.org
International Open Science communities	https://osf.io/vz2sy/ https://osf.io/tbkzh/

OSF institutions	https://osf.io/institutions https://www.cos.io/products/osf-institutions
The Declaration on Research Assessment (DORA)	https://sfdora.org/read/
Libraries	
Figshare for institutions	https://knowledge.figshare.com/institutions
FAIR Data principles	https://www.go-fair.org/fair-principles/
Data management plans and examples	https://www.nwo.nl/en/research-data-management https://rmit.libguides.com/researchdata
Example open access publishing schemes	http://www.oacompact.org/ https://www.ucl.ac.uk/library/open-access
Open culture guide	https://uk.sagepub.com/sites/default/files/library-oareport.pdf
Journals	
List of Open access journals	https://doaj.org/
Journals that offer Registered Reports	https://www.cos.io/initiatives/registered-reports
Request a paywalled article	https://openaccessbutton.org
Transparency and Openness Promotion (TOP) guidelines	https://cos.io/top/ https://osf.io/fe2pz/ https://www.cos.io/initiatives/top-guidelines
Open Science badges guide	https://cos.io/our-services/open-science-badges/
Funders	
Data management templates	https://dmponline.vu.nl/public_templates
cOAlition S: Funding open access in Europe	https://www.coalition-s.org/about/
Open science guide for collaborating with funders	https://www.cos.io/blog/how-to-collaborate-with-industry-using-open-science

Commitment statements for grant applications	http://www.researchtransparency.org/

Researchers

A commonly portrayed aphorism in academia is to 'publish or perish'. Among journals there remains a bias to publish results that are both novel and positive (Nosek et al., 2012; Rosenthal, 1979). Almost every researcher is well-intentioned; they want to produce good scientific research. However, studies take considerable time, energy, and resources. Pressure is placed on researchers to make their work as palatable to journals as possible. The prevailing incentive structures can therefore make it tempting for researchers to engage in QRPPs even without awareness. Scientists like anyone are prone to biases, such as confirmation bias (favouring results that confirm one's beliefs) and hindsight bias (overestimating one's ability to have predicted an outcome that could not have been predicted; Roese & Vohs, 2012). Raising awareness about how biases can affect scientific practices and findings is therefore critical to a culture of Open Science (Nuzzo, 2015).

The wider scientific community incurs significant cost from the false positive findings that result from QRPPs. Erroneous conclusions can influence future research and public policy, potentially wasting significant time and money. At present, there is little incentive to adopt more open practices and many misconceptions continue to dissuade academics from adopting open practices (Abele-Brehm et al., 2019). Institutional changes that align with Open Science are unlikely to occur without strong support from researchers. A shift in culture toward better scientific practice therefore hinges on incremental change at the grassroots level. Though there are now many Open Science reforms taking place (e.g., Open Science Communities Netherlands, Reproducibility Networks in Germany, Switzerland, Australia and the UK, and the Berkeley Initiative for Transparency in the Social Sciences), here we focus on two behaviours that are easy for researchers to adopt and integrate into their research workflow: preregistration and preprinting. We then describe ways in which researchers can change how they evaluate research.

Preregistration and Preprints

Preregistration is a public commitment to predictions, research, and analysis plans without advanced knowledge of a study's outcomes (Nosek et al., 2018). This commitment constrains how one can use the data one has gathered and also moves crucial decisions related to

recruitment strategies, stopping rules, exclusion criteria, materials, procedures, predictions, data analyses, and statistical tests upfront before data is collected (Gelman & Loken, 2013). Shifting this work to occur earlier in the research process helps to ensure that unforeseeable issues with an experiment are addressed early. Although some have questioned the utility of preregistration (see Devezer et al., 2020; Szollosi et al., 2019), the act can serve partial antidote to QRPPs such as HARKing and p-hacking (Fischhoff & Beyth, 1975; Munafò et al., 2017; Nosek et al., 2018; Wicherts et al., 2016). Preregistration can also partly address file drawer problems by improving the visibility of otherwise undetectable null findings. There are now several online registries dedicated to preregistration (see Table 1).

Registered reports take preregistration to the next level. In a Registered Report, one details the research questions, methodology, and analysis plan and submits this for review prior to collecting data. Once a Registered Report is accepted, the journal agrees to publish the study regardless of the outcomes as long as the quality control criteria are met. Many journals now accept Registered Reports as a publication format. Preregistration together with Registered Reports can help to ensure that the scientific value of hypothesis testing is determined by the quality of research questions and methodology rather than the findings themselves.

A preprint, on the other hand, is a version of a scientific paper that precedes a formal peer-reviewed publication in a scholarly journal and is often made freely available to the public. Papers that make it through the peer review process are then copyedited and typeset before publication. There is no doubt that peer review is an integral aspect of science, but the process can result in less nuanced findings and interpretations being published. For instance, negative or 'messy' findings that do not present a 'nice story' can be removed at the recommendation of a reviewer. The preprints can offer a raw, unedited version of a study for people to consider. They also enable authors to openly share versions of their papers in ways that are openly accessible before or during the peer review process as well as following publication in an academic journal to allow members of the public to access the paper. Sharing scientific manuscripts as preprints is becoming increasingly popular for many researchers (Narock & Goldstein, 2019).

Nudging preregistration and preprints. There are many means to potentially improve the transparency and rigour of scientific research (e.g., open code, data analysis, and materials), but preregistration and preprints are relatively easy first steps. Devoting a minute or two to preregistration and preprints during a research seminar or workshop can serve as a point of entry into Open Science. It can also signal a descriptive norm to your colleagues as well as an injunctive norm if the benefits of preregistration and preprints to the scientific community are highlighted.

Simply knowing that other researchers preregister their studies and post preprints, however, does not provide the opportunity for researchers to it themselves. Organising Open Science seminars and workshops for colleagues to attend may also be highly effective. So too could inviting Open Science advocates to present at your department or faculty. These events allow researchers to learn more about preregistration and preprints — what they entail, how they can be done, and why they are important, for instance, because of cognitive biases and QRPPs (e.g., the effects of p-hacking on the interpretability of findings).

Preregistration and preprints are becoming more and more commonplace (Fu & hughey, 2019; Nosek & Lindsay, 2018). A need to connect can be leveraged at these events by strengthening the sense of these practices as increasingly normative. Noting the advantages of preregistration and preprints can also incentivise researchers to engage in these behaviours. For example, both practices prevent 'scooping' and intellectual overlap because they are associated with time-stamped digital-object identifiers (DOIs). Many journals also offer Open Science badges that signal the use of practices such as preregistration (McKiernan et al, 2016). Papers associated with preprints also tend to be cited more than papers with no accompanying preprint (Fu & Hughey, 2019; Serghiou & Ioannidis, 2018), which may be particularly beneficial to early career researchers (Allen & Mehler, 2019; Berg et al., 2016; Sarabipour et al., 2019). These behaviours could also be framed as minor additions to a researcher's workflow and basic templates could be used to run through worked examples. Holding these workshops and seminars at times when colleagues tend to begin new projects will undoubtedly attract even greater attention and is an ideal time for researchers to form new habits. In addition, such events offer the opportunity for researchers to raise reservations and lively debate could help dispel any misconceptions people may have. In Tables 2 and 3 we outline some common misconceptions to preregistration and preprinting, and ways to respond to these objections.

Table 2.

Responses to Misconceptions about Preregistration.

Misconceptions about preregistration	Reality
"Preregistration stifles creativity. If I preregister then I cannot run any more exploratory analyses."	Preregistration is not intended to discourage exploratory analyses or creativity. It is simply a mechanism to distinguish confirmatory from exploratory analysis (i.e., prediction from postdiction). It best fits more mature research questions or direct replications where theories and methods are well-developed, effect sizes of interest are well-informed, and where predictions can be likewise specific (McIntosh, 2017). However, it can also fit exploratory research if greater emphasis is placed on parameter estimation and hypothesis generation than on a priori hypotheses and p-values (McIntosh, 2017). As DeHaven (2017) stated it, a preregistration is "a plan, not a prison".
"I don't need to preregister my work because it isn't experimental."	Open Science means engaging in behaviours that make research more transparent to readers and it can take many forms. Specifying how one will conduct a study and the methodology used can apply to many kinds of analysis, even when conducting secondary data analyses of already existing data (Haven & van Grootel, 2019; Mertens & Krypotos, 2019).
"When I preregister, other labs will 'scoop' me."	If one is worried that their ideas will get scooped, preregistrations can be embargoed until a specified date until which the project is only viewable by contributors. Moreover, a preregistration is a time-stamped proof of one's idea early in its conception. Thus, it is actually a precautionaury measure against getting scooped.
"I won't get published because I will be constrained by the analysis plan I laid out in my preregistration."	It is legitimate to deviate from one's preregistered plans as long these deviations are transparently reported. In fact, additional, unplanned analyses that improve the quality of the final analyses will only serve to illuminate the research process more clearly (Nelson, Simmons, & Simonsohn, 2017). Though the results may be messier than if one were to selectively report findings, studies that follow open practices tend to be more impactful in the long term (e.g., it attracts more citations; McKeirnan et al. 2016).
"Preregistration will only slow down my output because it requires far more work up front."	Preregistration does mean more work early in the research process, but it can reduce work later on as methodological, theoretical, and statistical flaws are likely to be noticed and ironed out earlier, and the analysis plan laid out. Preregistrations can also be as detailed or as short as one prefers and many templates (e.g., on the OSF) that make the process easy. More detailed preregistrations can also be submitted to journals as Registered Reports, which are more likely to be accepted than traditional manuscripts (Chambers, 2019).

Table 3.

Responses to Misconceptions about Preprints.

Misconception about preprints	Reality
"Preprints are not peer-reviewed and therefore not scientifically sound and less trustworthy. So why bother? "	Though not peer-reviewed, preprints are often what is submitted to a journal for publication. It is possible for researchers to upload a half-baked manuscript in theory, but most are aware that once something is available on a preprint server, remains there for all to see and evaluate. Manuscripts are usually accompanied by a permanent individual DOI as well. These mechanisms mean that researchers hold some responsibility for the preprints they post. Researchers also typically add revised versions of their manuscripts after peer-review to preprint servers simply to make the work more accessible. Peer-reviewed articles associated with preprints have 36% more citations than those that are not (Fu & Hughey, 2019). Posting preprints also allows for researchers receive feedback, which can help authors improve their manuscript.
"When I preprint my work, other labs will scoop me."	Preprints receive a time-stamped DOI, which can prevent ideas from being scooped because a citable document is created before the peer-review process, which often takes many months. This DOI can be especially helpful when two labs are working independently on the same scientific problem.
"If I preprint my work, I cannot publish it anymore."	Many journals today accept preprints prior to submission and publication. Some journals (e.g., eLife) are also beginning to acknowledge the value of preprints to an even greater extent by offering preprint review. This process is similar to the typical review process, but reviews are published alongside the preprint on BioRxiv (eLife, 2020). Resources for determining a journal's preprint policy can be found in Table 1.
"Uploading preprints is difficult and takes so much time."	A preprint is simply a manuscript-for-submission in PDF format and uploading a preprint (e.g., on PsyArXiv or BioRxiv) only takes a few minutes. Resources to help with preprinting can be found in Table 1.

Hosting regular 'ReproducibiliTea' meetings (Orben, 2019) or Open Science meetings can provide further social environments for researchers to discuss interesting Open Science ideas, papers and tools. In these meetings, researchers provide constructive feedback on each other's preregistrations and preprints for later publication. Moreover, attendees will be frequently reminded to preregister and preprint their studies because these behavioural norms are continuously on display. Regular meetings can also serve to introduce members to other practices such as open-source statistical software, publicly sharing data, simulating statistical analyses prior to collecting data and open access publishing.

Open Science behaviours do not appear stable over time and this is perhaps because many barriers to entry and maintenance can arise during the research process (Corker, 2018; Munafò et al., 2017; Nosek et al., 2015). Shifting these groups or clubs to online workplaces can

offer further opportuniy to share tips, links, templates, guides, and papers. Providing links and materials on departmental or faculty websites will also reduce these barriers and regularly prompt open behaviours among researchers. Early career researchers and graduate students in particular may benefit most from these social initiatives in a rapidly changing research landscape and because their habits are less entrenched.

A sound infrastructure for open practices makes it easier to create a normative culture. A physical 'Open Science wall' in the department or an Open Science section in the departmental newsletter or website can signal the widespread use of such practices among colleagues. Those already interested in Open Science can post the latest information on preregistration, preprints via flyers, and infographics, and onlookers will be reminded regularly of these behaviours.

Early adopters can also build 'open' norms by highlighting preprints on their websites and CVs next to peer-reviewed publications. Researchers can create forums and webpages dedicated to video tutorials, animations, infographics, and other resources to encourage Open Science. Fostering group cohesion in this way can inspire people to identify with the Open Science movement. Common goals can also strengthen bonds among researchers and rally more commitment. Some universities, for example, have taken part in the OSF's Preregistration Challenge, which ranks universities on the number of preregistrations within their institution. Although the challenge has ended, institutions can build in-group solidarity through this sort of collective action.

Moving from Quantity to Quality and from Data to Theory

Changing how we evaluate research is crucial to promoting open practices as well. The current 'publish or perish' culture not only incentivises novel and positive results, but it can also motivate unnecessary and costly data collection that may contribute little to scientific progress. Seeking only results that are positive and novel may encourage QRPPs among otherwise well-intentioned researchers. Similarly, overweighting the quantity of publications can motivate quick and easy experiments that produce just enough new data for a new publication. For example, the fastest way to accumulate publications would be to tweak experiments in minor ways and to write ap a separate article for each of these least publishable units (LPUs; also referred to as 'salami slicing').

Above we note that open practices such as preprinting can attract more citations, but ideally the primary goal of research should not be to increase one's citation count. If the metric

was quality, or 'contribution to scientific progress' (rather than the number of publications), then researchers would be incentivised to devise careful experiments that aim to falsify or expand key theories in the field, and to publish single papers with a strong emphasis on how the data contributes to theory. Some have even argued that preregistration and statistics will not fix science, because scientific progress critically depends on strong theories that map well onto statistical models (Fiedler, 2017; Szollosi et al., 2019). Psychology, for example, may have become too focused on theorising about specific phenomena that are often created by the experiments themselves, rather than on more general human capacities (Hommel, 2019). While psychology is a relatively young science, the focus on publication quantity may be partly responsible for the lack of strong theory.

When there are excessive publications, grasping the core findings of any subfield becomes increasingly challenging, which in turn discourages interdisciplinary work and creates scientific siloing. While some scientific siloing is inevitable and perhaps even desirable, collecting new data for new findings—for the sake of new data and new findings—is *not* a recipe for scientific progress, but *is* currently an ingredient of career progress. In contrast, a culture that values quality would inspire interdisciplinary work that requires more time and collaboration, but ultimately moves the field forward.

The growing trend of open data also creates exciting opportunities for researchers to test hypotheses and larger theoretical questions using highly powered integrated datasets from multiple paradigms and diverse populations. Recent examples include The Confidence Database comprising more than four million trials and 8,700 participants (Rahnev et al., 2020). Another is a recent data driven analysis of approximately one quarter of the fMRI literature, comprising approximately 17,000 experiments (Taylor et al., 2015). These efforts require multi-lab, multi-institution, and multidisciplinary efforts that would only be advantageous under a quality over quantity value scheme.

Nudging Changes to Evaluation. It goes without saying that researchers need *some* way to evaluate research, and that citation metrics or publication output can sometimes make for useful heuristics. But given growing awareness of the drawbacks of citation metrics and 'publications for the sake of publications', changes to our schemas for evaluating research are likely inevitable. Thus, one way we can start to encourage each other to focus on quality over quantity and theory over data may be to acknowledge that our metrics *will inevitably change*.

Knowing this fact may encourage researchers to avoid the risk of investing time and resources to fulfil goals that will not be incentivised in the future (i.e., anticipated regret; Zeelenberg, 1999).

On a more practical level, researchers may opt to hide their citation metrics where possible. Withdrawing overt advertising of these metrics on personal websites may help to create a new social norm. For example, the current norm may be to scroll past papers that have few citations but are otherwise relevant. A preferable norm, if those metrics are not visible, would be to briefly skim an abstract or a methods section before committing to a full read of a paper. Given that scientists tend to have relatively good intuitions about which papers will replicate (Camerer et al., 2018), a brief skim of the abstract or methods will likely provide a much better estimate regarding the quality of the research than will the citation count. We can encourage this norm simply by not advertising such metrics; for example, making it easier for the reader to click the article than to seek out a citation count. With their publications, researchers can also list links to preregistration documents and/or the open-source data and scripts of published work on their websites and CVs, as another indication of study quality.

But what other heuristics can we develop for evaluating research? This is a domain ripe for innovation and there are some straightforward alternatives. For example, there is already a growing trend of advertising one's two, five or ten 'Best Papers' in job applications. This is a simple and effective way to avoid arbitrarily counting publications or citations. Another option is to innovate metrics that quantify a paper's theoretical contribution and methodological rigour. Public peer review of papers on open access platforms such as PsyArxiv or ResearchGate, is one mechanism through which experts in a field could collectively endorse different metrics of a paper's quality. Taken together, we can nudge other researchers by a) raising awareness that metrics are changing, b) changing social norms by advertising the quality of one's work (e.g., 'Ten Best Papers') rather than citation count, and c) encouraging innovations in evaluating researchers, such as public peer review. Additional guidelines for evaluating researchers can be found in Table 1. But perhaps the simplest thing researchers can do is stop celebrating articles or academics merely for their citation counts, and celebrate them instead for the exciting, rigorous, replicable, and theoretically motivated research.

Students

Nudging career academics is an important step toward a culture of more transparent scientific research. Early immersion is another. In addition to nudging the behaviour of seasoned

academics, good habits can be ingrained in students early in their training. The ability to think critically about research designs, statistical claims, and everyday events has long been touted as a core learning outcome of psychology undergraduate programs in particular (Nisbett et al., 1987). Indeed, psychology training has been shown to produce large gains in statistical and methodological reasoning compared with other disciplines (Lehman et al., 1988). Examples of confounding variables and how to deal with them (e.g., random assignment, random sampling, control groups, blinding, etc.) are common features in undergraduate methods curricula as is training in probability theory and statistical techniques for dealing with uncertainty.

As training is foundational to good scientific practice, many universities now teach these concepts in their science degrees. Further steps to teach open methods to students from the outset ought to carry on into their future research projects. Many students are intrinsically motivated to learn, but others are looking to get a competitive edge in the job market. Teaching Open Science tools can provide both an engaging learning environment and valuable skill set.

Nudging Students

University teachers and lecturers are uniquely placed to foster open research principles and practices in training the next generation of researchers and professionals. There are a number of strategies teachers can use to nudge students to adopt open practices. First, they can model open practices themselves. Authority figures play an important role in our social lives, including establishing and perpetuating a culture that takes certain values seriously (Robbennolt & Sternlight, 2013). If students observe their mentors thoughtfully integrate Open Science into their own work, including preregistration, preprinting, and open data and code, then they may be more likely to follow suit. Teachers could, for instance, signal their use of these practices when talking about studies in class along with examples.

When coordinating a course, another effective nudge may be to embed Open Science practices into assignments. It is common for students to be graded on how well they report experiments. Why not assign them to write a mock preregistration before conducting a class experiment? They could even post a mock preprint on an internal server for fellow classmates to read and review each other's work before submitting the revised version for grading. Preregistration could also be incorporated into thesis and dissertation projects as part of their research proposal. Academics might also consider designing courses devoted to Open Science theory and tools. Educating students about the consequences of the current status quo in research,

such as the replication crisis in psychology, could also make students more receptive to open practices (Chopik et al., 2018). Massive open online courses (MOOCs) can broaden the audience of these teachings further still. With these learning experiences in place, open practices may become the default as students venture into research careers and will be central to how they evaluate research.

Nudging Open Science via practical tools and statistical skills can also instil a culture of open practices among students. Learning to run analysis scripts at the click of a button and write detailed commentary alongside code can make analyses easy to interpret and reproduce. In turn, coding errors or inconsistencies in analyses are easy to discover. Moving toward open-source statistical programming tools — such as Python and R (alongside R scripts, R markdown, R notebooks, and the RStudio interface and other software built on R) — could benefit students as well because these platforms allow people to document code as they learn, not to mention the customizability of script-based languages like R and Python relative to other GUI-based statistical software. Familiarising students with platforms like GitHub can also introduce them to the ways in which researchers can share code.

Wrangling data, using sensible variable names, and producing attractive visualisations are other small nudges that go a long way toward making data analyses more interpretable. Practical challenges during class and running simulations on existing datasets are desirable difficulties that can greatly improve student learning. Using these open tools early in research training will establish them as the status quo and working in groups can ensure that students are supported socially as they learn these skills.

Departments and Faculties

Grassroots initiatives, such as those described thus far, will not in isolation persuade most researchers to adopt open practices. Researchers may be well-placed to organize seminars and online tools, but too often they are busy and under-resourced. Researchers may find themselves in a department where everyone is committed to promoting Open Science. Others, however, may be surrounded by colleagues who are wary of the movement or may be unmotivated to make significant changes. On the other hand, initiatives organized at the department or faculty level — for example, by deans, department heads, and academic committees — are more likely to be well-organised and well-resourced. Action at many nodes of the research ecosystem is more

likely to result in culture change and heads of departments or overseeing committees can greatly change how academics themselves conduct research.

Regularly curated resources that a faculty provides can make adopting open practices easier. Useful materials can be regularly sent to researchers via mailing lists. An Open Science tab could be added to a department's website where researchers can find FAQs and other support services (e.g., preregistration guides, how to responsibly share sensitive data). The department could even fund people to organise Open Science initiatives and workshops in much the same way that departments have dedicated statistics advisors. Entire graduate or undergraduate courses with a significant focus on Open Science can also be implemented (e.g., Sarafoglou et al., 2019). And departments could ask researchers to provide (mock) preregistrations as part of ethical approval applications (as is the default at the University of Amsterdam's Psychology Department).

Symbolic actions can be powerful in creating change as well. A public pre-commitment can help align one's future behaviour with their desired goals (Dolan et al., 2010). Commitments or declarations explicitly communicate the values and norms, and aspirations of an organization. They affirm the aspirations of those who already share Open Science values and can be a catalyst for change in departments and faculties that are yet to make significant changes. Departments from the Southern Methodist University, Göttingen University and Utrecht University are just some institutions that have openly voiced a commitment to open practices (see Table 1). Departments or faculties could also signal open values by presenting Open Science awards during a festive meeting attended by all staff.

Evaluating candidates for hire and promotion in faculties can also be modified to weight open practices more heavily. Such changes are likely to encourage researchers to reconsider their practices and can increase the perception that open practices are not only normative but also valued (Nosek, 2019). Job listings and interview questions could ask for evidence of open practices or for the candidate to illustrate commitment to transparent research in their cover letter. It may also be fruitful to ask candidates to provide an annotated CV detailing whether their articles have been preregistered or openly accessible, what datasets they have openly shared, or indicate only five or ten of their 'best articles'. Gernsbacher (2018) also provides some specific recommendations for how to reward open practices.

Theses and dissertations could also be evaluated not just on novelty and impact (as they now often still are), but also according to how well they demonstrate a critical attitude towards one's research findings and the steps taken to avoid QRPPs. Research students could describe how they have made their data, analysis, and materials publicly available, or justify why they have not. A greater focus on these aspects of research may create reward structures that enable open practices to flourish.

With this said, the majority of middle and senior academics are on permanent or tenured contracts (Coates et al., 2009), so relying on new hires and postgraduate students to shift the tide is an incomplete solution. It is critical to consider open practices and research quality in tenure and/or promotion decisions as well (League of European Research Universities, 2018; Munafò, 2019). Identifying specific nudges with regard to tenure and promotion criteria is difficult because there is considerable variety in how these decisions are made and by whom they are made. A number of Dutch universities and funding agencies have, however, revised their guidelines to have a broader, holistic approach rather than a metric-based approach (ScienceGuide, 2019). When deciding how to distribute internal research funding and yearly performance reviews, departments could recognise outputs such as open data, preregistration, open materials, and open-source code more positively (rather than neutrally), and committees could look beyond journal impact factors when assessing the quality of publications. Review processes could also reconsider their preference for sole-or few-author publications instead of large-scale, multi-author collaborations (e.g., Brock, 2020).

Nudging Departments and Faculties

How can we ensure that the initiatives above are adopted? Nudges can come in the form of emails or conversations involving those in positions of authority (e.g., the deans or department heads). Beyond those few who hold administrative positions, groups with decision power (e.g., academic committees) can also lead to declarations of commitment to open practices, promote platforms for open resources, and encourage changes to evaluation that value Open Science.

Resistance to change at the departmental or faculty level may have various causes, so it is crucial to establish resources and information for these initiatives. For example, sample declarations can be circulated throughout the workplace and to departmental heads or academic committees. The normative nature of Open Science ought to be highlighted in meetings and in emails as well, including sharp upward trend in open practices (Christensen et al., 2019).

Faculties and departments are motivated by rankings, funding, and student intake. It is therefore important to highlight the benefits (or potential losses) that foregoing Open Science initiatives can have. As journals and funding bodies call for more open research, failing to keep up may mean lower research rankings, less desirable prospects for students, and less funding (McKeirnan et al., 2016).

Departments and faculties tend to be responsible for hiring and promoting researchers. There are strong incentives that can be leveraged to ensure Open Science practices are prioritized when these decisions are made. Job advertisements typically detail the requisite credentials and preferred skills and expertise. Researchers can nudge departmental chairs (or equivalent) to include explicit statements about open practices in the advertisements they post. In line with the 'make it easy' principle, researchers can provide committees with a statement rather than leaving it to the committee to invest time and resources to do this (see useful suggestions offered by Schönbrodt et al., 2019).

Even if advertisements do not explicitly mention Open Science practices, researchers can determine a job candidate's practices by looking at their published work (e.g., open data, preregistration) or at their presence on online platforms such as OSF, Figshare or GitHub. If not provided as part of the application, this information can be shared with the hiring committee in evaluating a candidate's engagement with Open Science. It may be that some candidates (particularly those who recently finished a PhD or postdoctoral position) have been discouraged from engaging in open practices by their supervisors (e.g., Krishna & Peter, 2018); thus, it is important to give candidates the opportunity to demonstrate and discuss their attitudes toward Open Science.

Regardless of whether they are formal members of a selection committee or informal participants, those involved in the interview process can ask about a candidate's practices. However, serving on tenure and promotion committees can be a good platform from which to advocate for Open Science. Committee members can draw attention to research practices that improve (or threaten) research integrity, offer open evaluation criteria, and push to reward researchers who engage in Open Science. For example, the co-founder of the UK Reproducibility Network reported that his institution now requires applicants to demonstrate open data practices in order to be eligible for promotion (Munafò, 2019).

Universities

Universities are complex organisations with many often-competing interests. These include attracting and educating students, resourcing research endeavours, building connections with the wider community, and providing professional development to academic and professional staff. Nudging at the university level therefore requires considerable collaboration and knowledge of the university structure, but it is nonetheless possible and important.

University administrators are concerned with similar metrics to those of departments and faculties within universities, but on a larger, more diverse scale. The administration desires its researchers to produce high-quality research because these metrics are often used by governments when they evaluate research outputs (e.g., the Research Excellence Framework [REF] in the United Kingdom; Excellence for Research in Australia [ERA] framework). These metrics influence funding decisions, but some consider these frameworks problematic (e.g., Martin, 2011; Lin, et al., 2017).

Universities are also concerned with their place in national and international university rankings (e.g., Times Higher Education [THE] World University Rankings, Academic Ranking of World Universities [ARWU], Quacquarelli Symonds [QS] World University Rankings), which influence (among other things) enrolments from (fee paying) international students (Harvey, 2008). Several of these rankings are based on research outputs and/or reputation (for review, see Huang, 2012). The same indicators that affect these metrics in turn influence the local metrics that universities use to evaluate their academic staff. Nudging changes at the departmental level might have limited reach if a department and the university have conflicting goals. So, what changes can universities make?

Open Science Task Forces and Officers. An Open Science task force or officer can comprise anyone motivated to improve scientific practice in their university — academics, deans, professional staff. These task forces can lead initiatives on behalf of the wider community, on matters such as determining researchers' attitudes and perceived barriers to Open Science, examine institutional policies and practices and suggest alternative open policies, and make general recommendations to the office of the Deputy Vice Chancellor (or equivalent) on matters of Open Science. These task forces could also offer resources and on-going training to researchers and students at the university. In essence, they can make Open Science easy and normative by providing the necessary infrastructure and social environment. To have the most

impact, these task forces ought to be university-wide and endorsed by the administration (see Munafò, 2019).

OSF Institutions. Many universities are beginning to adopt *OSF Institutions*, which is a free scholarly web tool that aims to enhance transparency, foster collaboration and increase the visibility of research outputs at the institutional level (see Table 1). *OSF Institutions* has single sign-on authentication, making it easy for users to incorporate the OSF into their existing research workflow. There is also an option for universities to recommend the OSF as a platform on which to manage research projects and make materials and data available to others.

The DORA. More than 1,800 organisations and over 15,000 individuals across the world are now signatories on the San Francisco Declaration of Research Assessment (DORA, 2012). The DORA makes 18 recommendations to revise how the academic community evaluates researchers and research outputs. The DORA makes specific recommendations for researchers, organisations that supply metrics, publishers, institutions, and funding agencies. Many of these stakeholders have revised their research assessment guidelines in line with DORA.

One potential challenge is the conflict between the DORA recommendations and the research assessment frameworks used in different countries. For example, some universities have financial incentive structures entirely geared to reward research that is published in high impact journals. The financial reward for publishing a single paper in *Science* or *Nature* in China's top 100 universities, for instance, has reached as high as 165,000 USD (Quan et al., 2017). Financial incentive structures of this are employed in many countries (Abritis & McCook, 2017). A cash-per-publication reward policy can fuel QRPPs, emphasizes quantity over quality, and is simply not conducive to truth-seeking. Conflict between how things currently are, and the changes outlined in the DORA will need to be addressed. However, we foresee that, as more individuals and organisations sign the DORA, institutional frameworks will more closely align with its recommendations.

Nudging Universities

Those in (recognised) positions of power within the university hierarchy need to approve of the initiatives suggested above. Researchers can draw the administration's attention to emerging Open Science issues and push for new initiatives. One effective nudge may be a well-organised face-to-face pitch. Like-minded academics can give a 10-minute Open Science presentation to the Vice-Chancellor or Pro-Vice-Chancellor (or equivalent) advocating for Open

Science initiatives. An effective pitch might explain the problem (i.e., the replication crisis), demonstrate its insidiousness across many fields; discuss solutions (e.g., preregistration, open data, etc.), and highlight efforts that other universities have already undertaken to combat these issues, including the adoption of OSF Institutions, the DORA, and task forces/officers. A pitch of this kind would highlight that a problem of real concern exists and suggest readily implementable solutions.

The benefits that result from the proposed initiatives could be highlighted as well. There is potential for the university to become a leader in the emerging Open Science space. Universities that adopt official statements on open practices (e.g., UK Reproducibility Network) signal that they are responding to the replication crisis and that they are committed to producing high quality, reproducible research rather than solely focused on impact factors.

Following the pitch, it is important to check in on the progress an administrator has made on said issues, and to suggest to easy and actionable steps that they can take next. Any change at an institutional level can have a snowball effect. Once academics successfully advocate for change in one area, there can be considerable momentum when leading change in other areas. As such, rather than waiting for the 'perfect' opportunity, there is value in taking any steps (no matter how large) to initiate change.

Academic Libraries

For the benefits of Open Science to be actualised, restrictions on the exchange of software, code, data, and publications need to be addressed. Currently, much of scientific knowledge is proprietary. A significant proportion of the public, and even researchers, are unable to access important scientific insights and information because it is locked behind a paywall. A 'pay to know' system has led many to request access to a published paper from the authors themselves, or even pay for the article, because their institution does not own a site license to an expensive commercial journal. Answers to the crucial scientific problems of today, however, may require a 'wisdom of crowds' approach where ideas and data are freely exchanged (Tacke, 2010). A wider dissemination of knowledge can lead to more economic growth and societal improvement (European Data Portal, 2020).

Academic libraries collect, create, manage and disseminate data and knowledge, and help scientists to become aware of, share, use, and reuse the work of others. Each library comes with a distinct culture and distinct objectives, and some have already invested a great deal into

promoting openness (Ogungbeni et al., 2018). However, administrative and financial status quos, and a drive to satisfy customers (students and staff), may be preventing widespread changes.

Libraries can promote open practices by establishing guidelines, training and roadmaps within their institution, which researchers can use to make their work more transparent. Libraries can also subsidize article publication charges at their institution and promote universal access to research that the institution generates. The Compact for Open-Access Publishing Equity (COPE) have pioneered this approach and several institutions have followed suit (Eckman & Weil, 2010). These changes can help ensure that publications at an institution are freely available online.

Furthermore, libraries can influence how FAIR (findable, accessible, interpretable, and reusable) the datasets in their repositories are. They can also adopt research data management strategies so that data are recorded, preserved and widely accessible (Christensen-Dalsgaard et al., 2012; Cox et al., 2017; Tzanova, 2019; Pinfield et al., 2014). The linking of data and code to the publications they are associated with can also be facilitated by the right online infrastructure.

Universities are by definition exclusionary; they offer limited positions to prospective students. As curators of information, however, academic libraries can make educational resources openly accessible (Open Educational Resources) to other researchers and the broader the public. The recent growth of MOOCs offered by prestigious universities has illustrated that good that they open resources can do. Libraries can move forward in this space by creating and providing access to educational resources such as textbooks, lecture notes, exams, videos, presentation slides and other media.

Nudging libraries

Individuals can nudge academic libraries primarily by liaising and communicating with librarians either in person or over email. As a first point of contact, researchers can link preregistrations, preprints, or online datasets related to a study and ask the library how to cross link these resources in their online repository. If more researchers do so, libraries may begin to link these supplementary materials as the default course of action. Researchers could also offer to coordinate data management workshops to highlight the importance of recording and generating interpretable data and code for others to use.

Suggesting an open access funding initiative for researchers within the institution may be another effective nudge. One could pitch this idea and present it along with a survey of likeminded academics. It is critical to frame any change as an injunctive norm. If the goal of

libraries is to disseminate knowledge and information widely, then appealing to the public good that results from the initiative would help invoke a sense of moral or civic duty and in turn motivate change. Providing links to frameworks that other universities have used can help libraries to easily model their own initiative (see Table 1).

Journals

Despite an increase in preprints, research continues to be disseminated primarily via refereed journal articles. As such, it is crucial to nudge those who review and publish research in academic journals (i.e., editors, reviewers). For the most part, journals are concerned with prestige. Prestige helps attract the best research in the respective field, which means more citations, more subscriptions, and higher revenue. Journals are concerned with how people perceive the quality of the research they publish. While researchers want to publish in journals with a high impact factor, open access publications actually receive more citations than average (e.g., Piwowar et al., 2018). Open research is also becoming more entwined with notions of research rigour and quality. There are many initiatives that journals can implement that align with this new research climate.

TOP Guidelines. Editors, funders, and researchers have proposed the Transparency and Openness Promotion (TOP) guidelines to describe different ways in which editors can adopt open practices in the journals they lead (Nosek et al., 2015). Across eight different dimensions (e.g., preregistration, transparency of data, research materials, analysis code), the guidelines specify different degrees of policies regarding the promotion of transparency and openness in their journals (ranging from absence of policies to policies that require authors' use of open science practices). The TOP guidelines can be a useful starting point and continuous source of guidance for editors in promoting open practices.

Open Science Badges. A simple and effective way editors can increase the visibility of open practices is by adopting Open Science badges (McKiernan et al., 2016). These badges are awarded to journal articles, for example, if authors preregister, or make their materials and data open. The use of badges is an easy and low-cost means of enhancing open practices. It is also an injunctive norm that signals desirable research behaviours. The introduction of these badges has increased the extent to which researchers engage in Open Science practices (Kidwell et al.,

2016). These badges are also likely to be attractive to editors because they strengthen the reliability and trustworthiness of the research that is published in their journal.

The Power of Defaults. Changing defaults is another powerful option that editors have at their disposal if they want to promote Open Science. Editors can set the default option at their journal to favour open practices: authors must opt-out of linking their study to a preregistration and/or opt out of making their data and materials openly available. An evaluation of the mandatory open data policy implemented at the journal *Cognition* revealed that policies of this kind enhanced the prevalence of data availability statements and the reusability of the data that they made available (Hardwicke et al., 2018). Prior to the introduction of the policy, a minority of researchers made their data available (and a minority of these data were reusable), but the vast majority of researchers did so after its introduction.

Widening Publication Formats. Journals can also easily restructure editorial and publication processes to support Open Science is another easy change that journals can make. A simple (and increasingly common) change is offering a variety of publication (submission) formats that emphasize the process rather than the outcome of research. These new formats may include Registered Reports (Chambers, 2013; Nosek & Lakens, 2014) or manuscripts that are sent out for peer review where the results of the study are blinded (Grand et al., 2018).

Manuscript Evaluation. Editors could also invite specialized reviewers on their editorial board who evaluate and encourage open practices and reproducible methods and statistics (Hardwicke et al., 2019). Similarly, when providing evaluation criteria for reviewers, editors could offer explicit evaluation criteria that emphasise open practices. Journals could even implement an open peer-review process. Open peer-review leads to more tactful and constructive feedback, and clearer communication between reviewers, editors and authors in how and why a manuscript may have been accepted or rejected, or why certain changes are necessary (Ross-Hellauer, 2017).

Nudging Journals

Editors can draw on a range of simple, social, and attractive means and resources to encourage more transparent science. Even when some editorial teams may see drawbacks or have reservations about promoting open practices (Hopp & Hoover, 2019), researchers can nudge journals to make changes. For one, researchers can promote these changes when serving

as editors and reviewers. Researchers are often selected by editors to review papers or are members of societies to which journals are associated. These are positions from which well-worded emails can nudge journals to alter the way the journal operate. There are already how-to guides, infographics, and other tools available online for many of these initiatives (see Table 1). These can be linked explicitly in an email so that editors are one click away from the online infrastructure needed to implement such changes. One could also point to the normative nature of these practices, highlighting that currently (in early 2021) more than 75 journals have implemented Open Science badges, more than 250 have registered reports as a publication format, and more than 1000 have implemented TOP guidelines (https://www.cos.io/).

Outlining what journals can potentially gain from these changes will also make these initiatives more appealing. Adopting TOP guidelines can increase the quality of submitted publications by improving the standards of reporting and helping to detect errors before publication as well as reducing the time that authors and reviewers spend communicating (Nosek et al., 2015). As previously mentioned, Open access publications also receive more citations than closed publications (Hajjem et al., 2006; Li et al., 2018; Davis, Lewenstein et al., 2008; Piwowar et al., 2018). Registered reports are also less prone to QRPPs than papers published through conventional means and Open Science badges promote data sharing (Kidwell et al., 2016). Benefits such as these are highly attractive to journals and ought to be included in any pitch.

Funders

Research funding is limited and difficult to obtain. Grant applications are typically written by researchers before being sent to specialists in the field for review. A committee assesses these applications and then ranks them so that they can prioritise the available funds. The judgements of reviewers in this anonymous review process are often highly inconsistent (Mayo et al., 2006) and favours mainstream scientific enterprises. Anonymous reviews process also tend to favour researchers with more citations, placing them in a better position to publish further research (i.e., the Matthew effect; Bol et al., 2018). In fact, researchers with the highst citations counts (top 20%) received over 60% of the funding from the National Science Foundation (Drutman, 2012). Awarding funding to more established, senior academics might be stifling the uptake of Open Science because they are perhaps less responsive to these reforms (Rowlands & Nicholas, 2006).

Alternative funding review processes have been proposed, including innovation lotteries, open review processes and crowd-funded research (Eisfeld-Reschke & Wenzlaff, 2013, Giles, 2012). However, as researchers, it may be prudent to focus on already existing funding pathways. Some funding bodies have adopted policies that require funded articles to be made freely available and they may also pay reasonable open access charges (see the Canadian Institutes of Health Research, the Social Sciences and Humanities Research Council of Canada; National Institutes of Health, the Research Council UK and cOALition S).

Funding bodies, such as Netherlands Organisation for Scientific Research (NWO) and the European Research Council (ERC), have also embraced 'FAIR data principles' (Wilkinson et al., 2016). In fact, the ERC has proposed that funded projects need to have openly accessible research data following publication (European Research Council, 2020). Further, both the ERC and NWO expect grant applicants to specify a data research management plan that adheres to the FAIR principles. The Australian Research Council (ARC) and National Health and Medical Research Council (NHMRC) funding bodies in Australia also have open access policies, where outputs arising from funded research must be made openly accessible, but there polices are largely ineffectual (Holcombe & Todd, 2013).

Returning to the review process, funders can more deliberately evaluate investigators on the basis of the quality, rather than the quantity, of their scientific contributions. They can also evaluate proposals on the basis of an investigator's plan to make their research open access, to preregister and preprint their studies, or to share data on a public repository. The NWO, for instance, now adheres to the DORA when evaluating the grant applications of scientists (NWO, 2019). It has introduced the narrative CV format which consists of two parts: a narrative academic profile and a list of no more than five or ten key outputs (depending on seniority and the grant itself). Researchers are also not allowed to mention H-indexes, journal impact factors, or any metric that refers to the journal, publisher or publication platform, rather than to the individual output item.

Nudging Funders

Researchers can help nudge Open Science among funders and grant reviewers in several ways. First, they can include prepared statements on open practices when they write grant applications. Funders often ask for broader impact statements a history of translating research into action via open practices can be seen favourably (e.g., National Institute of Health, 2011).

Researchers can leverage their track record of open practices by outlining that funded research will be made available as a preprint and the data will be openly available. Grant reviewers may also appreciate intentions to provide Open Science training to postgraduate and post-doctoral researchers. We recommend highlighting instances of these actions in the past and to include these plans in the project's budget. At first, these statements might make a particular project stand out as a rigorous and transparent, but as more applications include them, such statements will become an expectation rather than the exception.

Grant applications commonly undergo editing at a university's research office before they are sent off to the funding body for review. These offices often recommend that traditional metrics such as h-indexes be emphasised. However, researchers ought to highlight less traditional metrics of research quality such as the number of open access publications or public projects on the OSF or underscoring one's 'Ten Best Papers'. Changing the norms and highlighting the appeal of these alternative metrics may change what information is ultimately considered important when grants are evaluated.

Researchers might also consider using open practices and open tools when collaborating with partnered industry funders. In applied fields, for instance, there is a great deal of communication between researchers and industry collaborators. Searston et al. (2019) have outlined ways in which the OSF and other tools can keep partners involved and updated at every stage of a research project. Transparency while working with industry improves the quality of the end product and establishes a norm of open collaboration between industry and the academy.

Conclusions

In each section of this paper, we described the roles and goals of the key stakeholders in the research ecosystem, along with changes that can promote open scientific practices. Using two frameworks — EAST and the Pyramid of Culture Change —we also offer ways in which individuals and small groups can nudge these stakeholders to adopt change. It is true that progress in this space may be ushered in from the top-down by larger institutions and organisations, or via conventional economic solutions (Loewenstein & Chater, 2017). However, without pressure from researchers themselves there will be little demand driving such change. Significant improvements in infrastructure, norms and reward structures are needed before policy change is even possible or seen as necessary. The behaviours of the various agents in the

scientific community ultimately determine the quality of the research that is generated and disseminated. We hope the resources and nudges we offer will provide a valuable toolbox for those interested in improving scientific practices.

Contributions

Here we list the authors who contributed to each section: Introduction (SGR), Researchers: Preregistration (MAB, CDK & DM), Researchers: Preprints (JB & HB), Researchers: Data to theory and quantity to quality (REL & HAS), Students (RAS), Departments/faculties (JMC & KJ), Universities (JLB & SGR), Journals (NKS), Libraries (SGR) and Funders (SGR & HAS). Additionally, MAB, JB, JLB, KJ CDK, SGR, HAS, NKS and JMT contributed to general editing. The idea for this paper was conceived by JMT during the Society for the Improvement of Psychological Science (SIPS) 2019 meeting in Rotterdam.

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Conflict of interest

The authors declare no conflict of interest.

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