



Received: 10 December 2021  
Accepted: 06 March 2022

\*Corresponding author: Christopher Osborne, School of Anthropology and Museum Ethnography, Institute of Human Sciences, University of Oxford, UK  
E-mail: [christopher.osborne@anthro.ox.ac.uk](mailto:christopher.osborne@anthro.ox.ac.uk)

Reviewing editor:  
Daryl O'Connor, United Kingdom

Additional information is available at the end of the article

## HEALTH PSYCHOLOGY | RESEARCH ARTICLE

# Pre-registration as behaviour: developing an evidence-based intervention specification to increase pre-registration uptake by researchers using the Behaviour Change Wheel

Christopher Osborne<sup>1\*</sup> and Emma Norris<sup>2</sup>

**Abstract:** Pre-registration is an open research practice that can mitigate against questionable research practices and contribute to enhanced research outcomes, such as increased research transparency. This paper explores barriers and enablers to pre-registration, and develops an evidence-based behaviour change intervention specification to increase its uptake. The Behaviour Change Wheel (BCW) framework of intervention development and COM-B model of behaviour change were used to inform the development of a mixed-methods online questionnaire, assessing barriers and enablers to pre-registration. Data were collected from 18-05-2020 to 12-07-2020, and explored using descriptive statistics, reflexive thematic analysis, and COM-B. BCW was used to develop an intervention specification. Respondents were researchers ( $n = 105$ ) who were mostly engaged in psychological research (71%) and had pre-registered before (75%). Insufficient knowledge and skill (psychological capability), social support (social opportunity), time (physical opportunity), and incentivisation (reflective motivation) were the most substantial barriers to pre-registration, whereas belief in pre-registration contributing to desirable research outcomes (reflective motivation) was the most substantial enabler. These findings

### ABOUT THE AUTHOR

Christopher Osborne is a PhD Student at the University of Oxford, who has an MSc in Behaviour Change from University College London and BSc in Psychology from the University of Sussex. His PhD explores how behaviour and systems change approaches can be integrated to optimise research artefact reusability. Emma Norris is a Lecturer in Public Health, and researcher in behaviour change and health psychology, with an interest in applying behavioural change approaches to increase Open Science in researchers. She is the Co-Chair of Brunel's Health Behaviour Change Research Group and Chair of Brunel's Open Research Working Group. This research applies an internationally-established approach to behaviour change intervention development to understand the research behaviour of pre-registration.

### PUBLIC INTEREST STATEMENT

Pre-registration is a practice where researchers publicly note what methods and analysis they plan to conduct in a study, before they start to collect and analyse the data. Pre-registration aims to limit manipulations of data by researchers and increase research visibility. This study assessed reasons why researchers do and do not pre-register their research, by distributing an online questionnaire. This questionnaire assessed respondents' reasons to pre-register or not based on the COM-B model of behaviour change: assessing their capabilities, opportunities and motivation to pre-register. 105 researchers participated, with insufficient knowledge and skills to pre-register, social support, time, and incentivisation identified as the top barriers to pre-registering their research. From these findings, an intervention outline to improve pre-registration in researchers was developed. This study applies behavioural science to improve research behaviours in a novel way.

informed the development of an intervention specification to increase pre-registration uptake by researchers. This paper demonstrates the strong potential of BCW to facilitate open research practices. The identified barriers and enablers, intervention specification, and the behaviour change approach outlined, may be used to increase pre-registration uptake; for example, developing new or refining existing training and incentivisation interventions. This paper may inspire others to consider the strong potential of BCW to facilitate open research practices and so contribute to enhanced research outcomes.

**Subjects:** Psychological Science; Psychological Methods & Statistics; Applied Social Psychology

**Keywords:** preregistration; open research; meta-science; intervention; COM-B; Behaviour Change Wheel

### 1. Introduction

Within psychology and across disciplines, researchers appear to have produced an abundant number of non-replicable research findings (e.g., Baker, 2016; Camerer et al., 2016; Open Science Collaboration, 2015). Non-replicable findings are those that cannot be independently re-derived using the same or similar methods (Schmidt, 2009) and may arise from helpful or unhelpful sources. Helpful sources of non-replicable findings arise from insufficient knowledge about the characteristics of the phenomenon under study and are helpful because they may be used to advance knowledge about the phenomenon (e.g., non-replication may reveal insufficient knowledge about how to reliably measure the phenomenon and so prompt the development of a more reliable measure). In contrast, unhelpful sources arise from the improper designing, undertaking, and reporting of research studies and are unhelpful because they may not be used to advance knowledge about the phenomenon (e.g., non-replication would not relate to the phenomenon itself but to how the research was undertaken; National Academies of Sciences, Engineering and Medicine, 2019). To reduce the number of unhelpful non-replicable findings, improper research practices should be identified and mitigated against.

Questionable research practices (QRPs) concern the improper designing, undertaking, and reporting of research studies, and substantially increase the potential for non-replicable findings (Schimmack, 2020). Such practices may further concern the hidden flexibility researchers have to select from a potentially limitless number of options when undertaking their research, despite this producing a potentially limitless number of non-replicable findings (researcher degrees of freedom; Simmons et al., 2011). Example QRPs applicable to quantitative and qualitative forms of research include: reporting exploratory research as confirmatory (hypothesising after the results are known; HARKing; Kerr, 1998) and exploring multiple analysis strategies but not reporting this (Dienlin et al., 2021; Wicherts et al., 2016). Whereas QRPs are possible because of researcher degrees of freedom, cognitive biases (e.g., confirmation bias; attending to and selecting information supporting a preferred belief, but ignoring and rejecting challenging information; Bishop, 2020; Nickerson, 1998; Peters, 2020) and problematic incentive structures (e.g., rewarding new or exciting findings with publication, despite being non-replicable; Higginson & Munafò, 2016) make them beneficial for researchers to employ. For example, researchers exploring multiple analysis strategies to produce new or exciting findings, increase their potential for publication and so career advancement (Nosek et al., 2012); however, this also increases their potential produce non-replicable findings (Schimmack, 2020). Consequently, what benefits researchers individually (e.g., career progression), may not benefit them collectively (e.g., access to a more reliable corpus of knowledge; Edwards & Roy, 2017).

Open research (otherwise known as open science or open scholarship) practices concern the open, transparent, and rigorous designing, undertaking, and reporting of research studies, and can mitigate against QRPs (Crüwell et al., 2019). These practices stem from the open research movement, which promotes and encourages research best practices in pursuit of enhanced research

outcomes, such as increased knowledge production efficiencies and research credibility. Three example open research practices include: pre-registration (submitting a date-stamped, un-editable research plan to a repository prior to the research commencing; Nosek et al., 2018), registered reports (a publishing format that extends pre-registration with an initial peer-review of the research prior to its pre-registration, and offers a commitment to publish irrespective of the findings; Chambers et al., 2015), and data sharing (public sharing of research data; Klein et al., 2018). Open research practices can mitigate against QRPs because of their greater openness, transparency, and rigour (Munafò et al., 2017). For example, greater openness and transparency can make QRPs more detectable, and so less desirable, whereas greater rigour can reduce their potential when researcher degrees of freedom are restricted (Nosek et al., 2018). Open research practices are clearly preferable to questionable ones, and so their uptake should be facilitated.

## **2. Research as behaviour**

Behaviour is fundamental to research: researchers produce research questions, plan studies, run studies, collect data, analyse data, and report their findings (Norris & O'Connor, 2019). However, there is variation in how these behaviours are undertaken. For example, researchers may plan their studies using open research practices or QRPs, and so increase or decrease their potential for producing non-replicable findings (Dienlin et al., 2021). Furthermore, behaviours may be performed more or less effectively, also influencing outcomes (Bakker et al., 2020). The behaviour of pre-registering a research plan is now considered, relevant to the entire research process.

## **3. Pre-registration as behaviour**

### **3.1. Pre-registration**

Pre-registration is the behaviour of submitting a date-stamped, uneditable research plan to a public repository prior to the research commencing (Lindsay et al., 2016). This behaviour involves detailing important elements of a study in advance, such as its proposed research questions, methods, and analysis strategy. When important elements of a study are made public in advance, research transparency and rigour may increase. Increased transparency can make QRPs more detectable, and so less desirable, whereas increased rigour can inhibit them through the restriction of researcher degrees of freedom. Therefore, pre-registration can mitigate against QRPs and should be facilitated (Nosek et al., 2018).

### **3.2. Pre-registration effectiveness**

Pre-registration effectiveness is predicated on the quality and completeness of the pre-registration (Bakker et al., 2020). Clearly, high-quality pre-registrations are preferable to low-quality ones, and fully specified ones to partially specified ones. However, partially specified pre-registrations may be as effective as fully specified ones when addressing specific QRPs. For example, a high-quality but partially completed pre-registration may clearly state whether the research is exploratory or confirmatory, and so effectively mitigate against HARKing (Kerr, 1998); or fully state the proposed methods and/or analysis strategy, and so effectively mitigate against researcher degrees of freedom concerning the methods and/or analysis strategy (Simmons et al., 2011). However, pre-registration is not a panacea: researchers may still base their studies on weak theories, as well as design, undertake, and report them improperly (National Academies of Sciences, Engineering and Medicine, 2019; Szollosi et al., 2019). Nevertheless, pre-registration remains a valuable tool for researchers to use to enhance the transparency and rigour of their research (Bakker et al., 2020; Nosek et al., 2018; O'Connor, 2021).

### **3.3. Pre-registration is a complex behaviour**

Pre-registration is a complex behaviour, comprising multiple implementation behaviours (Norris & O'Connor, 2019). For example: (1) accessing a pre-registration repository (e.g., Open Science Framework; OSF); (2) selecting an appropriate pre-registration template (e.g., AsPredicted, Preregistration of Quantitative Research in Psychology Template, or Qualitative Preregistration Template) (3) completing the template; (4) selecting when the pre-registration is publicly released (e.g., immediately or after an embargo); and (5) submitting the pre-registration, at which point it

becomes date-stamped and uneditable, and the research pre-registered. Thereafter, follow-up behaviours include: (6) undertaking the research according to the pre-registration; (7) undertaking the analysis according to the pre-registration; and (8) linking the eventual findings to the pre-registration; and (9) if applicable, reporting deviations from the pre-registration (deviations are acceptable, but must be reported; Sullivan et al., 2019).

### **3.4. Pre-registration uptake**

Pre-registration uptake by researchers appears minimal within psychology and across disciplines, but the evidence is mixed. Serghiou et al. (2021) assessed 2,751,420 PubMed Central open access publications from a range of research fields between 1959–2020 (e.g., the biological sciences, engineering, and the social sciences), and found 5.7% were pre-registered in 2020. Similarly, Hardwicke et al. (2021) assessed 188 psychology publications between 2014–2017 and found 3% were pre-registered. In contrast, Norris et al. (2021) assessed 100 smoking cessation behaviour change intervention publications involving clinical trials between 2018–2019 and found 74% were pre-registered; however, this higher proportion could be due to the requirements funders place on researchers to pre-register their clinical trials (Kaplan et al., 2015). Nevertheless, there are substantial gains to be made in pre-registration uptake.

### **3.5. Pre-registration: barriers and enablers**

Evidence for barriers and enablers to pre-registration uptake by researchers is limited. Suggested barriers include insufficient training and incentivisation (Nosek et al., 2018; Stewart et al., 2020), as well as misconceptions about pre-registration; for example, believing that pre-registration hampers exploratory research or that plans cannot be deviated from (Chambers & Tzavella, 2021). Sarafoglou et al. (2021) reported additional barriers as well as enablers, when the beliefs of 299 researchers who had pre-registered before were assessed: barriers included pre-registration costing time, as well as increasing work-related stress, whereas enablers included belief in pre-registration enhancing practical and theoretical aspects of a research study. To better understand what encourages and restricts pre-registration so that evidence-based behaviour change interventions can be developed to increase its uptake, more evidence would be useful.

### **3.6. Pre-registration: past and present interventions**

Despite limited evidence for barriers and enablers to pre-registration, behaviour change interventions have been delivered to increase pre-registration uptake by researchers. For example, some journals (e.g., Cogent Psychology) incentivise researchers to pre-register with a pre-registration badge (see front page of this paper), demonstrating their commitment to open research practices (Kidwell et al., 2016). Others have produced and shared primers to increase researcher knowledge; for example, *Easing into Open Science* (Kathawalla et al., 2021) and *Pre-registration and Registered Reports: a Primer* from UKRN (Stewart et al., 2020). Furthermore, OSF incentivised researchers with a \$1,000 prize upon publishing their pre-registered findings (Preregistration Challenge; 2017–2018). However, it is unclear how these interventions were developed; for example, using a systematic and evidence-based framework of behaviour change, or the “it seemed like a good idea at the time” approach (Michie et al., 2014, p. 14).

## **4. Behaviour change**

### **4.1. The field of behaviour change**

Behaviour change is a field of enquiry aimed at addressing individual, societal, and global problems involving human behaviour (Michie et al., 2014). Psychologists, sociologists, economists, and anthropologists all contribute to the field (Davis et al., 2015). These researchers develop frameworks, theories, and models of behaviour change, as well as design, deliver, and evaluate behaviour change interventions (Michie et al., 2014). Consequently, behaviour change has strong potential to facilitate open research practices, including pre-registration (Norris & O'Connor, 2019).

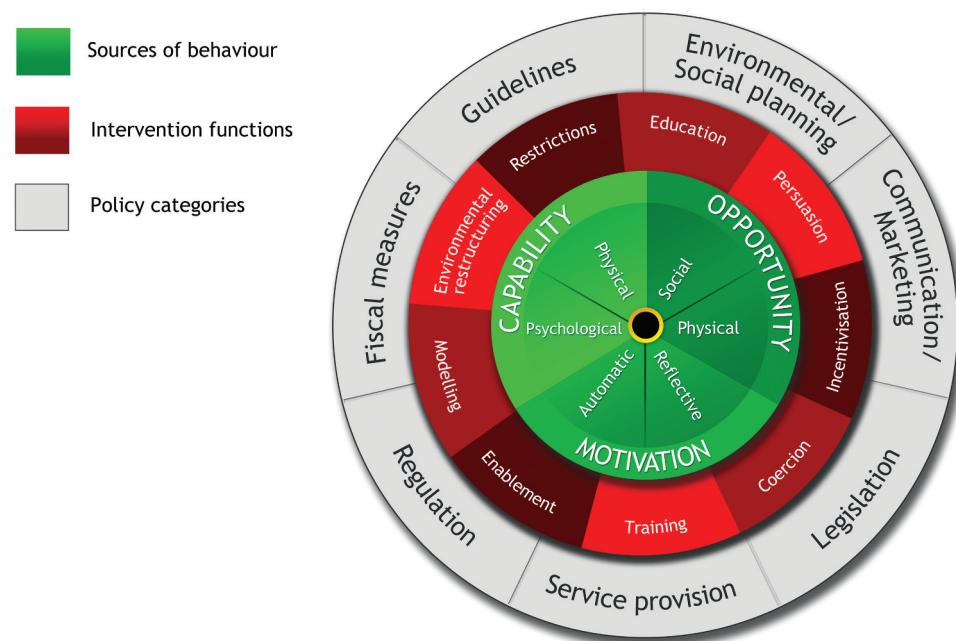
#### 4.2. The Behaviour Change Wheel

The Behaviour Change Wheel (BCW; see, figure 1) framework may be used to develop evidence-based behaviour change interventions (Michie et al., 2014, 2011; West et al., 2019). BCW offers a comprehensive, systematic method applicable to individuals, groups, and populations, and indeed any behaviour (Michie et al., 2014). Consequently, BCW can be used to increase pre-registration uptake by researchers.

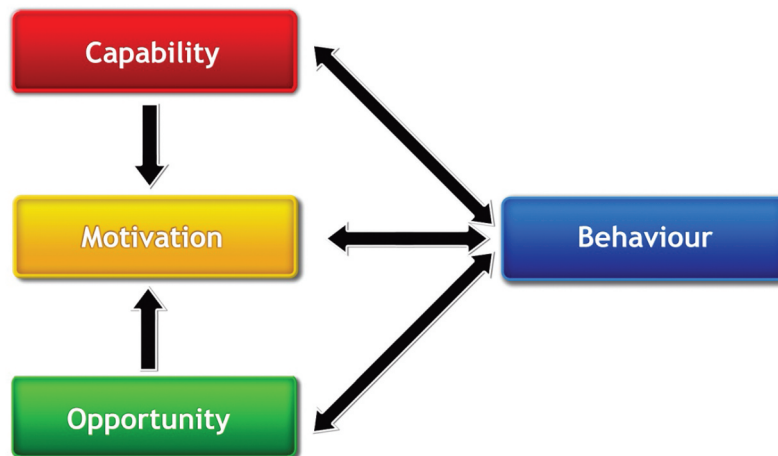
BCW intervention specifications are iteratively developed across eight stages: (1) define the problem in behavioural terms; (2) identify all behaviours relevant to the problem, assess them for their potential to address the problem, and select one or more behaviours as targets for change; (3) specify the selected behaviour(s); (4) collect evidence to identify barriers and enablers to the behaviour(s) using the COM-B model of behaviour change (see, Section 4.3.); (5) use the identified barriers and enablers to identify relevant intervention functions (the nine broad categories responsible for behaviour change: *education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling, and enablement*), assess them for their potential to address the problem, and select the most promising one(s); (6) use the selected intervention functions to identify relevant policy categories (*communication/marketing, guidelines, fiscal measures, regulation, legislation, environment/social planning, and service provision*), assess them for their potential to address the problem, and select the most promising one(s); (7) use the selected intervention functions to identify relevant behaviour change techniques (BCTs; the 93 active components responsible for behaviour change; Michie et al., 2013), assess them for their potential to address the problem, and select the most promising ones; and (8) use the behaviour change intervention ontologies to identify who will deliver the intervention (Norris et al., 2021), where the intervention will be delivered (Norris et al., 2020), and how the intervention will be delivered (Marques et al., 2021). The intervention specification is then constructed using the outputs from all eight stages (Michie et al., 2014).

When undertaking the eight stages, the APEASE criteria (Affordability, Practicability, Effectiveness, Acceptability, Side-effects, and Equity; Michie et al., 2014; West et al., 2019)

**Figure 1. The Behaviour Change Wheel.**  
**Note.** Courtesy of Michie et al. (2011).



**Figure 2. The COM-B model of behaviour change.**  
**Note.** Courtesy of Michie et al. (2011).



are used to assess various options (e.g., assessing which intervention functions or policy categories should be selected from those identified ones). These criteria ensure that important social and practical factors are considered (e.g., equity concerns whether the intervention could result in desirable outcomes for one group of individuals but undesirable ones for another group). Ideally, decisions should be made in collaboration with stakeholders to ensure diverse perspectives are considered, as well as to integrate valuable knowledge and expertise (West et al., 2019).

#### **4.3. The COM-B model of behaviour change**

The COM-B model of behaviour change (see, figure 2), the inner ring of BCW (see, figure 1), offers a simple but effective account of human behaviour (Michie et al., 2014, 2011; West et al., 2019). COM-B asserts that when Capability (including psychological capability and physical capability), Opportunity (including social opportunity and physical opportunity), and Motivation (including reflective motivation and automatic motivation) are sufficient, behaviour occurs, whereas when one or more of them is insufficient, it does not. Capability, opportunity, motivation, and behaviour influence each other as part of an interacting system. For example, researchers may have sufficient physical opportunity to pre-register (e.g., sufficient access to pre-registration repositories and primers; see, Sections 3.3. and 3.6.), but lack sufficient psychological capability (e.g., insufficient knowledge about how to pre-register) and reflective motivation (e.g., insufficient belief in pre-registration being beneficial as a consequence of believing that pre-registration causes stress; see, Section 3.5.). However, were these researchers to learn that partially completed pre-registrations may still mitigate against specific QRPs (increased psychological capability; see, Section 3.2.), this may challenge their belief in pre-registration necessarily causing stress (increased reflective motivation), which prompts them to access a primer and learn how to pre-register their research as exploratory or confirmatory (increased psychological capability), which then prompts the pre-registration of their first exploratory study (behaviour). Consequently, COM-B can be used to inform the development of evidence-based interventions, because it offers a simple but effective account of human behaviour that can be used to explore barriers and enablers to any behaviour (Michie et al., 2014).

#### **5. Research questions**

This exploratory research addresses two questions: (1) what are barriers and enablers to pre-registration by researchers? And (2) how can pre-registration uptake by researchers be increased?

## 6. Methods

### 6.1. Design and recruitment

This study features a mixed-methods online questionnaire design. Self-selected sampling was used, with recruitment taking place via Twitter (using the account of a UK-based researcher) and emails (sent directly to UK-based researchers or via the mailing lists of UK-based research organisations). Recruitment took place from 18/05/2020 to 12/07/2020. Ethical approval was granted by UCL Research Ethics Committee: CEHP/2020/57.

### 6.2. Respondents

One-hundred-and-twenty researchers (defined here as PhD in progress or awarded) responded to the questionnaire, of whom 12% (15/120) did not consent to their data being used and so were excluded. Sixty-six percent (69/105) identified as early-career-researchers (ECRs), 28% (29/105) as mid-career-researchers (MCRs), and 7% (7/105) as late-career-researchers (LCRs). Sixty-eight percent (71/105) reported primarily using quantitative data, 7% (7/105) as using qualitative, and 26% (27/105) as using both quantitative and qualitative data. Seventy-one percent (74/105) reported being primarily involved in psychological research, 8% (8/105) in neuroscientific, and 22% (23/105) in research from other disciplines. Seventy-five percent (79/105) reported pre-registering before (minimum of 1, maximum of 30;  $M = 4.47$ ,  $SD = 5.14$ ).

### 6.3. Questionnaire

The questionnaire was developed across six stages, using guidance from Rattray and Jones (2007), and Williams (2003). COM-B informed Stage 1 and BCW Stage 2 (Michie et al., 2014).

The six questionnaire development stages were: (1) the COM-B Behavioural Diagnosis Form (Michie et al., 2014) was used to produce an initial pool of 23 generic barriers and enablers items; for example, for a behaviour to occur, individuals may need to “know more about how to do it” (p. 70); (2) Stages 1–3 of BCW (Michie et al., 2014; see, Section 4.2.) informed by pre-registration papers (e.g., Sullivan et al., 2019), templates (e.g., AsPredicted), and websites (e.g., OSF), were used to tailor the initial pool of items; for example, “know more about how to do it” became “know more about how to select a pre-registration template” (Sullivan et al., 2019); (3) item response options were considered and a 101-point slider-scale selected to assess quantitative barriers and enablers to pre-registration items (0% = “complete and utter disagreement” with the item statement and 100% = “complete and utter agreement”); whereas optional qualitative comment boxes were selected to enable respondents to freely expand on their quantitative responses; (4) tailored items were refined to match the slider-scale items; for example, “know more about how to select a pre-registration template” became “I am confident I know how to select a pre-registration template”; (5) six researchers piloted the questionnaire, of whom five had pre-registered before; and (6) piloting feedback was used to further refine the items (e.g., items were re-worded to improve clarity, less relevant items excluded, and all items relating to physical capability and automatic motivation excluded; e.g., because researchers were assumed to have the physical capability to pre-register, given its similarity to other essential researcher behaviours, such as submitting an ethics application).

Upon completion, the questionnaire featured five demographic items, 33 quantitative barriers and enablers to pre-registration items, and six optional qualitative comment boxes. Respondents completed the questionnaire in six minutes and nine seconds on average.

## 6.4. Data analysis

### 6.4.1. Quantitative analysis

SPSS Statistics (v26) was used to analyse slider-scale responses. Outliers  $\pm 3$  standard deviations were coded as missing for all individual responses. Descriptive statistics (means, standard deviations, and correlations) were then produced.

### 6.4.2. Qualitative analysis

Reflexive thematic analysis (RTA; Braun & Clarke, 2006; Braun et al., 2019) and NVivo (v12) were used to analyse comment box responses. RTA was undertaken across six stages and selected because it encourages researchers to take a more active role in knowledge production, thus meaning our knowledge and experience of pre-registration could be used to enhance our findings. When undertaking RTA, we assumed a constructionist epistemology, an experiential orientation, a primarily deductive approach using COM-B, and used both semantic and latent coding (Byrne, 2021).

The six RTA stages were: (1) comment box responses were read, re-read, and detailed notes taken (e.g., notes about what we thought and felt about responses); (2) initial codes were generated using a primarily deductive approach, because our focus was on identifying barriers and enablers to pre-registration using COM-B; (3) initial codes were used to generate potential themes; (4) potential themes were reviewed in relation to the coded extracts, as well as the entire dataset, and then revised; (5) themes were defined and named; with some themes then being integrated or renamed; and (6) the thematic report was produced (Braun & Clarke, 2006; Braun et al., 2019).

RTA was primarily undertaken by this paper's first author; however, its second author also contributed. To mitigate against confirmation bias (Nickerson, 1998), we deliberately searched for and selected responses that challenged our preferred beliefs (e.g., we searched for responses concerning the ineffectiveness of pre-registration to challenge our preferred belief that pre-registration is effective; Becker, 1998).

### 6.4.3. Intervention specification

The intervention specification was developed using the eight BCW stages (Michie et al., 2014; see, Section 4.2.). The APEASE criteria (West et al., 2019) were used by this paper's first author to select promising intervention development options.

## 6.5. Pre-registration and transparent deviations

This exploratory research was pre-registered using the AsPredicted template and OSF repository. There were four deviations: (1) items relating to incentivisation had been incorrectly aligned to physical opportunity and so were realigned to reflective motivation; (2) principal components analysis was not reported because there were insufficient data to meet its assumptions (Pallant, 2020), and so coefficient omega and inferential tests were not reported given their dependence on it; (3) group comparisons were not reported due to a substantial imbalance between groups (e.g., seven of 105 respondents were LCRs) but career stage comparisons are provided as supplementary materials; and (4) correlations were not pre-registered due to an oversight but were considered useful and so reported (see, Section 7.1.2.).

## 7. Results

### 7.1. Quantitative analysis

#### 7.1.1. Means and standard deviations

Table 1 presents means and standard deviations for barriers and enablers to pre-registration item responses.



**Table 1. Means and standard deviations for barriers and enablers to pre-registration item responses**

<b>Items</b>	<b>n</b>	<b>M</b>	<b>SD</b>
<b>Psychological capability</b>			
I am confident I know what pre-registration is (Q12)	101	90.37	15.83
I am confident I know at least one website which offers a pre-registration service (Q13)	99	93.43	19.70
I am confident I know how to select an appropriate pre-registration template (Q14)	105	66.65	30.81
I am confident I know how to specify a study's hypotheses in advance (Q15)	102	86.35	14.24
I am confident I know how to specify a study's predictions in advance (Q16)	103	82.45	17.26
I am confident I know how to specify a study's design in advance (Q17)	104	88.33	13.40
I am confident I know how to specify a study's inference criteria in advance (Q18)	105	66.34	28.53
I am confident I know how to specify a study's data stopping rule in advance (Q19)	105	69.18	34.29
I am confident I know how to specify a study's data inclusion criteria in advance (Q20)	103	87.31	16.03
I am confident I know how to specify a study's data exclusion criteria in advance (Q21)	102	87.50	15.25
I am confident I know how to pre-register a study (Q22)	105	78.13	27.71
I am confident I know how pre-registration aims to improve research rigour (Q24)	101	92.27	10.90
I am confident I know how pre-registration aims to improve research transparency (Q25)	103	93.72	9.97
I am confident I know how pre-registration aims to improve research credibility (Q26)	103	91.80	12.26
<b>Social opportunity</b>			
I am influenced by someone junior to me who encourages pre-registration (Q28)	105	16.87	28.57
I am influenced by someone junior to me who discourages pre-registration (Q29R)	101	1.69	4.18
I am influenced by someone in a similar role to me who encourages pre-registration (Q30)	105	54.70	37.46
I am influenced by someone in a similar role to me who discourages pre-registration (Q31R)	101	4.84	11.58
I am influenced by someone senior to me who encourages pre-registration (Q32)	105	58.06	38.54
I am influenced by someone senior to me who discourages pre-registration (Q33R)	102	14.08	23.73
<b>Physical opportunity</b>			
I have the time to pre-register (Q35)	105	67.90	31.96
I have access to the training I would need to pre-register (Q36)	105	58.02	35.14
<b>Reflective motivation</b>			
I am incentivised by at least one funder to pre-register (e.g., increased likelihood of funding) (Q37)	105	22.30	31.33
I am incentivised by at least one publisher to pre-register (e.g., increased likelihood of publication) (Q38)	105	35.78	36.47
I am incentivised by my university to pre-register (e.g., increased likelihood of career progression) (Q39)	103	16.23	22.86
I believe pre-registration could stifle my creativity (Q41R)	103	15.17	22.91

(Continued)

**Table 1. (Continued)**

Items	<i>n</i>	<i>M</i>	<i>SD</i>
I believe pre-registration could make me vulnerable to being scooped (Q42R)	104	18.00	23.61
I believe pre-registration could hamper my ability to make unexpected discoveries (Q43R)	105	19.20	28.26
I believe pre-registration could reduce my chances of being published (Q44R)	105	14.57	24.04
I believe pre-registration could lead to embarrassment, because if a mistake were made, it would become public (Q45R)	102	26.08	27.92
I believe pre-registration could improve research rigour (Q47)	101	87.19	18.60
I believe pre-registration could improve research transparency (Q48)	102	89.95	15.98
I believe pre-registration could improve research credibility (Q49)	102	86.30	20.11

Note. Slider-scales were used to assess barriers and enablers to pre-registration items (0% = “complete and utter disagreement” and 100% = “complete and utter agreement” with the item statement). “R” indicates reverse-scored items.

### 7.1.2. Correlations

Table 2 presents Spearman’s rank correlation coefficients, assessing the relationship between barriers and enablers to pre-registration item responses, and past pre-registration behaviour (the number of times respondents reported pre-registering before; Q10). Inspection of scatterplots suggested that only six of 33 items had the required monotonic relationship (Field, 2018), and so correlations were limited to these items.

**Table 2. Correlations between barriers and enablers to pre-registration item responses, and past pre-registration behaviour**

Items	<i>n</i>	<i>r<sub>s</sub></i>
I am confident I know how to pre-register a study (psychological capability) (Q22)	102	0.53***
I believe pre-registration could improve research transparency (reflective motivation) (Q48)	99	0.43***
I am confident I know what pre-registration is (psychological capability) (Q12)	98	0.39***
I believe pre-registration could improve research rigour (reflective motivation) (Q47)	98	0.36***
I believe pre-registration could improve research credibility (reflective motivation) (Q49)	99	0.33***
I am confident I know how to specify a study’s data inclusion criteria in advance (psychological capability) (Q20)	100	0.23*

Note. \**p* < .05. \*\*\**p* < .001.

## 7.2. Qualitative analysis

### 7.2.1. Reflexive thematic analysis

Table 3 presents the 15 qualitative barriers and enablers to pre-registration themes produced using RTA (Braun & Clarke, 2006; Braun et al., 2019). Themes are based on the 117 comment box responses submitted by 45% (47/105) of respondents, of whom 66% (31/47) were ECRs, 26% (12/47) MCRs, and 9% (4/47) LCRs. Example extracts from comment box responses are provided for each theme, below (see, Sections 7.2.1.1.-7.2.1.4). To mark the removal of text irrelevant to a theme within extracts, “...” was used, whereas “\*\*\*\*” for text which could potentially be used to identify respondents. Respondent identifiers (11-digit codes) are provided after each extract and can be used to cross-reference them using the raw data and thematic analysis extracts.

**Table 3. Reflexive thematic analysis themes produced using comment box responses**

Themes	Career stage			Total	%
	ECR	MCR	LCR		
<b>Psychological capability</b>					
Pre-registration requires greater knowledge (barrier)	7	2	0	9	19%
Pre-registration requires determination (enabler)	4	4	0	8	17%
Pre-registration does not prevent exploration (enabler)	4	1	1	6	13%
Pre-registration requires greater skill (barrier)	4	0	0	4	9%
<b>Social opportunity</b>					
Pre-registration is encouraged by others (enabler)	5	5	0	10	21%
Pre-registration is discouraged by others (barrier)	2	4	0	6	13%
<b>Physical opportunity</b>					
Pre-registration costs time (barrier)	1	5	0	6	13%
Pre-registration saves time (enabler)	2	1	0	3	6%
Pre-registration templates are unsuitable (barrier)	2	1	0	3	6%
<b>Reflective motivation</b>					
Pre-registration is not incentivised (barrier)	6	4	1	11	23%
Pre-registration is desirable, despite its potential to reveal mistakes or be embarrassing (enabler)	5	2	0	7	15%
Pre-registration is ineffective (barrier)	3	2	2	7	15%
Pre-registration contributes to enhanced research outcomes (enabler)	5	1	0	6	13%
Pre-registration is incentivised (enabler)	3	1	0	4	9%
Pre-registration remains desirable, despite its potential to reduce publication opportunities (enabler)	2	1	0	3	6%

Note. Percentages express the proportion of respondents who commented on a specific theme, to those who commented ( $n = 47$ ).

#### 7.2.1.1. Psychological capability.

**Pre-registration requires greater knowledge.** Seven ECRs and two MCRs commented on needing to know more about how to pre-register. In five instances, the comments described general challenges:

I used \*\*\* and I'm still not entirely sure I actually pre-registered my study or whether I just uploaded a template? – 11691125819 (ECR)

In the remaining four instances, the comments described specific challenges associated with specifying a study in advance:

For most instances where I've rated slightly lower it's because in my experience there are \*always\* unexpected things that happen and so far none of my pre-registrations have accounted for every possibility! – 11636045117 (ECR)

**Pre-registration requires determination.** Four ECRs and four MCRs commented on their determination to pre-register. In all but one instance, comments described how this enabled them to overcome an apparent lack of social or institutional support:

I independently chose to pursue pre-registration and personally know of very few others who do so – 11644077847 (ECR)

I have mostly taught myself how to do it. – 11718244857 (MCR)

**Pre-registration does not prevent exploration.** Four ECRs, two MCRs, and one LCR commented on knowing it is acceptable to deviate from a pre-registration when doing so transparently:

I regularly report unanticipated findings that would not have been pre-registered—as along as the reader knows an analysis is post-hoc, I see no ethical problem with reporting it. – 11777827987 (LCR)

**Pre-registration requires greater skill.** Four ECRs commented on the importance of practice to develop the skills needed to pre-register effectively. In all but one instance, comments described how initial attempts at pre-registration had been sub-optimal:

Whatever I know, it is the result of practice, not only abstract understanding. The quality of my first preregistration was much worse than the last. I'm confident the next will be slightly better. – 11657567895 (ECR)

We note that extracts from *pre-registration requires greater knowledge* and *pre-registration requires greater skill* suggest pre-registration is a challenging behaviour to undertake effectively. Respondents commented on needing greater knowledge and skills, and especially when specifying analysis strategies in advance.

**7.2.1.2. Social opportunity. Pre-registration is encouraged by others.** Five ECRs and five MCRs commented on other people encouraging them to pre-register. In all but one instance, senior researchers were an important source of encouragement:

I know some senior scholars ... who have absolutely taught me how to do the best science and I look up to these people. – 11691129166 (MCR)

However, in three instances, such encouragement appeared exceptional:

Re senior people: there are very few who encourage pre-reg and I do not work with them directly but try to learn from them anyway. – 11718244857 (MCR)

In a further three instances, ECRs appeared to be an important source of encouragement:

Definitely positively influenced by other early career researchers ... – 11638304779 (ECR)

**Pre-registration is discouraged by others.** Two ECRs and four MCRs commented on other people discouraging them from pre-registering. Common to all but one of these responses was discouragement coming from someone in a position of power, with the exception making no reference to the source of discouragement. In two instances, the comments described discouragement from reviewers:

I've had a reviewer interpret my preregistration as some sort of affront to exploratory research. – 11635816272 (ECR)

Whilst in three instances, the comments described discouragement from supervisors:

when the senior person (when on the project) does not want to pre-register it would be a battle to do so anyway. – 11611757961 (ECR)

We note that extracts from *pre-registration is encouraged by others* and *pre-registration is discouraged by others* contrast strongly. Respondents appeared either to find themselves in social environments strongly encouraging or strongly discouraging of pre-registration. However, respondents in discouraging environments nevertheless reported pre-registering; perhaps as a consequence of being determined to pre-register (*pre-registration requires determination*; see, Section 7.2.1.1.).

**7.2.1.3. Physical opportunity. Pre-registration costs time.** One ECR and five MCRs, commented on pre-registration costing time:

The biggest barrier for me has been having the time to pre-register studies ... Pre-reg takes me about 3-4 days to get absolutely spot-on, and represents time that I never used to have to spend. – 11691129166 (MCR)

**Pre-registration saves time.** Two ECRs and one MCR commented on pre-registration saving time. In one instance, the comment described how time was saved in contrast to undertaking a registered report:

I would have liked to go for registered reports, however as a PhD student, this could pose potential delays for completing the PhD. The next best alternative is pre-registration. – 11635901560 (ECR)

In two instances, the comments described costing time at the beginning, but then saving time later one:

I feel preregistration saves me time later down the line. I don't have the time to NOT preregister! – 11699229818 (MCR)

We note that extracts from *pre-registration costs time* and *pre-registration saves time* contrast in their perspective. Respondents who found pre-registration cost them time focussed on overall time whereas those who found it saved time, focussed on relative time (e.g., costing time towards the beginning of a study but saving time towards the end, or saving time compared to a registered report).

**Pre-registration templates are unsuitable.** Two ECRs and one MCR commented on pre-registration templates being unsuitable for their needs:

Re templates: there are none available for the types of research I do – 11718244857 (MCR)

**7.2.1.4. Reflective motivation. Pre-registration is not incentivised.** Six ECRs, four MCRs, and one LCR commented on lack of incentivisation to pre-register. Common to most responses, was an overall lack of incentivisation. In four instances, the comments described a lack of incentivisation from funders:

I don't think this is properly incentivised by ... grant awarding bodies yet, at least in my field. – 11780244417 (MCR)

In three instances, the comments described a lack of incentivisation from publishers:

not journals encountered that “require” pre-registration (which in my field—cognitive neuroscience—is still rather uncommon). – 11644080306 (ECR)

In five instances, the comments described a lack of incentivisation from institutions:

I do not think my university cares if I pre-register my studies or not, so long as I meet my key performance indicators. – 11691129166 (MCR)

In two instances, there was also a related comment about the irrelevance of pre-registration to career prospects:

I do not believe pre-registering improves my employment chances in anyway. – 11690875825 (ECR)

**Pre-registration is desirable, despite its potential to reveal mistakes or be embarrassing.** Five ECRs and two MCRs commented on openness and transparency being of greater importance than being seen to be correct:

It's more about being open and transparent than about being correct. – 11635901560 (ECR)

In six instances, the comments also described how openness about mistakes could be embarrassing, but that such embarrassment was preferable to not being open:

I believe recognizing an honest mistake in a pre-registered report is less embarrassing than the discovery of an hidden one in a non-pre-registered paper. – 11690959076 (ECR)

**Pre-registration is ineffective.** Three ECRs, two MCRs, and two LCRs questioned the effectiveness of pre-registration. In five instances, the comments described concern over the quality of submitted pre-registrations:

Most pre-registration is done so poorly that it has turned into a meaningless badge. – 11640029064 (ECR)

In a further two instances, the comments described how pre-registration may not mitigate against the behaviour of dishonest researchers (e.g., researchers who fabricate data):

I know how pre-registration achieves these aims in theory. Whether it does in practice, is open to question. For example, it does not prevent researchers faking or “massaging” data. – 11746169477 (LCR)

We note that the potential ineffectiveness of pre-registration described in *pre-registration is ineffective* may be explained with reference to several other themes. First, extracts from *pre-registration requires greater knowledge* and *pre-registration requires greater skill* suggest that pre-registration is a challenging behaviour to undertake effectively (see, Section 7.2.1.1.). Second, extracts from *pre-registration is discouraged by others* (see, Section 7.2.1.2.), *pre-registration costs time* (see, Section 7.2.1.3.), and *pre-registration is not incentivised* may in part explain the suggested ineffectiveness of pre-registration: it is unsurprising that a challenging behaviour is undertaken less effectively when those responsible for it are discouraged, time limited, and not rewarded for doing so. However, perhaps believing *pre-registration contributes to enhanced research outcomes* and being determined to pre-register (*pre-registration requires determination*) could mitigate against these factors, although this would not necessarily increase pre-registration effectiveness.

**Pre-registration contributes to enhanced research outcomes.** Five ECRs and one MCR commented on their belief that pre-registration contributes to enhanced research outcomes. In all instances, comments either described how pre-registration was beneficial overall, beneficial to the researcher, and/or beneficial to research itself:

I think overall it's a good thing for the research and for me. – 11691560037 (ECR)

Specific reasons were also given for the belief in pre-registration contributing to enhanced research outcomes:

Pre-registration is a very positive move: transparency, reduces harking, encourages publication of null results. Makes researchers think carefully about hypotheses, predicted results, power, sampling and analysis strategies before collecting data. – 11635922304 (ECR)

**Pre-registration is incentivised.** Three ECRs and one MCR commented on being incentivised to pre-register. In one instance, the comment described a funder incentivising pre-registration:

I have ... applied for one funding source ... which required pre-registration. – 11639887291 (ECR)

In two instances, the comments described journals incentivising pre-registration:

Some of the studies I've preregistered are \*\*\* and here many journals stick to guidelines like \*\*\* and require a preregistered protocol. – 11638304779 (ECR)

In one instance, the comment described the researcher's institution incentivising pre-registration:

My department has an open science policy that strongly encourages/ requires preregistration – 11644057531 (ECR)

**Pre-registration remains desirable, despite its potential to reduce publication opportunities.**

Two ECRs and one MCR commented on their belief in pre-registration potentially reducing publication opportunities, but this being beneficial:

I believe that it may decrease the chances of being published in certain journals that practically require authors to cherry pick results to make manuscripts too good to be true. This is still a good thing; we should stop aspiring to publish in these anti scientific outlets. – 11640376114 (ECR)

We note that some extracts from *pre-registration remains desirable, despite its potential to reduce publication opportunities* and *pre-registration is desirable, despite its potential to reveal mistakes or be embarrassing* suggest that some respondents were ethically motivated to pre-register their research. These respondents appeared to pre-register whilst accepting a cost (e.g., embarrassment or reduced publication opportunities), perhaps as a consequence of believing that *pre-registration contributes to enhanced research outcomes*.

### 7.3. Intervention specification

#### 7.3.1. Define the problem in behavioural terms

The problem was defined as a question: how can pre-registration uptake by researchers be increased?

#### 7.3.2. Select one or more behaviours as targets for change

A long list of behaviours relevant to pre-registration was produced and ranked using four criteria: impact of change, likelihood of change, impact on other related behaviours, and ease of measurement (Michie et al., 2014, p. 45). Promising behaviours were selected from this ranked list to produce a short list of behaviours. Behaviours from this short list were explored using a conceptual map. The behaviour of *submitting a pre-registration* was identified as the most promising target for change and so selected (see, Section 3.3.).

### 7.3.3. Specify the selected behaviour

The selected behaviour of *submitting a pre-registration* was specified using six criteria: who, what, when, where, how often, and with whom (Michie et al., 2014, p. 48). *Submitting a pre-registration* was specified as follows: *researchers who collect or analyse data* (who) *should pre-register their research* (what) *prior to it commencing* (when) *at a computer* (where) *for all studies involving data collection or analysis* (how often) *and do so alone or with other members of the research team* (with whom).

### 7.3.4. Identify barriers and enablers to the selected behaviour

Descriptive (see, Tables 1 and 2) and qualitative (see, Table 3) findings were used to identify barriers and enablers to pre-registration with COM-B (Michie et al., 2014). Insufficient knowledge and skill (psychological capability), social support (social opportunity), time (physical opportunity), and incentives (reflective motivation) were the most substantial barriers to pre-registration, whereas belief in pre-registration contributing to desirable research outcomes (reflective motivation) was the most substantial enabler.

### 7.3.5. Identify relevant intervention functions

BCW was used to link the identified COM-B barriers and enablers (see, Section 7.3.4.) with relevant intervention functions (the broad categories responsible for behaviour change) using a matrix table (Michie et al., 2014, p. 116). All nine were relevant: *education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling, and enablement*. The APEASE criteria (West et al., 2019) were used to assess the potential of each intervention function. *Education, persuasion, incentivisation, training, and modelling* were identified as the most promising functions and so selected.

### 7.3.6. Identify relevant policy categories

BCW was used to link the selected intervention functions (see, Section 7.3.5.) with relevant policy categories (the broad categories responsible for how the intervention is delivered) using a matrix table (Michie et al., 2014, p. 138). All seven were relevant: *communication/marketing, guidelines, fiscal measures, regulation, legislation, environmental/social planning, and service provision*. The APEASE criteria (West et al., 2019) were used to assess the potential of each policy category. *Communication/marketing, guidelines, fiscal measures, and service provision* were identified as the most promising categories and so selected.

### 7.3.7. Identify relevant behaviour change techniques

BCW and the behaviour change technique taxonomy (Michie et al., 2013) were used to identify relevant BCTs (the active components responsible for behaviour change) relating to selected intervention functions (see, Section 7.3.5.) using a linking table (Michie et al., 2014, pp. 250–253). *Instruction on how to perform a behaviour* (BCT 4.1), *information about social and environmental consequences* (BCT 5.3), *demonstration of the behaviour* (BCT 6.1), *prompts/cues* (BCT 7.1), *credible source* (BCT 9.1), and *material reward* (BCT 10.2) were identified as the most promising techniques and so selected.

### 7.3.8. Identify implementation options

The *intervention source* (Norris et al., 2021), *setting* (Norris et al., 2020), and *modes of delivery* ontologies (Marques et al., 2021) were used to identify who, where, and how the intervention will be delivered. *Researcher* (BCIO:010083); *relatedness between person source and the target population* (BCIO:010094); *expertise of person source* (BCIO:010120); *university facility* (BCIO:026028); *face to face* (BCIO:011003); *at a distance* (BCIO:011004); *email* (BCIO:011025); and *website* (BCIO:011027) were selected.

### 7.3.9. Production of the intervention specification

Table 4 presents the intervention specification, constructed using the outputs from all eight BCW stages (Michie et al., 2014).



<b>Table 4. Intervention specification</b>	
<b>Participants</b>	Researchers employed by an academic institution who collect or analyse data to report research findings.
<b>Design</b>	Pre-post intervention study.
<b>COM-B</b>	<i>Psychological capability; social opportunity; physical opportunity; reflective motivation.</i>
<b>Intervention functions</b>	<i>Education; persuasion; incentivisation; training; modelling.</i>
<b>Policy categories</b>	<i>Communication/marketing; guidelines; fiscal measures; service provision.</i>
<b>Behaviour change techniques</b>	<i>Instruction on how to perform a behaviour (BCT 4.1); information about social and environmental consequences (BCT 5.3); demonstration of the behaviour (BCT 6.1); prompts/cues (BCT 7.1); credible source (BCT 9.1); material reward (BCT 10.2).</i>
<b>Implementation options</b>	<i>Researcher (BCIO:010083); relatedness between person source and the target population (BCIO:010094); expertise of person source (BCIO:010120); face to face (BCIO:011003); at a distance (BCIO:011004); email (BCIO:011025); website (BCIO:011027); university facility (BCIO:026028).</i>
<b>Intervention summary</b>	The intervention will be delivered within an academic institution ( <i>university facility</i> ) across five stages, with a 3-month gap between each stage to assess the impact of each stage. The intervention will be fully delivered by month 12 but will continue for as long as it is beneficial. Stage 1 (S1) assesses baseline levels of pre-registration. Stages 2–5 (S2–S5) aim to increase pre-registration uptake using four complementary incremental interventions (thus making this a complex intervention; Craig et al., 2008). <i>Emails</i> will be sent to researchers from their various Heads of Department ( <i>credible source; relatedness</i> ) at the beginning of each stage from S2 onwards to introduce each intervention, as well as to <i>educate</i> (increased <i>psychological capability</i> ) them about pre-registration and <i>persuade</i> them to pre-register (e.g., sharing information about the potential for pre-registration to enhance their research as well as contribute to enhanced research outcomes; <i>information about social and environmental consequences; increased reflective motivation</i> ).
<b>Stage 1</b>	S1 aims to assess baseline levels of pre-registration. To assess levels, a question will be added to the institutional ethics application form most researchers need to complete prior to commencing their research: “Have you pre-registered this study? If yes, please provide a link”.
<b>Stage 2</b>	S2 aims to increase pre-registration uptake by providing researchers with access to an institutional ( <i>credible source</i> ) pre-registration <i>website</i> ( <i>service provision</i> ). <i>Information about the social and environmental consequences</i> of pre-registration will be provided to <i>educate</i> (increased <i>psychological capability</i> ) and <i>persuade</i> (increased reflective motivation) researchers to pre-register. Furthermore, instruction on how to pre-register to three incremental standards will be provided ( <i>instruction on how to perform a behaviour; increased psychological capability</i> ): basic (differentiation between exploratory or confirmatory research), intermediate (basic plus specification of methods), and advanced (intermediate plus specification of analysis strategy; see, Section 3.2.). Thus, researchers may match their pre-registration knowledge and skill, as well as their available time, to an appropriate template (mitigating against insufficient <i>psychological capability</i> and <i>physical opportunity</i> ).
<b>Stage 3</b>	S3 aims to increase pre-registration uptake by offering researchers an opportunity to meet <i>face to face</i> or online ( <i>at a distance</i> ) with a departmental pre-registration champion ( <i>credible source; expertise; researcher</i> ) to receive <i>training</i> ( <i>service provision</i> ) on how to pre-register their research ( <i>instruction on how to perform a behaviour; increased psychological capability</i> ) as well as to demonstrate how studies can be pre-registered ( <i>modelling; demonstration of the behaviour; increased social opportunity</i> ).
<b>Stage 4</b>	S4 aims to increase pre-registration uptake by updating institutional career progression criteria ( <i>guidelines</i> ) available online ( <i>website</i> ) so that researchers are incentivised ( <i>fiscal measures; material reward; increased reflective motivation</i> ) to pre-register their research and for being a departmental pre-registration champion (see S3).

(Continued)

**Table 4. (Continued)**

<b>Stage 5</b>	S5 aims to increase pre-registration uptake by updating the S1 ethics application form question ( <i>website</i> ) to: “Pre-registering your study could improve the credibility of your findings. To find out more, click here [link to S2 website]. Have you pre-registered this study? If yes, please provide a link” ( <i>communication/marketing; education; information about social and environmental consequences; prompts/cues; increased psychological capability</i> ).
<b>Evaluation</b>	This intervention will be primarily assessed using the S1 ethics application form question, providing a measure of behaviour (whether studies were pre-registered). However, S2 will be further assessed by recording the specific ways in which the <i>website</i> has been accessed; S3 by recording the number of researchers meeting with each departmental pre-registration champion, as well as the overall total number of meetings held; and S4 the number of career progression applications that include evidence of pre-registration as well as other open research practices (to assess the potential for positive side-effects). Rather than assessing S5, an additional sentence will be added to the updated question in S4: “If no, please select from one of the following options to state your reason for not doing so”. This additional question will be used to refine the intervention during the months following its full delivery.

Note. This intervention specification was produced using BCW (Michie et al., 2014). Italicised words or phrases indicate COM-B components, intervention functions, policy categories, behaviour change techniques, or implementation options.

## 8. Discussion

This paper demonstrates the strong potential of behaviour change to facilitate open research practices using pre-registration as an example. BCW and COM-B (Michie et al., 2014) were used to inform the development of a mixed-methods online questionnaire, assessing barriers and enablers to pre-registration by researchers. Insufficient knowledge and skill (psychological capability), social support (social opportunity), time (physical opportunity), and incentivisation (reflective motivation) were the most substantial barriers to pre-registration, whereas belief in pre-registration contributing to desirable research outcomes (reflective motivation) was the most substantial enabler. BCW was then used to develop an evidence-based intervention specification to increase pre-registration uptake by researchers. This appears to be the first paper to demonstrate how a framework and model of behaviour change can be used to facilitate an open research practice.

The presented findings support past research addressing barriers and enablers to pre-registration. Respondents reported insufficient incentivisation and access to training (Nosek et al., 2018; Stewart et al., 2020), as well as insufficient time (Sarafoglou et al., 2021), as barriers to pre-registration. Respondents also reported belief in pre-registration contributing to desirable research outcomes (Sarafoglou et al., 2021). The presented findings also extend this past research. Relating to incentivisation, respondents reported minimal incentivisation but nevertheless greater incentivisation from publishers, followed by funders, and then institutions (see, Table 1). Relating to training, respondents specifically reported lack of confidence in selecting an appropriate pre-registration template as well as knowing how to specify inference criteria and data stopping rules in advance (see, Table 1). Relating to time, respondents who reported time as a barrier focussed on overall time whereas those reporting time as an enabler focussed on relative time (e.g., costing time towards the beginning of a study and saving time towards the end, or saving time in relation to registered reports; see, Section 7.2.1.3.). Finally, relating to pre-registration contributing to desirable research outcomes, respondents reported belief in pre-registration having similar potential to increase research transparency, rigour, and credibility (see, Table 1). Evidence was also found for respondents having misconceptions about pre-registration (Chambers & Tzavella, 2021; see Table 1); however, these misconceptions were not considered substantial barriers.

One strength of this study concerns its use of mixed-methods to provide complementary insights. For example, when explaining the potential for pre-registration to be ineffectively undertaken (see, Section 7.2.1.4). Ineffectively undertaken pre-registrations were explained as a consequence of

researchers being discouraged from pre-registering (qualitative; see, Section 7.2.1.2.), time limited (quantitative; see, Table 1; and qualitative; see, Table 3 and Section 7.2.1.3.), and not rewarded for doing so (quantitative; see, Table 1; and qualitative; see, Table 3 and Section 7.2.1.3.). Complementary insights also extended past research. For example, relating to incentivisation, quantitative findings indicated that publishers incentivised pre-registration most of all, followed by funders, and then institutions (see above and Table 1). However, relating to institutional incentivisation, qualitative findings distinguished between researchers not being incentivised to pre-register by their current institution as well as by alternative institutions when seeking employment from them (see, Section 7.2.1.4.). This extension is useful, because institutions wishing to incentivise pre-registration may wish to consider doing so for both current and potential future employees. However, it is crucial that institutions collectively incentivise pre-registration because researchers who are incentivised by their current institution to pre-register, may be at a disadvantage when seeking employment from alternative institutions that do not (Munafò et al., 2022).

Two further strengths of this study concern its use of systematic methods and open research practices. Systematic methods were used to develop the questionnaire (see, Section 6.3.) and intervention specification (see, Section 7.3.). These methods prompted consideration of crucial elements that may otherwise have been overlooked, and so were preferable to the “it seemed like a good idea at the time” approach (Michie et al., 2014, p. 14). Open research practices included pre-registration, and both FAIRly and openly sharing the research artefacts used to produce the presented findings (e.g., the questionnaire, data, and supporting materials). This study’s pre-registration clearly states it was exploratory, and both the methods and analysis strategy were pre-registered (data were collected according to the methods but there were deviations from the analysis strategy; see, Section 6.5.). Consequently, this study’s pre-registration mitigated against HARKing (Kerr, 1998), and restricted the potential for multiple methodological and analytical strategies to be explored in pursuit of a desirable finding (Dienlin et al., 2021). To FAIRly and openly share this study’s artefacts, the FAIR Guiding Principles were used (Wilkinson et al., 2016). The Principles are foundational to open research, and concern the degree to which research artefacts are Findable, Accessible, Interoperable, and Reusable (Ayrís et al., 2018). For example, artefacts were uploaded to OSF (enhancing Accessibility as well as openness), where they were automatically assigned unique and persistent identifiers (enhancing Findability). Artefacts were shared in non-proprietary file formats (e.g., plain-text) and linked to the pre-print of this paper (enhancing Interoperability). Finally, artefacts were licensed for reuse (enhancing Reusability). The use of systematic methods meant this study was undertaken more rigorously whereas the use of open research practices also increased transparency, as well as provide others with an opportunity to verify and extend the presented findings.

One limitation of this study concerns its susceptibility to selection bias. The majority of respondents identified as ECRs, and reported primarily using quantitative data, being involved in psychological research, and having pre-registered before. Consequently, the presented findings may not fairly reflect the experiences of those in the mid-to-late stages of their careers, those primarily using qualitative, or qualitative and quantitative data, those from other disciplines, or those who have not pre-registered before. However, similar to Sarafoglou et al. (2021), who also delivered a questionnaire assessing barriers and enablers to pre-registration, it appears that recruiting respondents who have not pre-registered before for a study concerning pre-registration is challenging. To overcome this limitation, follow-up studies could employ random sampling. Nevertheless, the presented findings are supported by past research addressing barriers and enablers to pre-registration.

Two further limitations concern not collecting demographic data on the nationality of respondents and not including stakeholders in the intervention specification development process. Relating to demographic data, collecting data on the nationality of respondents would have been useful because open research practices may differ between countries (e.g., some countries mandate certain open research

practices whereas others do not, thus influencing researcher motivation to undertake them; Schmidt et al., 2016). However, given the promotional methods used (i.e., Twitter posts from a UK-based account, direct emails to UK-based researchers, and emails sent from UK-based research organisations), we suspect that most respondents were UK-based. Therefore, these findings may be most applicable to UK-based researchers. Relating to stakeholder inclusion, this would have been valuable and especially when using the APEASE criteria (see, Section 4.2.; West et al., 2019) to assess BCW recommendations when developing the intervention specification (see, Section 7.3.). Therefore, it would be useful to undertake follow-up research to assess how barriers and enablers to pre-registration may vary across countries, as well as to engage with stakeholders to assess and refine the presented specification.

Future research could extend this study in at least three ways. First, the presented barriers and enablers to pre-registration could be validated as part of a follow-up confirmatory study. Such a study could also extend the presented findings by recruiting a broader range of researchers to assess group differences. For example, assessing differences between different career stages, institutions, and countries.

Second, the presented intervention specification could be assessed, refined, and delivered. Stakeholder focus groups could be undertaken to assess the intervention specification using the APEASE criteria as well as contribute to its refinement (West et al., 2019). These focus groups could also be used to develop the intervention materials (ideally in collaboration with those who have already developed similar materials; see, Section 3.6.). Thereafter, the intervention could be piloted, further refined, and potentially delivered to multiple institutions to benefit from economies of scale (Munafò et al., 2022). However, it may first be useful to determine the extent to which barriers and enablers to pre-registration, as well as stakeholder APEASE assessments of the intervention itself (West et al., 2019), differ between career stage groups, institutions, and countries. If substantial differences are found, a more successful approach may be to tailor the intervention to these specific groups, institutions, and countries so that their individual needs can be accounted for.

Lastly, BCW could be applied to other open research behaviours and groups. Relating to other behaviours, a natural extension of this study is to explore how the uptake of the registered reports publishing format could be increased (Chambers et al., 2015). There would also be substantial value in exploring how the FAIRness and openness of research artefacts could be enhanced (Wilkinson et al., 2016); for example, European Commission (2018) estimates that the EU economy could generate an additional €26.2 billion per annum were its researchers to produce FAIRer data artefacts. However, there are numerous other open research behaviours that could also be considered. Relating to groups, we note an opportunity to explore how behaviour change may be applied to behaviour change researchers. Such meta-behaviour change could create a reinforcing feedback loop whereby the optimisation of behaviour change researcher behaviour further optimises their behaviour and so on. Such a loop could have positive consequences; for example, enhancing the potential of behaviour change researchers to effectively address the individual, societal, and global problems their research is dedicated to. Excitingly, this is presently being explored by this study's first author in relation to how the FAIR Guiding Principles may be used to optimise the reusability of behaviour change artefacts. Alternatively, the behaviour of other important research stakeholders, for example, those working for funders, publishers, and institutions, could also be considered. In summary, behaviour change has strong potential to facilitate the uptake of open research practices and so contribute to enhanced research outcomes.

## 9. Conclusion

This appears to be the first paper to demonstrate how a framework and model of behaviour change can be used to develop an intervention specification to facilitate an open research practice, using pre-registration as an example. We hope this research inspires others to explore the strong potential of behaviour change to contribute to enhanced research outcomes. We further hope that any such exploration is undertaken in a way that not only supports researchers in their desire to produce high-quality research, but in a way that benefits them individually as well as collectively.

### Funding

This research was performed without funding.

### Author details

Christopher Osborne<sup>1</sup>

E-mail: [christopher.osborne@anthro.ox.ac.uk](mailto:christopher.osborne@anthro.ox.ac.uk)

ORCID ID: <http://orcid.org/0000-0003-4664-7144>

Emma Norris<sup>2</sup>

ORCID ID: <http://orcid.org/0000-0002-9957-4025>

<sup>1</sup> Institute of Human Sciences, School of Anthropology and Museum Ethnography, University of Oxford, UK.

<sup>2</sup> Health Behaviour Change Research Group, Department of Health Sciences, Brunel University London, London, UK.

### Data availability statement

The data described in this article are openly available in the Open Science Framework at <http://osf.io/ev8jw>.

### Open Scholarship



This article has earned the Center for Open Science badges for Open Data, Open Materials and Preregistered. The data and materials are openly accessible at <https://osf.io/dfcem/>, <https://doi.org/10.17605/osf.io/dfcem> and <https://osf.io/9pvn6>.

### Disclosure statement

Both authors are open research advocates. CO is undertaking a PhD part-funded by the UK Reproducibility Network (UKRN). EN is a UKRN Local Network Lead at Brunel University London.

### Author contributions

CO and EN conceptualised the study, developed the methodology and materials, wrote the original draft, and reviewed and edited the final version. CO curated the data, led the investigation, project management, formal analysis, validation, and visualisation. EN supervised the project.

### Data availability statement

All data and materials for this project are available: <https://doi.org/10.17605/osf.io/dfcem>

### Citation information

Cite this article as: Pre-registration as behaviour: developing an evidence-based intervention specification to increase pre-registration uptake by researchers using the Behaviour Change Wheel, Christopher Osborne & Emma Norris, *Cogent Psychology* (2022), 9: 2066304.

### References

- Ayris, P., López de San Román, A., Maes, K., & Labastida, I. (2018). Open science and its role in universities: A roadmap for cultural change. Leuven: LERU Office. Retrieved February, 20, 2022.
- Baker, M. (2016). 1,500 scientists lift the lid on reproducibility. *Nature*, 533(26), 353–366. <https://doi.org/10.1038/533452a>
- Bakker, M., Veldkamp, C. L., van Assen, M. A., Crompvoets, E. A., Ong, H. H., Nosek, B. A., Wicherts, J. M., Wicherts, J. M., & Soderberg, C. K. (2020). Ensuring the quality and specificity of preregistrations. *PLoS Biology*, 18(12), e3000937. <https://doi.org/10.1371/journal.pbio.3000937>
- Becker, H. S. (1998). *Tricks of the trade*. University of Chicago.
- Bishop, D. V. (2020). The psychology of experimental psychologists: Overcoming cognitive constraints to improve research: The 47th Sir Frederic Bartlett Lecture. *Quarterly Journal of Experimental Psychology*, 73(1), 1–19. <https://doi.org/10.1177/1747021819886519>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Braun, V., Clarke, V., Hayfield, N., & Terry, G. (2019). Thematic analysis. In P. Liamputtong (Ed.), *Handbook of research methods in health social sciences*. Springer. [https://doi.org/10.1007/978-981-10-5251-4\\_103](https://doi.org/10.1007/978-981-10-5251-4_103)
- Byrne, D. (2021). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality & Quantity*, 1–22.
- Camerer, C. F., Dreber, A., Forsell, E., Ho, T. H., Huber, J., Johannesson, M., Kirchler, M., Almenberg, J., Altmejd, A., Chan, T., Heikensten, E., Holzmeister, F., Imai, T., Isaksson, S., Nave, G., Pfeiffer, T., Razen, M., & Wu, H. (2016). Evaluating replicability of laboratory experiments in economics. *Science*, 351(6280), 1433–1436. <https://doi.org/10.1126/science.aaf0918>
- Cane, J., O'Connor, D., & Michie, S. (2012). Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implementation Science*, 7(1), 1–17. <https://doi.org/10.1186/1748-5908-7-37>
- Chambers, C. D., Dienes, Z., McIntosh, R. D., Rotshtein, P., & Willmes, K. (2015). Registered reports: Realigning incentives in scientific publishing. *Cortex*, 66, A1–A2. <https://doi.org/10.1016/j.cortex.2015.03.022>
- Chambers, C. D., & Tzavella, L. (2021). The past, present and future of registered reports. *Nature Human Behaviour*, 1–14.
- Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: The new medical research council guidance. *BMJ (Clinical Research Ed.)*, 337. <https://doi.org/10.1136/bmj.a1655>
- Crüwell, S., van Doorn, J., Etz, A., Makel, M. C., Moshontz, H., Niebaum, J. C., Orben, A., Parsons, S., & Schulte-Mecklenbeck, M. (2019). Seven easy steps to open science. *Zeitschrift für Psychologie*, 227(4), 237–248. <https://doi.org/10.1027/2151-2604/a000387>
- Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: A scoping review. *Health Psychology Review*, 9(3), 323–344. <https://doi.org/10.1080/17437199.2014.941722>
- Dienlin, T., Johannes, N., Bowman, N. D., Masur, P. K., Engesser, S., Kümpel, A. S., Lukito, J., Bier, L. M., Zhang, R., Johnson, B. K., Huskey, R., Schneider, F. M., Breuer, J., Parry, D. A., Vermeulen, I., Fisher, J. T., Banks, J., Weber, R., Ellis, D. A., ... De Vreese, C. (2021). An agenda for open science in communication. *Journal of Communication*, 71(1), 1–26. <https://doi.org/10.1093/joc/jqz052>
- Edwards, M. A., & Roy, S. (2017). Academic research in the 21st century: Maintaining scientific integrity in a climate of perverse incentives and hypercompetition. *Environmental Engineering Science*, 34(1), 51–61. <https://doi.org/10.1089/ees.2016.0223>
- European Commission. (2018). Cost-benefit analysis for FAIR research data: Cost of not having FAIR research data. Publications Office. <https://data.europa.eu/doi/10.2777/02999>
- Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). Sage.
- Hardwicke, T. E., Thibault, R. T., Kosie, J., Wallach, J. D., Kidwell, M. C., & Ioannidis, J. (2021). Estimating the prevalence of transparency and reproducibility-related research practices in

- psychology (2014–2017). *Perspectives on Psychological Science*. <https://doi.org/10.1177/2F1745691620979806>
- Higginson, A. D., & Munafò, M. R. (2016). Current incentives for scientists lead to underpowered studies with erroneous conclusions. *PLoS Biology*, 14(11), e2000995. <https://doi.org/10.1371/journal.pbio.2000995>
- Kaplan, R. M., Irvin, V. L., & Garattini, S. (2015). Likelihood of null effects of large NHLBI clinical trials has increased over time. *PLoS one*, 10(8), e0132382. <https://doi.org/10.1371/journal.pone.0132382>
- Kathawalla, U. K., Silverstein, P., & Syed, M. (2021). Easing into open science: A guide for graduate students and their advisors. *Collabra: Psychology*, 7(1).
- Kerr, N. L. (1998). HARKing: Hypothesizing after the results are known. *Personality and Social Psychology Review*, 2(3), 196–217. [https://doi.org/10.1207/s15327957pspr0203\\_4](https://doi.org/10.1207/s15327957pspr0203_4)
- Kidwell, M. C., Lazarević, L. B., Baranski, E., Hardwicke, T. E., Piechowski, S., Falkenberg, L. S., Nosek, B. A., Sonnleitner, C., Hess-Holden, C., Errington, T. M., Fiedler, S., Nosek, B. A., & Kennett, C. (2016). Badges to acknowledge open research practices: A simple, low-cost, effective method for increasing transparency. *PLoS Biology*, 14(5), e1002456. <https://doi.org/10.1371/journal.pbio.1002456>
- Klein O et al. (2018). A Practical Guide for Transparency in Psychological Science. *Collabra: Psychology*, 4(1), 10.1525/collabra.15810.1525/collabra.158.pr
- Lindsay, D. S., Simons, D. J., & Lilienfeld, S. O. (2016). Research preregistration 101. *APS Observer*, 29(10), 23–25. <https://www.psychologicalscience.org/observer/research-preregistration-101>
- Marques, M. M., Carey, R. N., Norris, E., Evans, F., Finnerty, A. N., Hastings, J., Jenkins, E., Johnston, M., West, R., & Michie, S. (2021). Delivering behaviour change interventions: development of a mode of delivery ontology. *Wellcome Open Research*, 5(125), 125. <https://doi.org/10.12688/wellcomeopenres.15906.2>
- Michie, S., Atkins, L., & West, R. (2014). *The Behaviour Change Wheel: A guide to designing interventions*. Silverback Publishing.
- Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., ... Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus of the reporting of behavior change interventions. *Annals of Behavioral Medicine*, 46(1), 81–95. <https://doi.org/10.1007/s12160-013-9486-6>
- Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, 6(1), 42. <https://doi.org/10.1186/1748-5908-6-42>
- Munafò, M. R., Chambers, C., Collins, A., Fortunato, L., & Macleod, M. (2022). The reproducibility debate is an opportunity, not a crisis. *BMC Research Notes*, 15(1), 1–3. <https://doi.org/10.1186/s13104-022-05942-3>
- Munafò, M. R., Nosek, B. A., Bishop, D. V., Button, K. S., Chambers, C. D., du Sert, N. P., Simonsohn, U., Wagenmakers, E.-J., Ware, J. J., & Ioannidis, J. P. (2017). A manifesto for reproducible science. *Nature Human Behaviour*, 1(1), 0021. <https://doi.org/10.1038/s41562-016-0021>
- National Academies of Sciences, Engineering, and Medicine. (2019). Reproducibility and replicability in science.
- Nickerson, R. S. (1998). Confirmation bias: A ubiquitous phenomenon in many guises. *Review of General Psychology*, 2(2), 175–220. <https://doi.org/10.1037/1089-2680.2.2.175>
- Norris, E., He, Y., Loh, R., West, R., & Michie, S. (2021). Assessing markers of reproducibility and transparency in smoking behaviour change intervention evaluations. *Journal of Smoking Cessation*, 2021, 6694386. <https://doi.org/10.1155/2021/6694386>
- Norris, E., Marques, M. M., Finnerty, A. N., Wright, A. J., West, R., Hastings, J., Williams, P., Carey, R. N., Kelly, M. P., Johnston, M., & Michie, S. (2020). Development of an intervention setting ontology for behaviour change: Specifying where interventions take place. *Wellcome Open Research*, 5, 124. <https://doi.org/10.12688/wellcomeopenres.15904.1>
- Norris, E., & O'Connor, D. B. (2019). Science as behaviour: Using a behaviour change approach to increase uptake of open science. *Psychology & Health*, 12(34), 1397–1406.
- Norris, E., Wright, A. J., Hastings, J., West, R., Boyt, N., & Michie, S. (2021). Specifying who delivers behaviour change interventions: Development of an intervention source ontology. *Wellcome Open Research*, 6, 77. <https://doi.org/10.12688/wellcomeopenres.16682.1>
- Nosek, B. A., Ebersole, C. R., DeHaven, A. C., & Mellor, D. T. (2018). The preregistration revolution. *Proceedings of the National Academy of Sciences*, 115(11), 2600–2606. <https://doi.org/10.1073/pnas.1708274114>
- Nosek, B. A., Spies, J. R., & Motyl, M. (2012). Scientific utopia: II. Restructuring incentives and practices to promote truth over publishability. *Perspectives on Psychological Science*, 7(6), 615–631. <https://doi.org/10.1177/1745691612459058>
- O'Connor, D. B. (2021). Leonardo da Vinci, preregistration and the architecture of science: Towards a more open and transparent research culture. *Health Psychology Bulletin*, 5(1), 39–45. <http://doi.org/10.5334/hpb.30>
- Open Science Collaboration. (2015). Estimating the reproducibility of psychological science. *Science*, 349(6251), aac4716. <https://doi.org/10.1126/science.aac4716>
- Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS*. Routledge.
- Peters, U. (2020). What is the function of confirmation bias? *Erkenntnis*, 1–26. <https://doi.org/10.1007/s10670-020-00252-1>
- Ratray, J., & Jones, M. C. (2007). Essential elements of questionnaire design and development. *Journal of Clinical Nursing*, 16(2), 234–243. <https://doi.org/10.1111/j.1365-2702.2006.01573.x>
- Sarafoglou, A., Kovacs, M., Bakos, B. E., Wagenmakers, E. J., & Aczel, B. (2021). A survey on how preregistration affects the research workflow: Better science but more work.
- Schimmack, U. (2020). A meta-psychological perspective on the decade of replication failures in social psychology. *Canadian Psychology/Psychologie Canadienne*, 61(4), 364. <https://doi.org/10.1037/cap0000246>
- Schmidt, S. (2009). Shall we really do it again? The powerful concept of replication is neglected in the social sciences. *Review of General Psychology*, 13(2), 90–100. <https://doi.org/10.1037/a0015108>
- Schmidt, B., Gemeinholzer, B., Treloar, A., & Guralnick, R. (2016). Open data in global environmental research: The Belmont Forum's open data survey. *PLoS one*, 11(1), e0146695. <https://doi.org/10.1371/journal.pone.0146695>
- Serghiou, S., Contopoulos-Ioannidis, D. G., Boyack, K. W., Riedel, N., Wallach, J. D., & Ioannidis, J. P. (2021). Assessment of transparency indicators across the biomedical literature: How open is open? *PLoS Biology*, 19(3), e3001107. <https://doi.org/10.1371/journal.pbio.3001107>

- Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2011). False-positive psychology: Undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychological Science*, 22(11), 1359–1366. <https://doi.org/10.1177/0956797611417632>
- Stewart, S., Rinke, E. M., McGarrigle, R., Lynott, D., Lunny, C., Lautarescu, A., ... Crook, Z. (2020). Pre-registration and registered reports: A primer from UKRN. from <https://osf.io/8v2n7/download?format=pdf>
- Sullivan, I., DeHaven, A., & Mellor, D. (2019). Open and reproducible research on open science framework. *Current Protocols Essential Laboratory Techniques*, 18(1), e32. <https://doi.org/10.1002/cpet.32>
- Szollosi, A., Kellen, D., Navarro, D., Shiffrin, R., van Rooij, I., Van Zandt, T., & Donkin, C. (2019). Is preregistration worthwhile?
- West, R., Michie, S., Atkins, L., Chadwick, P., & Lorencatto, F. (2019). *Achieving behaviour change: A guide for local government and partners*. Public Health England. from [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/875385/PHEBI\\_Achieving\\_Behaviour\\_Change\\_Local\\_Government.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/875385/PHEBI_Achieving_Behaviour_Change_Local_Government.pdf)
- Wicherts, J. M., Veldkamp, C. L., Augusteijn, H. E., Bakker, M., Van Aert, R., & Van Assen, M. A. (2016). Degrees of freedom in planning, running, analyzing, and reporting psychological studies: A checklist to avoid p-hacking. *Frontiers in Psychology*, 1832.
- Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.-W., da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., ... Mons, B. (2016). The FAIR guiding principles for scientific data management and stewardship. *Scientific Data*, 3(1), 1–9. <https://doi.org/10.1038/sdata.2016.18>
- Williams, A. (2003). How to ... Write and analyse a questionnaire. *Journal of Orthodontics*, 30(3), 245–252. <https://doi.org/10.1093/ortho/30.3.245>



© 2022 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:

Share — copy and redistribute the material in any medium or format.

Adapt — remix, transform, and build upon the material for any purpose, even commercially.

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.

You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

No additional restrictions

You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.



**Cogent Psychology (ISSN: 2331-1908) is published by Cogent OA, part of Taylor & Francis Group.**

**Publishing with Cogent OA ensures:**

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

**Submit your manuscript to a Cogent OA journal at [www.CogentOA.com](http://www.CogentOA.com)**

