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EDITORIAL

Science as behaviour: Using a behaviour change approach to increase uptake of open science

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Introduction

Psychology as a science is undergoing a revolution. The well-documented replication crisis has impacted psychology as well as many other disciplines over recent years. The Open Science Collaboration attempt to replicate 100 experiments from three leading psychology journals found 97% of original studies to report significant effects compared to only 36% when replicated (Open Science Collaboration, 2015). Open Science, an umbrella term including a range of knowledge creation and dissemination behaviours to increase research transparency (Fecher & Friesike, 2014) is now gaining strong traction. A global movement of interdisciplinary scientists, funding bodies and universities is working collaboratively to increase reproducibility and transparency in the science process, reporting and teaching (Button, 2018). Making study materials, data and analysis code openly available facilitates scientific scrutiny and accurate replication, as well as data synthesis such as via meta-analyses (Crutzen, Peters, & Abraham, 2012; Crutzen, Ygram Peters, & Mondschein, 2019). This editorial applies the Behaviour Change Wheel approach to understand how Open Science behaviours may be identified, how barriers towards these behaviours may be addressed and how interventions can be developed to increase Open Science behaviours.

Various leading advocates for Open Science have contributed guides to reproducible and open working. For example, the "Manifesto for reproducible science" outlined a range of approaches to encourage change towards Open Science practices across methods, reporting and dissemination, reproducibility, evaluation and incentives (Munafò et al., 2017). The Open Science Framework (OSF; http://osf.io) established by the Centre for Open Science is a free online repository allowing researchers to share their data, analysis and study materials, as well as publish pre-registrations and pre-prints and post-prints with citable Digital Object Identifiers (DOIs).

The benefits of Open Science working are numerous (Markowetz, 2015), including facilitating clearer documentation of research process and analysis (Gorgolewski & Poldrack, 2016), open publications receiving more citations (Davis, Lewenstein, Simon,

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Booth, & Connolly, 2008) and opening your work to wider global collaborators (Klein et al., 2014). A useful overview of the benefits of Open Science for researchers can be found in McKiernan et al. (2016). Implications of the Open Science movement for Health Psychology include the need for effective pre-registration (Nosek & Lindsay, 2018), protocol reporting and sample size estimations for large-scale intervention research, as well as updating university taught curricula to transmit the skills of Open Science research to future generations (Hagger, Peters, Heino, Crutzen, & Johnston, 2017).

Over the last couple of years, the scientific publishing landscape has changed considerably as a result of the Open Science movement. An important development is the introduction of Registered Reports (https://osf.io/rr/). The aim of this new type of article is to increase the transparency of science, to allow peer review of research studies before the results are known and, crucially, to guarantee acceptance of the paper (irrespective of the findings following review at Stage 1; known as an In Principle Acceptance, IPA). As a consequence, it is hoped this will help reduce the use of questionable research practices while improving the quality of our research protocols; that will ultimately improve the robustness of our evidence base. *Psychology and Health* has been keen to promote and support this new initiative, and therefore, late last year introduced this format. However, uptake has been slow, with informal feedback from across the psychology discipline suggesting that the main barriers relate to lack awareness, concerns about "stifled creativity", worries about being "scooped" and resistance to change existing working practices. However, the tide is turning, psychology is leading the way (see Chambers, 2019; Hardwicke & Ioannidis, 2018) and a growing number of health psychologists are adopting Open Science practices. Therefore, *Psychology and Health* would welcome your submission of a Registered Report (see https://cos.io/rr/ for a full list of journals offering Registered Reports).

Nevertheless, firm and well-documented barriers to adopting and maintaining Open Science behaviours remain for some researchers (Nosek et al., 2015). Publishing norms remain inherently focused on rewarding novelty rather than replication (Nosek, Spies, & Motyl, 2012) and unclear recommendations remain for qualitative research (Branney et al., 2019): a particularly prevalent concern for health psychology. A recent survey of 600 psychology article authors found that although data sharing was perceived as desirable, perceptions of not being allowed to share data, being scooped by other researchers and lack of training in making data open prevented many of them from doing so (Houtkoop et al., 2018). More recently, a German Psychological Society survey explored attitudes towards open science and data sharing (Abele-Brehm, Gollwitzer, Steinberg, & Schonbrodt, 2019). These authors found that there were positive expectations ("hopes") and negative expectations ("fears") towards open science and data sharing. However, interestingly, hopes were highest among early career researchers and lowest among professors. Science needs to identify the barriers and facilitators for all researchers (irrespective of career stage) if we are to make Open Science research the norm.

Applying behaviour change within open science

Science is behaviour. Conducting scientific research can be broken down into a series of discrete behaviours (e.g., planning study design, formulating hypotheses, choosing measures). Conducting 'bad science' can also be broken down into a series of behaviours – or questionable research practices (e.g., p-hacking, hypothesising after the results are known [HARKING], selective reporting). It is the latter behaviours that we need to change in order to improve our science as an important step forward towards open science becoming the norm. Evidence from behaviour change research has a key, untapped potential to assist in improving the adoption and maintenance of good Open Science practices. As a multidisciplinary field, it provides a plethora of theories and approaches across psychology, sociology and economics that have been applied to diverse behaviours across health, education, finance and beyond (Michie, West, Campbell, Brown, & Gainforth, 2014).

Strategies used so far to help move researchers towards Open Science practices have largely focused on the provision of incentives such as journal badges recognizing pre-registration of research protocols, open data and open materials (Kidwell et al., 2016). The provision of training to students and researchers in more reproducible research software such as R and R Markdown has also been common. However, the rationale for the provision of these particular interventions is often unclear. Why were these interventions selected and how are they intended to change behaviour?

To explore the potential of behaviour change to improve Open Science behaviours, we discuss an approach to develop effective interventions using the Behaviour Change Wheel (BCW) (Michie, Van Stralen, & West, 2011). The BCW was chosen as one of many potential frameworks and theories (Eldredge et al., 2016; Michie, Atkins, & West, 2014; O'Cathain et al., 2019) due to its development from a broad range of nineteen multidisciplinary frameworks (Michie et al., 2011) and its systematic guidance on designing and evaluating interventions that has been applied to a diverse range of behaviours internationally (Richardson, Khouja, Sutcliffe, & Thomas, 2019; Seppälä, Hankonen, Korkiakangas, Ruusuvuori, & Laitinen, 2018). To the authors' knowledge, as of yet no research has explored Open Science behaviours using the BCW. This editorial discusses Open Science behaviours and their potential malleability through the BCW approach to understanding and designing behaviour change interventions.

What do we mean by behaviour in open science?

There are a wide range of connected behaviours that constitute Open Science (Corker, 2018; FOSTER Open Science, 2019; Pontika, Knoth, Cancellieri, & Pearce, 2015), existing across the whole research process (Table 1). For example, uploading a pre-print to PsyArXiv (i.e., a pre-print server) or creating an R Markdown file (i.e., a file format used in R) to explain your statistical work can be seen as Open Science behaviours. As posited by Stage 1 of the BCW (Michie et al., 2011), it is imperative to specify the exact behaviour in question. Behaviours are distinct from determinants, such as attitudes or intentions towards Open Science, and outcomes, such as increased citations as a result of Open Access publishing. Importantly, Open Science behaviour is comprised of a variety of discrete, lower-level behaviours that need to be performed to achieve the

Table 1. Examples of behaviours across facets of Open Science.

Open Science facet	Example behaviour(s)	Parties involved
Open Notebooks	Putting lab diaries on Open Science Framework	R, F
Open Data	Putting data from a recently completed study on GitHub Using an existing open data set e.g from the Open Data Institute	R, F
Open Peer Review	Submitting a non-anonymised peer review	J, R
Open Access	Submitting paper to a Gold Open Access journal Publishing a pre-print on PsyArXiv	J, I, F, R
Open Source	Making an R Markdown file to show and annotate your analysis Putting your meta-analysis R script on Open Science Framework	R, F
Scientific social networks	Discussing Open Science on Twitter Updating details of your new paper on ResearchGate	J, I, F, R
Citizen Science (including co-production)	Co-producing research aims and design with patient group Crowdsourcing data collection on a project	R, F
Open educational resources	Posting lecture slides on Open Science Framework Teaching statistics in R	R, I

Note. Facets taken from the Open Science beehive framework (FOSTER Open Science, 2019). Abbreviations for key stakeholders: J, journals/publishers, F, funders, I, institutions, R, researchers.

overall behaviour. For example, for a researcher to achieve the behaviour of uploading a pre-registration onto OSF, they first need to perform implementation tasks such as setting up an OSF account and adding collaborators, choosing a pre-registration template and establishing version control (Sullivan, DeHaven, & Mellor, 2019). A breakdown of any one of these lower-level behaviours may prevent the end-point Open Science behaviour from being achieved. This cumulative nature of Open Science means that important basic behaviours, such as opening an OSF account, facilitate more complex future behaviours, such as uploading data sets and code to OSF. The BCW posits that interventions are more effective when they intervene intensely on a small number of specific, key behaviours rather than intervening less intensively on multiple behaviours (Michie et al., 2011), meaning that Open Science interventions should address one or a few of these behaviours, following detailed intervention development.

As with any behaviour, Open Science behaviours may not be stable over time (Corker, 2018). Researchers' behaviours may change as they move between projects depending on the methods, timescales or project aims, or research teams depending on the priorities of the group (Kwasnicka, Dombrowski, White, & Sniehotta, 2016; Michie et al., 2011). Open Science behaviours also involve interactions between a broad range of parties, often carried out by individual researchers and research groups but facilitated (or not) by wider departments, university institutions, funding bodies and publishers (Munafò et al., 2017). The BCW emphasizes the need to think about behaviour within the wider system, charting who the key people and organisations are that need to change and how they may influence each other's behaviour (Michie, Atkins, & West, 2014; Michie et al., 2011). Specific Open Science behaviours apply to researchers, departments, universities, funding bodies and publishers (Table 1). As such, development of interventions to promote Open Science behaviours need to anticipate and incorporate these inter-relationships. Implementation of Open Science behaviours may also lead to spillover effects into other behaviours within or across parties. For example, an increase in pre-registration behaviours in researchers may

require strategy development and increased workload for publishers. A researcher's increased time spent preparing analysis plans may lead them to require less time on analysis later in the project.

Barriers and facilitators to open science behaviours

As previously outlined, barriers and facilitators of Open Science behaviours have been explored generally (Munafò et al., 2017; Nosek et al., 2015). However, these concerns could be further elucidated related to specific Open Science behaviours using the BCW approach. Stage 1 of the BCW involves identifying what needs to change to impact the target behaviour and exploring why behaviours are as they are, known as a 'behavioural diagnosis'. Specifically, use of the COM-B model at the hub of the Behaviour Change Wheel is recommended to frame the behavioural diagnosis in a given population (Michie, Atkins, & West, 2014). In short, COM-B posits three essential conditions as required to result in a behaviour: 'capability' in the individual's psychological and physical capacity to enact a behaviour, 'opportunity' in the physical and social environment beyond the individual that allow a behaviour and 'motivation' in the reflective and automatic mechanisms that activate or inhibit a behaviour (Michie et al., 2011). Assessment of barriers and facilitators to specific Open Science behaviours using the COM-B could be performed via online questionnaires, interviews and focus groups to all relevant stakeholders: researchers, institutions, funders and journals. Further elucidation of Open Science concerns could be achieved by also applying the Theoretical Domains Framework (TDF) to question design and analysis (Atkins et al., 2017; Cane, O'Connor, & Michie, 2012): comprising of 14 theoretical constructs such as 'Knowledge', 'Skills', 'Intentions' and 'Social Influences'.

Research into barriers and facilitators of Open Science behaviours using COM-B is absent at present. To open the discussion here we compile a range of barriers and facilitators reported in published research and from the authors' own experiences, mapped to COM-B components (Table 2). Future research using full BCW methodology would provide far more insight into Open Science behaviours, especially if specified to more specific behaviours such as publishing Registered Reports, or setting up an Open Science Framework account. This research would provide insight into which components of COM-B are most crucial for a given Open Science behaviour.

Table 2. Barriers and facilitators to Open Science behaviours mapped to COM-B.

COM-B component	Open Science examples
Physical Capability	Ability to use Open Science platforms such as Open Science Framework, AsPredicted, GitHub
Psychological Capability	Remembering to upload updates to data and analysis
Physical Opportunity	Availability of free training to learn R, webinars on Registered Reports
Social Opportunity	Principal Investigator encouraging implementation of Open Science Institution recognizing Open Science in promotion and appraisal (Munafò et al., 2017)
Reflective Motivation	Having beliefs that putting in the effort to get a Registered Report published will mean your final results paper will be accepted (Chambers, Dienes, McIntosh, Rotshtein, & Willmes, 2015)
Automatic Motivation	Developed habit of uploading pre-print as soon as a paper is written

Note. Based on published research without COM-B analysis and authors' own experiences.

Development of interventions to increase open science practice

Various initiatives have been introduced to date to increase uptake of Open Science behaviours, as noted in Munafo's Manifesto for Reproducible Science (Munafò et al., 2017). However, initiatives and interventions for Open Science have not been developed using a behaviour change approach to-date. More consideration is needed to assess what types of interventions are required to address which barriers to Open Science. According to the BCW approach, Stage 2 after behavioural diagnosis is identifying intervention options: broad categories of the means in which behaviour can be changed. The BCW posits nine intervention functions of education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling and enablement (Michie, Atkins, & West, 2014).

The BCW suggests that COM-B components identified as of importance to a given behaviour, can be used to inform which intervention functions are used within an intervention. Researchers' Open Science behaviours are currently being targeted in various ways. In terms of Capability, training initiatives for Open Science such as MOOCs (e.g https://opensciencemooc.eu/), international workshop initiatives (e.g https://www.bristol.ac.uk/psychology/events/reproducibility2019/reproducibility-2019.html) and public engagement events (https://www.bps.org.uk/news-and-policy/moving-psychological-science-forward-videos-replication-event-now-online) are targeting the Physical and Psychological Capability of researchers by increasing their confidence and research skills. Motivation for Open Science can be seen as targeted by incentivisation strategies such as Open Science badges from journals (Kidwell et al., 2016), attempting to increase researchers' intentions to publish using pre-registration, open data and open materials. Opportunity for researchers to employ Open Science research behaviours can be encouraged by restructuring the environment to increase social support in research institutions, such as via the ReproducibiliTea journal club initiatives (https://osf.io/3qrj6/) to enable group discussion of Open Science.

Higher-level policy changes are also essential to the establishment of Open Science behaviours. Within Stage 2 of the BCW, seven policy categories are posited to represent the types of authority-level decisions that can help support and enact interventions: Communication/marketing, guidelines, fiscal measures, regulation, legislation, environmental/social planning and service provision (Michie, Atkins, & West, 2014). These policy categories are potential outlets for delivering aforementioned intervention functions. Within the context of Open Science, these policy-related authorities include universities, publishers and funding bodies. For example, the provision of the intervention function Persuasion could be achieved via the policy category of Guidelines, such as persuading people to publish pre-prints of their research by establishing departmental guidelines on doing so. Moreover, universities should modify promotion criteria to include evidence of engaging in Open Science practices and explicitly emphasize quality of outputs and not quantity by moving away from a 'publish or perish' academic culture.

Behaviour change also has much to contribute in terms of the more fine-grained content and implementation options of Open Science interventions. Stage 3 of BCW involves the identification of specific content and implementation options. The Behaviour Change Techniques Taxonomy (BCTTv1) (Michie et al., 2015) can be used to

specify the 'active ingredients' of Open Science interventions. For example, an intervention to get researchers posting analysis plans on OSF could involve researchers experienced in this behaviour showing others how to prepare their plan and upload it (Modelling as an intervention function via the BCT of Demonstration of behaviour)(Michie, Atkins, & West, 2014). Another intervention could aim to encourage researchers to make their data open by hosting a webinar of an internationally renowned and experienced professor sharing their experiences of how making their data open facilitated collaboration (Persuasion as an intervention function via the BCTs of credible source and information about social and environmental consequences). An intervention's Mode of Delivery should also be considered and tailored to the intervention at-hand. Given the international audience for Open Science discussions, to-date many interventions have focused on distance-delivered interventions, such as via websites (e.g., OSF, journal websites, online MOOC training).

Moving forward

Open Science comprises a range of behaviours across a variety of parties that are malleable and ripe for intervention development. Behaviour change offers a plethora of tools that may enhance the effectiveness of interventions to increase Open Science practices. This discussion outlined a behaviour change approach to identifying and designing interventions to increase Open Science behaviours using the Behaviour Change Wheel approach. Many variations of behaviour change insights and frameworks exist, with BCW discussed in this article to open discussion on the use of behaviour change strategies in the Open Science domain. Another possibility might be to develop a Volitional Help Sheet for Open Science (VHS-OS; Armitage, 2008). The VHS technique is a simple technique that has been developed to help facilitate the formation of if-then plans (or implementation intentions). This technique has been shown to be effective by encouraging respondents to actively form plans that help overcome salient barriers to engaging in a range of behaviours (Armitage, 2008; Armitage & Arden, 2012; O'Connor, Armitage, & Ferguson, 2015). Therefore, this might represent another fruitful way forward.

Open Science working provides an exciting plethora of training, dissemination and connectivity opportunities. What is important to remember is that researchers should not feel obliged or pressurised to integrate the full range of Open Science behaviours into their workflow to become an 'Open Scientist' (Corker, 2018). Not all behaviours are suitable for every research question. Try adding one Open Science behaviour at a time to your next project: maybe publish a pre-print on PsyArXiv, or publish your analysis plan on OSF or submit your study as a Registered Report. Ensure that you evaluate what you have learned from your Open Science experience and consider what next step you may like to take.

It is important to acknowledge that some researchers feel that there may be a small number of potential drawbacks to engaging in Open Science practices and to recognise these possible risks and concerns going forward. For example, as the number of not-yet-peer-reviewed pre-print articles published increases, this will lead to a growth in science output more generally, but also potentially a reduction in the quality of

research available (given that there will be an unknown percentage of these pre-prints that are rejected following peer review that remain discoverable)(Sheldon, 2018). Another concern that has been voiced is that the movement towards Registered Reports may have a detrimental impact on the workloads of Editors and Associate Editors. It has also been suggested that the pressures to conform to Open Science practices will make conducting research more expensive and this may have a differential impact across the university sector nationally and internationally. To our mind, we understand that there are differing views on Open Science. However, on balance, we believe that each of these concerns can be mitigated, and overtime, the adoption of Open Science practices will yield enormous benefits (cf., Munafò et al., 2017).

It is an exciting time for our discipline, and it is great that psychology continues to lead the way. Further adoption of Open Science practices will propel psychological researchers forward by improving scientific practice and trigger new ways of working that will ultimately improve the robustness of our evidence base. A plethora of behaviour change insights, in part contributed to by the Health Psychology literature, is ready and waiting for application to the Open Science domain. We hope this article opens the conversation on how behaviour change can contribute to the Open Science movement and that it acts as a catalyst for further adoption of Open Science behaviours more generally, as well as specifically in the area of Health Psychology.

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