

Pre-registration: Weighing costs and benefits for researchers[☆]

Jennifer M. Logg^{a,*}, Charles A. Dorison^b

^a McDonough School of Business, Georgetown University, United States

^b Kellogg School of Management, Northwestern University, United States

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ABSTRACT

In the past decade, the social and behavioral sciences underwent a methodological revolution, offering practical prescriptions for improving the replicability and reproducibility of research results. One key to reforming science is a simple and scalable practice: pre-registration. Pre-registration constitutes pre-specifying an analysis plan prior to data collection. A growing chorus of articles discusses the prescriptive, field-wide benefits of pre-registration. To increase adoption, however, scientists need to know who currently pre-registers and understand perceived barriers to doing so. Thus, we weigh costs and benefits of pre-registration. Our survey of researchers reveals generational differences in who pre-registers and uncertainty regarding how pre-registration benefits individual researchers. We leverage these data to directly address researchers' uncertainty by clarifying why pre-registration improves the research process itself. Finally, we discuss how to pre-register and compare available resources. The present work examines the *who*, *why*, and *how* of pre-registration in order to weigh the costs and benefits of pre-registration to researchers and motivate continued adoption.

1. Introduction

Social and behavioral science underwent a methodological revolution from 2010 to 2020 with an increasing focus on the replicability and reproducibility of research results. Scientists challenged bedrock theories of self-control, priming, affect, and memory (e.g., Hagger et al., 2016; Ranehill et al., 2015; Doyen, O'Klein, Pichon, & Cleeremans, 2012; Lucas & Lawless, 2013; Alogna et al., 2014; Cheung, Campbell, & LeBel, 2016; Wagenmakers et al., 2016). They questioned conventional (yet often detrimental) research practices, including determining statistical analyses after data collection, ignoring experimental conditions that produced null results, and flexibility around when to stop collecting data (Simmons, Nelson, & Simonsohn, 2011; John, Loewenstein, & Prelec, 2012; Button et al., 2013; Vul, Harris, Winkielman, & Pashler, 2009). As a result, the field overturned scientific norms (e.g., Eich, 2014; Vazire, 2016; Lindsay, 2015, 2017; Benjamin et al., 2018; Lakens et al., 2018) and began establishing new ones, including an increased emphasis on effect sizes and Bayesian statistics (Nosek et al., 2018; Nelson, Simmons, & Simonsohn, 2018; Lindsay, 2019; Munafò et al., 2017). It is not hyperbolic to describe the last decade's progress toward open science as a "scientific revolution," as originally coined by Kuhn (1962).

This methodological revolution calls for greater transparency in how science is conducted, a reform often called "open science" (for reviews,

see Camerer et al., 2018; Open Science Collaboration, 2015; Lindsay, 2019; for an alternative point of view, see Gilbert, King, Pettigrew, & Wilson, 2016). Individuals can easily contribute to open science by publicly posting three items with their published papers: data, study materials, and pre-registrations. Pre-registration, the focus of the current article, documents one's analysis plan. In a pre-registration document, the researcher specifies the design, sample size, hypotheses, and planned statistical analyses of a study or data set (Simmons, Nelson, & Simonsohn, 2017). This paper empirically identifies how researchers view pre-registration and then clarifies how it can benefit their own individual work.

1.1. What problems does pre-registration solve?

Pre-registration is a low-cost, scalable intervention with high potential benefit both for the field and individual researchers. In particular, it allows researchers to delineate between confirmatory analyses (testing predictions) and exploratory analyses (generating predictions for future testing). For example, a researcher may conduct an exploratory analysis within a dataset of negotiation outcomes and inspect whether the focal actor's confidence in their negotiation skills is related to any one of the other thirty measures collected. For *exploratory* analyses, predictions are *data-dependent*. A researcher conducts a

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* Corresponding author at: McDonough School of Business, Georgetown University, 3700 O St NW, Washington, DC 20057, United States.

confirmatory analysis when predicting that greater confidence correlates with higher first offers, collects data to test that prediction, and then analyzes the correlation. For *confirmatory* analyses, predictions are *data-independent* because predictions are made a priori.

1.2. Conflating exploratory vs. confirmatory analyses

In many cases, running exploratory analyses makes sense but the issues arise when confirmatory and exploratory analyses are conflated. Then, researchers may overstate the likelihood that a given pattern of results will replicate in the future. In these cases, researchers are unable to differentiate between a “true” effect that is likely to replicate and an effect due to statistical anomaly. When this occurs, problematic research practices (such as p-hacking, which we discuss below) become more difficult to identify. As [Vazire \(2018\)](#) points out, open science practices such as pre-registration don’t necessarily ensure research quality; however, they do increase the probability that research receives the credibility it deserves.

The issue of conflating these two types of analyses is exacerbated by a reliance on tools designed for confirmatory analyses and an incentive within the research publication process that prioritizes the discovery of novel results (e.g., Null Hypothesis Significance Testing; [Cumming, 2014](#)). Further complicating the issue, current publishing practices may incentivize researchers to describe exploratory analyses as confirmatory in order to increase the probability of their research passing the peer-review process ([Nosek, Spies, & Motyl, 2012](#)).

While scientists have long endorsed delineating between these two types of analyses, until recently, blending the two was viewed as a relatively minor transgression, akin to jaywalking (e.g., [Simmons, Nelson, & Simonsohn, 2011](#); [Nelson et al., 2018](#)). Many researchers have come to appreciate that the consequences are much more serious. More so than other practices (e.g., the classic “file drawer” problem of selectively publishing significant results), conflating confirmatory and exploratory analyses dramatically increases the probability of false positive results ([Simonsohn, Nelson, & Simmons, 2014](#)).

1.3. Pre-registration is a solution

Pre-registration can alleviate this problem in at least two ways. First, pre-registration safeguards against p-hacking, the selective reporting of statistically significant confirmatory analyses ([Simmons et al., 2017](#)). In doing so, pre-registration increases confidence that the reported confirmatory analyses were not cherry-picked from a broader set. Second, pre-registration defends against misinterpreting exploratory results as confirmatory ones – i.e., Hypothesizing After Results are Known, or “HARKing” ([Kerr, 1998](#)). This increases confidence that results reported as confirmatory were hypothesized before data analysis. By reducing (although not always eliminating) p-hacking and HARKing, pre-registration helps researchers maintain an endorsed 5% false positive rate for published confirmatory findings ([Nelson et al., 2018](#)).

Pre-registration thus benefits both the field as well as individual researchers in the search for truth. In theory, results from pre-registered analyses should have a higher likelihood of replication ([Nosek et al., 2018](#)). And individual researchers thus should benefit from others successfully building on their work. Moreover, replicable effects provide a better opportunity for the social and behavioral sciences to achieve greater cumulative knowledge more quickly.

2. Current work: Who, why, how

The main goal of this paper is to empirically identify the potential costs and benefits researchers think pre-registration holds for their

research process. While a growing literature investigates *prescriptive* benefits of pre-registration for the field of social and behavioral science (for reviews, see [Nosek et al., 2018](#); [Nelson et al., 2018](#)), to increase adoption of pre-registration, scientists additionally need to identify:

- 1) *Who* currently pre-registers?
- 2) *Why* are some researchers reluctant to incorporate pre-registration into their research process?
- 3) *How* can a researcher create a pre-registration?

We examined adoption rates, both from a six-year period in *Organizational Behavior and Human Decision Processes (OBHDP)* and from a survey of 248 active behavioral science researchers, which we call our “Researcher Survey.” In our Researcher Survey, we made two comparisons:

- 1) the *descriptive* reality of adoption across generations and
- 2) researchers’ perceptions of the *individual-level* costs of pre-registration with their actual benefits.

Our results reveal both generational differences in adoption as well as uncertainty regarding the individual-level benefits of pre-registration.

In the main section of our paper, we address uncertainty identified in the Researcher Survey by clarifying how pre-registration benefits individual researchers. The arguments we address are applicable to a broad audience, from graduate students to tenured faculty, from those considering whether to pre-register for the first time to those who currently pre-register but want to persuade their collaborators to do the same. Finally, we discuss how to pre-register and compare available resources.

There is growing acknowledgment in social and behavioral science that pre-registration is a healthy development for the field as a whole. This article sheds light on the descriptive realities of pre-registration at the level of the individual researcher. Further, it provides researchers prescriptive reasons to leverage pre-registration to improve their research practices and a practical roadmap for how to pre-register.

3. Relative adoption rates of open science in OBHDP

Open science is needed to improve science. But do adoption rates within the behavioral sciences reflect its importance? Or could researchers’ uncertainty around the individual benefits of pre-registration slow adoption? For instance, even if researchers see the benefit of open science for the field, they may hesitate to pre-register if they are uncertain about how it affects their research process. We compared adoption rates between three open science practices in recently published articles of *OBHDP*. Two research assistants coded all 322 empirical articles published in *OBHDP* in the six-year period from 2015 to 2020 based on the access each provided to pre-registrations, open data, and survey materials (see the supplement for the dataset that details each article).

Cumulatively from 2015 to 2020, 32% of published papers in *OBHDP* provided data, 22% provided materials, and only 10% provided pre-registrations. These percentages suggest that adoption of pre-registration lags behind adoption of the other two practices. In fact, published papers were more than two times as likely to include materials as pre-registrations (22% vs. 10%) and three and a half times as likely to include data as pre-registrations (32% vs. 10%).

Over time, the percentage of published papers that included data steadily increased (see [Fig. 1](#)) while papers providing materials increased less dramatically, until 2020. Finally, the percentage of papers including pre-registrations increased very little from 2015 to 2018 and only started to increase in 2019, but less gradually relative to the percentage of papers with materials. An independent analysis of articles

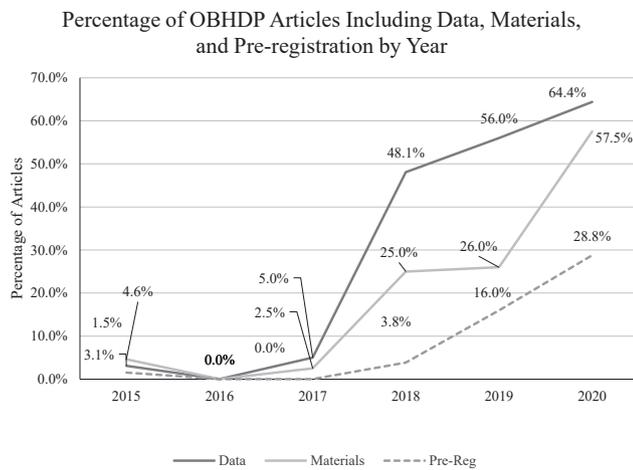


Fig. 1. While adoption of pre-registration has increased dramatically in recent years, it still lags behind posting data and posting materials.

published in other management and psychology journals revealed similar temporal dynamics (Lindsay, 2019; see also in this special issue, Tenney, Costa, Allard, & Vazire, 2021). While adoption of pre-registration initially lagged behind the other practices, it recently experienced a dramatic uptick in growth.

Might pre-registration lag because of the inherent time delay between researchers learning about pre-registration and their adoption reflected in published papers or will it continue to lag due to uncertainty about how it benefits their own research process? For example, a researcher may have started pre-registering studies and posting data and materials in 2016. While articles beginning in 2016 might include posted data and materials, the pre-registered experiments might not show up in published articles until 2019 due to the inevitable lag between study completion and publication. Indeed, results from our Researcher Survey (in the next section) provide initial support for this possibility: while only 21% of respondents reported having published work with pre-registrations, 50% reported currently pre-registering for unpublished projects. Thus, while the medical sciences have long used pre-registration, it appears that the social and behavioral sciences are poised at the beginning of a pre-registration revolution (Nosek et al., 2018).

4. Who pre-registers? Researcher Survey

Next, we examined *who* currently pre-registers and how researchers think about pre-registration. First, similar to our examination of published papers, we compared current adoption of pre-registration to posting data and materials. This comparison examines whether the field can expect pre-registration to continue to lag behind other open science practices. Second, we compared generational differences in adoption. We predicted that early-career researchers create more pre-registrations than their senior colleagues. Third, and perhaps most importantly, we measured researchers' perceptions of the potential costs and benefits of pre-registration for their own research.

For the Researcher Survey, we report how we determined our sample size and all measures. We do not exclude any data. Our descriptive survey does not include a manipulation. Pre-registration, materials, and data are posted as a supplement online at the Open Science Framework: (https://osf.io/ykh3v/?view_only=6e018ffaf5064c808fa3fc5b84e5761a).

4.1. Method

4.1.1. Participants

The final sample included 248 active social and behavioral science researchers. To ensure higher responses overall, we did not require responses to every question. Thus, sample size varies by question. We

recruited researchers through multiple email lists and an academic discussion board related to the social and behavioral sciences¹ by asking them to "Give your opinion on a variety of research practice topics." We purposely did not include any wording related to "open science." Researchers were told that their participation would enter them into a raffle to win a \$200 Amazon gift card. Of those who noted their position (16% did not), the majority were graduate students and postdocs (44% total; students: 33%, postdocs: 11%) or tenure-track faculty currently without tenure (33%). Most had backgrounds in management and organizational behavior (27%) or psychology (35%). See Table A1 (field) and Table A2 (academic position) in the Appendix.

4.1.2. Procedure

Researchers reported their current research practices, their thoughts on pre-registration, and demographics. Building on our analyses of papers published in *OBHDP*, we first assessed uptake of open science practices. We asked researchers to report whether they had ever posted data, materials, or pre-registrations online. Additionally, we asked researchers to estimate their total number of published papers and the percentage of those papers that included data, materials, or pre-registrations. This second question allowed for a direct comparison between the Researcher Survey data and our analysis of papers published in *OBHDP*.

Next, we measured how positively or negatively researchers viewed pre-registration by creating a 'sentiment score.' Researchers read 14 statements and indicated whether they agreed, disagreed, or were uncertain about each; 6 were benefits (e.g., "Pre-registration helps clarify ideas before running a study"), 6 were costs (e.g., "Pre-registration adds substantial work to the research process"), and 2 were neutral (e.g., "Pre-registrations are automatically made public"). These measures allowed us to calculate the percentage of positive and negative beliefs each researcher held.

As pre-registered, we removed the neutral statements. Then, we computed the sentiment score for each of the 12 remaining items. For the 6 positive statements, if a researcher agreed, their response was coded as a "1;" if they were unsure or disagreed, their response was coded as a "0." For the 6 negative statements, if a researcher agreed, their response was coded as a "-1;" if they were unsure or disagreed, their response was coded as a "0." Thus, we summed those responses such that scores ranged from -6 to 6, with 0 being neutral.

Finally, researchers predicted who currently creates pre-registration documents (e.g., graduate students, postdocs, tenured faculty, etc.) and reported their own academic position and field of study. For additional questions not reported here, see the materials in the online supplement.

4.2. Results

4.3. "Who": Who adopts pre-registration (and other open science practices)?

4.3.1. Published work

Our survey results are consistent with our analysis of published papers in *OBHDP*. Here, 222 researchers estimated their total number of published papers ($M = 15$, $Mdn = 5$), which ranged from 0 ($n = 25$) to 180 ($n = 2$). Researchers reported that a higher percentage of their published papers included data (43%) and materials (41%) than pre-registrations (21%) (Data vs. Materials: $\chi^2(1) = 0.048$, $p = .827$; Pre-Registration vs. Materials: $\chi^2(1) = 6.45$, $p = .011$; Pre-registration vs. Data: $\chi^2(1) = 7.56$, $p = .006$; omnibus: $\chi^2(2) = 8.46$, $p = .015$). While

¹ We posted the survey link to the Academy of Management's Managerial and Organizational Cognition Division Board and following email listservs: International Association for Conflict Management, Judgment and Decision Making, and Harvard Behavioral Insight Group's Doctoral Workshop.

Table 1
Adoption rates for pre-registration and coding scheme.

| Response | Coded as personally pre-registering | Percentage (count) |
|---|-------------------------------------|--------------------|
| Yes, I personally have | Y | 35% (82) |
| Yes, I have AND so has a collaborator | Y | 15% (35) |
| Yes, a collaborator has for our shared project but I have not | N | 5.6% (13) |
| No, know the term pre-registration | N | 32.5% (76) |
| No, do NOT know the term pre-registration | N | 12% (28) |
| | | Total: 234 |

Table 2
Adoption rates for each practice by researchers' career stage.

| Career status | Data | Materials | Pre-Reg |
|--------------------------|-----------|-----------|-----------|
| Junior researchers | 63% (58) | 53% (49) | 66% (61) |
| Tenure-track faculty | 62% (43) | 42% (29) | 51% (35) |
| Tenured faculty | 41% (14) | 44% (15) | 29% (10) |
| Across generations (195) | 59% (115) | 48% (93) | 54% (106) |

base rates were higher than in the papers published in *OBHDP* (13% for data, 7% for materials, and 3% for pre-registration), the pattern remains the same: pre-registration lags behind other open science practices in published work.

4.3.2. *Current adoption*

Next, we examined their research pipeline (i.e., unpublished projects). About half of the 234 researchers claimed they had adopted each of the practices, with 54% ($n = 126$) posting data, 43% ($n = 101$) posting materials, and 50% ($n = 117$) pre-registering.² This 50% of researchers who pre-register is reflected in the top two rows of [Table 1](#). Adoption rates neither differ between any of the practices, $ps > 0.096$, nor overall, omnibus: $\chi^2(2) = 2.80, p = .247$.

4.3.3. *Generational differences*

We next investigated generational differences in adoption of pre-registration, predicting that early-career researchers would not only hold more positive attitudes toward pre-registration, but also would pre-register more frequently. We pre-registered creating the following categories of generational groups: (1) Graduate Students and Postdoctoral fellows, called Junior Researchers (47%; $n = 92$), (2) Tenure-Track faculty (currently untenured, 35%; $n = 69$), and (3) Tenured faculty (17%; $n = 34$). This excludes teaching faculty who likely run fewer experiments ($n = 4$), individuals who chose the “other” response ($n = 9$, including mostly undergraduate students and retirees), and those who did not categorize their academic position ($n = 26$).

There are generational differences in pre-registration, omnibus: $\chi^2(2) = 14.19, p = .001$. More junior researchers pre-register (66%) than both tenure-track faculty (51%), $\chi^2(1) = 3.98, p = .046$, and tenured faculty (29%), $\chi^2(1) = 13.74, p < .001$ (see [Table 2](#), column 4).³ There are more tenure-track faculty than tenured faculty who pre-register, 29%, $\chi^2(1) = 4.21, p = .04$.

There are fewer tenured faculty posting data than both junior researchers, $\chi^2(1) = 4.85, p = .028$ and tenure track faculty, $\chi^2(1) = 4.12, p = .042$. But just as many junior researchers post data as tenure track faculty, $\chi^2(1) = 0.009, p = .925$. However, there are no generational differences in posting materials, $ps > 0.16$; omnibus: $\chi^2(2) = 2.21, p = .332$. These results are relatively optimistic in that these trends are likely

² As pre-registered, we combined answers for “I personally have” and “I have AND so has a co-author” to count as “yes” responses. All other responses, including “Yes, a collaborator has for our shared project but I have not” counted as a “no.”

³ Although 234 researchers reported adoption of practices, note that 195 researchers reported their career status, the sample in [Table 2](#).

Table 3
Researchers' predictions about who creates pre-registration documents.

| Career status | Percentage expecting creation of pre-reg |
|---------------------|--|
| Grad student | 55.1% (108) |
| Postdoctoral fellow | 20.9% (41) |
| Assistant professor | 17.3% (34) |
| Associate professor | 3.6% (7) |
| Full professor | 3.1% (6) |
| Total | 196 |

to fuel adoption of pre-registration. As younger researchers progress in their careers, they will likely train their own students to pre-register.

4.3.4. *Predicting who pre-registers*

When eliciting predictions from researchers, we provided a more granular breakdown of career status and asked them to select only one. Researchers expected generational differences for who creates the pre-registration document, $\chi^2(4) = 176.09, p < .001$ (see [Table 3](#)). More than half of the researchers expected graduate students to create pre-registrations, compared to 21% of postdoctoral fellows, $\chi^2(1) = 30.13, p < .001$.

Just as many researchers predicted that postdoctoral fellows and assistant professors were creating the document, $\chi^2(2) = 0.65, p = .419$. Fewer researchers chose associate professors than assistant professors, $\chi^2(2) = 17.78, p < .001$. In a similar question that did not require selection of one option, the majority of researchers selected graduate students (87%) and postdocs (89%). See [Table A3](#) in the Appendix.

4.4. *“Why”: What are researchers' perceptions of pre-registration?*

4.4.1. *Perceived costs and benefits of pre-registration*

Researchers viewed pre-registration positively overall. Averaging across agreement with positive statements and negative statements about pre-registration, more researchers agreed with the positive statements (56%) than the negative statements, (18%), $\chi^2(1) = 19.51, p < .001$. Next, we examined a generational gap in perceptions of pre-registration.

4.4.2. *Generational differences in perceptions of pre-registration*

Our sentiment score ranged from -6 (agreed with 6 negative statements and 0 positive statements) to 6 (agreed with 6 positive statements and 0 negative statements). Junior researchers had higher sentiment scores than tenure-track faculty, $\chi^2(10) = 26.84, p = .003$, and tenured faculty, $\chi^2(10) = 29.59, p = .001$. The tenure-track and tenured faculty did not differ from each other, $\chi^2(10) = 17.02, p = .074$. (Researchers'

Table 4
Perceived costs versus benefits of pre-registration.

| Statement | Agree | Unsure | Disagree | N = |
|--|-------------|-------------|-------------|-----|
| Negative | | | | |
| Pre-registration means there is no room for exploratory analyses | 8.4% (18) | 23.3% (50) | 68.4% (147) | 215 |
| Pre-registration adds substantial work to the research process | 37.5% (81) | 32.9% (71) | 29.6% (64) | 216 |
| Pre-registration is a waste of time | 9.3% (20) | 23.1% (50) | 67.6% (146) | 216 |
| Pre-registration is not worth it if the analysis is obvious | 12.6% (27) | 22.8% (49) | 64.7% (139) | 215 |
| Pre-registration does not contribute much to the field | 15% (32) | 25.5% (54) | 59.8% (128) | 214 |
| Pre-registration produces low benefits to me individually | 24.2% (52) | 34.9% (75) | 40.9% (88) | 215 |
| Positive | | | | |
| Pre-registration helps clarify ideas before running a study | 79% (169) | 17.3% (37) | 3.7% (8) | 214 |
| Pre-registration frontloads work in relation to writing up results | 50.2% (108) | 35.8% (77) | 14% (30) | 215 |
| Pre-registration helps communication between collaborators | 54% (116) | 33.5% (72) | 12.6% (27) | 215 |
| Pre-registration can save me money as an individual researcher | 11.2% (24) | 52.1% (112) | 36.7% (79) | 215 |
| Pre-registration can help in training new researchers | 68.2% (146) | 26.2% (56) | 5.6% (12) | 214 |
| Pre-registration can help signal to others that I do not p-hack | 73.1% (158) | 17.1% (37) | 9.7% (21) | 216 |
| Neutral | | | | |
| Only junior researchers pre-register | 10.6% (23) | 31.5% (68) | 57.9 (125) | 216 |
| Pre-registrations are automatically made public | 11.1% (24) | 38.9% (84) | 50% (108) | 216 |

scores ranged from -5 to 6; Junior: $M = 3.05, SD = 2.12$; Tenure Track: $M = 2.04, SD = 2.19$; Tenured: $M = 1.12, SD = 2.82$). Again, early career scholars' relatively more positive view of pre-registration bodes well for increased adoption rates in the future.

4.4.3. *Uncertainty about individual-level cost and benefits of pre-registration*

Importantly, despite researchers' general positivity toward pre-registration, they were uncertain about its benefits. For instance, consensus was low about pre-registration adding work to the research process (38% agreed and 33% were uncertain; Table 4, statement 2). Additionally, researchers were especially uncertain as to whether pre-registration produces low benefits to the individual researcher (24% agreed and 35% were uncertain; see Table 4, statement 6). To view this same table sorted by highest to lowest uncertainty, please see Table A4 in the Appendix.

4.5. *Discussion*

Our results revealed two key insights. First, we find generational differences: early-career researchers both hold more positive views of pre-registration and are more likely to currently pre-register. Second, despite generally positive views of pre-registration, researchers are uncertain about potential costs and benefits to their own research process. Researchers are especially uncertain about 1) the amount of additional work pre-registration requires and 2) its benefits to them personally.

Table 5
Perceived costs versus benefits of pre-registration.

| | Perceived costs of pre-registration | Potential benefits of pre-registration |
|----|--|---|
| | Limits freedom | Increases freedom |
| 1 | Odysseus Fallacy: "Doesn't pre-registration limit my freedom to explore data?" | Pre-registration can actually increase freedom Strengthens new projects by making early data collection more informative |
| | Decreases efficiency | Increases efficiency |
| 2A | "Analysis is obvious, why document?" | Requiring specificity encourages clarity of thought Specificity counteracts researchers' own cognitive biases |
| 2B | "Analysis is obvious, why discuss?" | Improves communication Improves mentorship Improves efficiency |
| | Incurs a High Opportunity Cost | Costs are Overestimated |
| 3A | "Doesn't it add work to the research process?" | Changes order of work Can save money |
| | | Signals High Likelihood of Replicability |
| 3B | "If others may not pre-register; why should I?" | Pre-registration is a meaningful signal to reviewers |

Next, we specifically address researchers' biggest uncertainty regarding pre-registration: its benefits to individuals.

5. **Why should researchers pre-register? Costs vs. benefits**

First, we focus on two commonly voiced concerns about pre-registration. We suggest that these concerns are actually reasons *in favor* of it: freedom and efficiency. One commonly perceived cost is that pre-registration limits researchers' freedom to explore data and unearth important discoveries they may not have predicted (1). Another is that pre-registering decreases efficiency (2A, 2B). Lastly, we address time spent creating the document (3A, 3B). See Table 5.

5.1. *Freedom*

5.1.1. *The Odysseus Fallacy*

The highest concern about cost in our Researcher Survey is the notion that pre-registration limits freedom of the individual researcher. This concern may invoke the canonical image of Odysseus "tying oneself to the mast." In Homer's *The Odyssey*, Odysseus limited his control over his future actions by tying himself to his ship's mast; all to avoid the temptation of the Sirens' song that would lead him away from his chartered course. Similarly, some researchers may question, "Doesn't pre-registration limit my freedom to explore data?"

5.1.2. Potential benefit: Pre-registration can increase freedom

This Odysseus Fallacy misinterprets the main goal of pre-registration, which is simply to document the decisions researchers make prior to data collection. Even with the most stringent pre-registration, researchers are free to conduct any analyses they like; it is a plan, not a prison. For example, researchers can include exploratory analyses without set predictions within their pre-registration. Pre-registration simply delineates between analyses that are confirmatory and those that are exploratory; including both in a pre-registration is possible. Even if a researcher runs an exploratory analysis that was not pre-registered or otherwise deviates from the pre-registered plan, they can report the analysis in the paper and merely note that it was not pre-registered. Making transparent any deviations from the plan allows reviewers and readers to evaluate those decisions and prevent them from incorrectly drawing inferential conclusions. Likely, this leads reviewers and editors to see the results as more modest, but also see the conclusions as more credible.

In fact, pre-registration allows them to conduct analyses that may have otherwise raised eyebrows, such as one-sided hypothesis tests, unconventional exclusion criteria, and optional stopping techniques (e.g., Lakens, 2014) without fear that readers will suspect p-hacking or analyses that are data-dependent. Without a time-stamped pre-registration, many researchers may view these analytic techniques as controversial. With a time-stamped pre-registration, such analytic techniques may still receive critique (e.g., for errors in reporting results; see Bakker & Wicherts, 2011; Brown and Heathers, 2017; Yamada, 2018), but not because they are a signal of potential p-hacking.

5.1.3. Potential benefit: Pre-registration strengthens new projects

Even for an experiment with solely exploratory analyses lacking any predictions, a researcher may include all of the dependent variables in the pre-registration and explicitly state which results are most theoretically or practically interesting (e.g., the survey in this paper). Pre-registering pilots can even save effort and money later on (which we detail in the section Opportunity Cost, 3A), increasing efficiency of the overall research process. For instance, if a researcher pre-registers a new study and finds an effect of their manipulation on three out of five dependent variables, they can include the study in the paper (null effects are also viable for inclusion in a paper). Many researchers may additionally run a self-replication with a sub-set of variables that produced an effect. Doing so allows them to gain confidence that the effect found in both studies is replicable and less likely due to statistical anomaly (i.e., a false positive). Likewise, pre-registering new projects provides transparency to ensure contradictory findings were not omitted and that other issues that arise from selective reporting are traceable.

5.2. Efficiency

5.2.1. 2A: The analysis is obvious; why document it?

First, some researchers may claim that an analytical strategy for an experiment is obvious and may assume that there are not many analytical choices.

5.2.2. Potential benefit: Pre-registration requires specificity which encourages clarity

Researchers must specify hypotheses and analytic plans at some point. Pre-registration requires that this specificity occurs prior to data collection, which encourages greater clarity earlier in the research process. Considering specific predictions and analyses by writing them down may spark ideas that would otherwise come to mind after data collection.

Specifying ideas earlier in the research process ideally leads researchers to iterate on predictions and analyses. Ultimately, these clarifications and iterations can improve the quality of surveys, allowing researchers to learn more from each set of results than they would otherwise. Further, merely thinking about how an audience may read a

pre-registration may encourage researchers to consider the appropriate analyses more carefully prior to data collection. Thus, documenting a plan encourages researchers to think more deeply and anticipate issues, such as flaws in study designs, that they might not have otherwise.

5.2.3. Potential benefit: Pre-registration helps counteract researchers' own cognitive biases

Researchers are human and thus fallible to cognitive biases. The specificity required by pre-registration helps counteract two cognitive biases: hindsight bias (the tendency to view events as more predictable after they have occurred) and the planning fallacy (underestimating how long a task takes to complete). Even if researchers have a clear idea of the analyses they plan to run when creating the experimental materials, they may fall prey to hindsight bias. In an ideal world, the researcher analyzes the data shortly after data collection. But as the title of Watts' (2011) influential book warns, "Everything is obvious (once you know the answer)." Perhaps the researcher initially had a clear prediction but ends up forgetting some details. Then, upon seeing the results, they assume those must have been the initially predicted results. Pre-registration allows researchers to document the intended analysis at the time they create materials, when analyses are clearest in their mind. This documentation allows them to revisit the plan whenever data is analyzed, even if data analysis is delayed.

Additionally, pre-registration can increase readers' confidence that the researcher originally planned to analyze the data the way the paper reports. Without pre-registration, it is impossible for a reader to discern which results are in fact predicted and which are not. Moreover, such discernment requires that the reader trust the perfect memory of the authors. Here, the planning fallacy can creep in. Data collection takes longer than expected as other responsibilities may interfere. Remembering how one intended to analyze the data is sometimes difficult.

5.2.4. 2B: The analysis is obvious, why discuss it?

Researchers may think pre-registration is costly because it creates a delay between creating materials and data collection. While it requires a marginal amount of time to create the document, pre-registration benefits research teams by improving communication and efficiency. Researchers can use pre-registration to generate discussions that improve 1) training of students, 2) communication between collaborators, and 3) efficiency and flexibility in terms of task allocation.

5.2.5. Potential benefit: Pre-registration helps collaborations by improving communication and mentorship

Introducing greater specificity to the research process through pre-registration can improve the efficiency of collaborations and establishment of norms between new collaborators. Oftentimes, creating a pre-registration highlights where different collaborators have different analyses in mind, and sometimes even different research designs. Creating a pre-registration starts a useful conversation that not only identifies different perspectives but also helps clarify the project's goals and predictions.

Pre-registration can serve as a guide in training new researchers, both when they *create* the document and when they *follow* it to analyze data. Creating the pre-registration allows students to apply their statistical knowledge by requiring them to determine and list the appropriate analyses for the predictions, a key step in graduate training. When a senior colleague reviews a pre-registration created by a student, this can lead to a useful discussion about the appropriate ways to analyze different types of data. We encourage younger scholars to approach mentors to discuss pre-registering as part of their training.

Mentors can utilize a pre-registration document as a playbook to help increase the efficiency of their mentoring. Following the pre-registration allows students another opportunity for learning. Suppose that a mentor, Ariel, and her mentee, Jack, create a survey and pre-register their experiment. When analyzing the data, Jack then focuses on learning how to use the statistical software to run each of the analyses in

the pre-registration. This is more efficient for his training than trying to infer from the survey which analyses are appropriate and how to use the software. Jack can even follow the pre-registration if he did not help create it. But when mentor and mentee create the pre-registration together, their document becomes a core aspect of training.

5.2.6. Potential benefit: Pre-registration improves the efficiency of collaborations

In collaborations, it is more efficient to discuss design decisions and the wording of measures prior to, rather than after, data collection. Collaborators can review the pre-registration and raise issues about the empirical tests *before* data are collected. If brought up after data is collected, it may require launching a new study. Reviewing a pre-registration can even produce discussions between collaborators that lead the team to revise the materials. By iterating on ideas and predictions prior to data collection, pre-registration helps researchers avoid iterating on their survey design and measures by running multiple costly experiments

Additionally, the handoff of a project between collaborators is sometimes cumbersome. Pre-registration provides greater flexibility for any of the collaborators to tackle a specific task during the research process. If Ariel created a survey and pre-registration herself and is currently unable to analyze the data, Jack could use the pre-registration to analyze the data and keep the project on schedule. Rather than playing mind reader, Jack can confidently analyze the data as Ariel intended when the survey was created and predictions were clear in her mind.

5.3. Opportunity cost

5.3.1. 3A: Pre-registration adds work to the research process

It takes time to create a pre-registration document, and in our survey, consensus was highest on this cost (38% agreeing, with 33% of respondents being unsure). However, we suggest that many researchers likely overestimate this cost. Initially, creating a new document for each survey might seem onerous, especially if the researcher assumes others have not adopted pre-registration. Further, they may assume that it is easier to pre-register an experiment after running multiple iterations, to establish an effect.

5.3.2. Potential benefit: Pre-registration changes the order of work

Two counterpoints merit note. As described in the “Pre-registration requires specificity which encourages clarity” section, pre-registering simply changes the order of work, rather than adding new work. Researchers must specify hypotheses and analyses at some point. Pre-registration simply ensures this occurs before data is collected, when ideas are fresh in the researcher’s mind, rather than after. Additionally, after creating the first pre-registration, it is easy to use that document as a template for future experiments, and even for similar projects, making small changes as predictions develop. In this way, the marginal cost of creating additional pre-registrations decreases over the course of a research project, and potentially over the course of a researcher’s career.

5.3.3. Potential benefit: Pre-registration can save money

Although our survey respondents were most uncertain about this potential benefit (52% were unsure and only 11% agreed), pre-registration can save an individual money. A researcher may initially expect to run two or three experiments to strengthen the manipulation and make other changes to test for an effect. But what if the first study’s results are viable for inclusion in a paper (independent of whether they are significant or null)?

Every researcher faces different constraints – time, money, or other resources. If a researcher pre-registers the first survey and the results show the predicted effect, they can save money by running fewer pre-registered replications (to be clear, self-replication is a great practice, regardless). Revising pre-registration documents is less costly than revising experiments and collecting multiple rounds of data.

Additionally, reviewers may ask for a pre-registered replication if the paper lacks any pre-registered studies. Pre-registering helps avoid this potential time delay in the review process.

5.3.4. 3B: Others may not pre-register, why should I?

Although our data suggest that pre-registration will become the norm in the social and behavioral sciences, researchers may assume that researchers who do not pre-register gain an advantage by submitting manuscripts faster.

5.3.5. Potential benefit: Pre-registration serves as a meaningful signal to reviewers

Pre-registration can offer reviewers and readers peace of mind that the researchers did not p-hack analyses, even unintentionally (Simmons et al., 2017). Relatedly, the information included in pre-registration can supplement the increasingly standard 21-word disclosure included in manuscripts (Simmons, Nelson, & Simonsohn, 2012).⁴ Notably, many reviewers use a standardized request for the authors to provide a disclosure statement (Nosek et al., 2017)⁵ if it is not already provided through pre-registration or the 21-word disclosure statement (Simmons et al., 2012).

6. How can researchers pre-register?

Pre-registration is as simple as posting a short document (ideally one page) specifying the plan to recruit a certain number of participants and planned analyses (Simmons et al., 2017). Pre-registrations for experimental studies typically include:

- Hypothesis
- Sample size
- Design, including all experimental conditions
- Dependent variable(s), including wording
- Analytic plan
- Procedure for handling outliers and potential exclusions

Researchers have flexibility regarding the specific format and content of their pre-registration, depending on their preferences, the field of study, or other factors (see the next section). Once the pre-registration is created, a researcher posts it to an online repository, where it is time-stamped. Researchers can then add data and materials to a folder for their project. They can share the materials with specific people, including reviewers in the review process. While authors may wish to make all of their pre-registrations public at the time of publication, this is by no means a necessary pre-condition.

6.1. Where to create and post pre-registrations

There are multiple templates available to guide the creation of a pre-registration document. Researchers in the social and behavioral sciences commonly post their pre-registrations to one of two websites: Aspredicted.org (AsPredicted) and The Open Science Framework (OSF).⁶ For a comparison of these sites, see Table 6.

⁴ 21 Word Solution: “We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study.”

⁵ Disclosure Request: “I request that the authors add a statement to the paper confirming whether, for all experiments, they have reported all measures, conditions, data exclusions, and how they determined their sample sizes. The authors should, of course, add any additional text to ensure the statement is accurate. This is the standard reviewer disclosure request endorsed by the Center for Open Science [see <http://osf.io/project/hadz3>]. I include it in every review.”

⁶ While this paper focused on these two options, many other options exist, including those suggested by a knowledgeable reviewer: clinicaltrials.gov, <http://preclinicaltrials.eu/>, <http://egap.org/design-registration/>, <http://ridie.3ieimpact.org/>, <https://sreereg.icpsr.umich.edu/sreereg/>

Table 6
Comparison of features between the Open Science Framework and As Predicted.

| | Open Science Framework | As Predicted |
|--|---|---|
| Automatically made public | Depends on Type* | N |
| Provides template | Y | Y |
| All pre-registrations are standardized | N | Y |
| All contributing authors must approve the pre-registration before it goes live | N | Y |
| Can anonymously share with reviewers | Y | Y |
| Can attach additional documents to the pre-registration | Y | N |
| Site requires login/sign in information | Y | N |
| Can edit the document after submission | N | N |
| Website | https://osf.io/ | https://aspredicted.org/ |

Note. *Pre-registrations posted without an OSF template remain private in perpetuity or until the researcher clicks the “make public” option. Pre-registrations made the OSF templates remain private for up to 4 years and are then made public by the site.

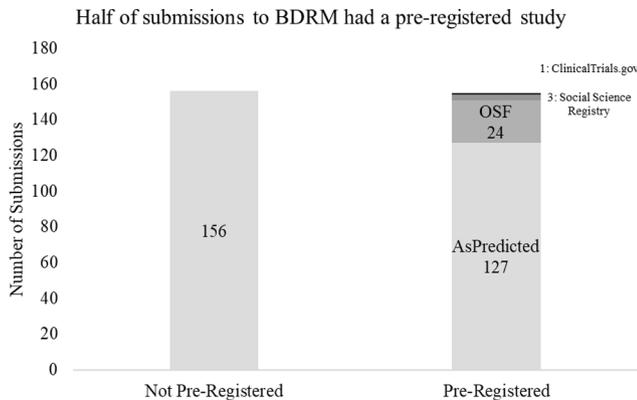


Fig. 2. Number of pre-registered paper submissions to the 2020 BDRM Conference. Note. Thank you to Joe Simmons, Leif Nelson, and Uri Simonsohn for generously sharing this data on BDRM conference submissions (Simmons, Nelson, & Simonsohn, 2020).

6.1.1. As Predicted

AsPredicted provides a streamlined nine-question, standardized template for pre-registering studies. This template helps researchers delineate between confirmatory hypotheses and exploratory hypotheses. A useful guide for filling out the template on AsPredicted is available here: <http://datacolada.org/64>. The logistics to posting it are straightforward. One researcher fills out and submits the pre-registration template. Collaborators receive a link via email to approve the submission or make changes, with no account or password necessary. Researchers can title submissions and organize documents in private folders.

Any pre-registration on AsPredicted remains private in perpetuity unless made public by one of the authors. The site allows researchers to share an anonymized link for the review process (for papers or conference abstracts). Data on conference submissions from the 2020 conference of Behavioral Decision Research in Management (BDRM) suggests that AsPredicted is especially popular among researchers who included pre-registrations in their paper submissions. See Fig. 2.

A key benefit of AsPredicted is its simplicity and ease. AsPredicted links directly to Researchbox.org, its sister platform for sharing pre-registrations along with data, code, and materials, although Researchbox can be used without AsPredicted as well (researchers can directly upload their own pre-registration to Researchbox). Researchbox uses the same log-in and pre-registrations that are linked between the sites. Further, Researchbox allows you to categorize documents when you upload them. It then automatically organizes your materials based on these categories so that supplemental materials are easy to locate.

6.1.2. Open Science Framework

Open Science Framework (OSF) is an online repository for supplementary materials including pre-registration documents, data, code, and survey materials. Authors can organize their work by project and create

nested folders within each. When a new project is created on OSF, researchers can choose whether the information within that project folder is made private or public. If starting in “private” mode, a researcher can change to “public” whenever they choose.

This site also allows researchers to create an anonymized link for the review process (either for papers or for conference abstracts). When submitting a manuscript for review, researchers can share an anonymized link with reviewers, who can view but not edit the project. After publication, researchers can choose to share the project publicly or allow others to request access to view the project.

OSF additionally provides templates for pre-registering: <https://osf.io/zab38/> (including the template from AsPredicted). Multiple templates allow for greater flexibility in adapting pre-registration documents to the researchers’ preferred style. Researchers can create pre-registrations without any template and upload a Word document as a file to a project folder (as done with this current paper), which allows for greater flexibility (but decreased searchability on OSF without the inclusion of meta-data).

Privacy constraints for pre-registration on this site depend on the type of pre-registration a researcher posts to OSF. Pre-registrations posted as word documents to project folders remain private in perpetuity or until the researcher clicks the “make public” option. Pre-registrations made directly through the OSF remain private for up to 4 years and are then made public by the site.

6.1.3. Comparison

While OSF provides greater flexibility than AsPredicted (multiple templates, looser page restriction), it also has slightly higher start-up costs – for example, it requires the user and collaborators to have an account. This flexibility may be helpful for researchers who prefer to create their own format for pre-registrations. The structured template of AsPredicted is likely helpful for researchers who are new to the practice of pre-registration. Thus, it is up to the individual researcher to decide which option provides a better fit for their purposes.

7. General Discussion

Catalyzed by the so-called “replication crisis” in psychology (alternatively termed “psychology’s renaissance” or the “credibility revolution”; Nelson et al., 2018; Vazire, 2018), myriad groundbreaking reforms recently entered the scientific consciousness as well as more mainstream discussion (for reviews, see Open Science Collaboration, 2015; Nosek et al., 2018; Nelson et al., 2018; Lakens & Evers, 2014). Although the prescriptive benefits of open science practices such as pre-registration have received much attention in the social and behavioral sciences, we know little about (1) current adoption rates and (2) how researchers view individual-level costs and benefits of pre-registration. This paper directly addresses researchers’ uncertainties about pre-registration as reflected in our empirical data by highlighting individual benefits. We describe the *who*, *why*, and *how* of pre-registration to

decrease the uncertainty surrounding it and encourage wider adoption.

Adoption of pre-registration lags relative to other open science practices in *OBHDP* papers from 2015 to 2020. Our Researcher Survey suggests generational differences in adoption of pre-registration. Early-career researchers not only hold more positive views of pre-registration than their senior counterparts, but are also more likely to pre-register. When reporting their practices for current projects, approximately half of our participants reported pre-registering, similar to their adoption rate for posting data and materials. Even within researchers who see field-wide benefits of pre-registration, there is uncertainty surrounding the costs and benefits to individuals.

This paper directly addresses researchers’ uncertainties by highlighting individual-level benefits of pre-registration while accounting for commonly perceived costs. In an ideal world, readers could rely on academic papers to clearly delineate between exploratory vs. confirmatory hypothesis testing. While this sounds appealing in theory, it relies on tenuous assumptions in practice: (1) the researchers knew exactly what they wanted to do before the study, (2) they perfectly recall this plan, and (3) they did not test alternatives that are not reported. In reality, pre-registration serves as a memory safeguard, helping researchers clearly check their own proposed analytic plan weeks or months after they conduct the study.

Pre-registration requires specificity, which benefits the research process. These benefits apply to both junior and senior colleagues and to researchers working individually or in collaborations. For those who wish to clarify their ideas prior to collecting data, improve the efficiency of collaborations, or improve mentorship of students, pre-registration is a useful tool.

7.1. Future directions

Future work should further examine how wider adoption of pre-registration affects its costs and benefits for individuals. When data are available, researchers can compare the time to publication between projects with and without pre-registration documents. Pre-registration may take time prior to data collection but it likely saves time when writing methods and results for the paper. Additionally, it could save time during the review process by increasing reviewers’ confidence in the results (potentially avoiding reviewer requests to replicate studies).

The field would also benefit from understanding how pre-registration affects researchers’ careers in the long-term. While the number of publications is important, so too is the replicability of science. As pre-registration becomes increasingly common, researchers could measure the rates of replicability between papers with and without pre-registrations. Future work should compare trends across fields. While this paper examines adoption rates and perceptions of pre-registration with a focus on social and behavioral science within management, a similar conversation is ongoing in the domain of consumer research (see Pham & Oh, 2020a, 2020b; Simmons et al., 2020). Research should continue to explore similar conversations in related fields including psychology, economics, and political science.

Finally, consider the adoption of open science as a social dilemma – that is, weighing the benefits to the individual and to the field. If a handful of researchers pre-register and their colleagues refuse to do so, neither the field nor the individuals benefit. Widespread adoption is necessary to improve science. Results from our Researcher Survey suggest that researchers are pre-registering current projects despite some uncertainty about the costs and benefits to them personally. We hope that more researchers pre-register when they consider how it can improve the process and quality of their research.

7.2. Conclusion

The key goal of science is to determine what is true and what is not (Popper, 1963; 2014). False-positive results are a hurdle to determining truth within the literature. Pre-registration can help reduce the presence

of false-positive findings, an individual benefit well worth the time spent creating a pre-registration. But that is not the only benefit. Increasing specificity throughout the research process greatly helps clarity of thought and thus efficiency for each researcher. We encourage researchers to appreciate the benefits that pre-registration holds for them by elaborating on the *who, why, and how* of pre-registration.

Author note

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CRediT authorship contribution statement

Jennifer M. Logg: Conceptualization, Writing, Methodology, Investigation, Visualization. **Charles A. Dorison:** Conceptualization, Writing.

Appendix A

See Tables A1–A4.

Table A1
Self-reported field of study of participants in the Researcher Survey.

| Field | Percentage of participants (count) |
|--------------------------------------|------------------------------------|
| Management / organizational behavior | 26.8% (56) |
| Marketing | 12% (25) |
| Psychology | 34.9% (73) |
| Behavioral economics | 5.7% (12) |
| Economics | 1.9% (4) |
| Public health | 1.9% (4) |
| Public policy | 2.9% (6) |
| Decision science | 7.7% (16) |
| Other | 6.2% (13) |
| Total | 209 |

Note. Other responses included: social science, I/O psychology, sociology, communication (*n* = 2), political science, public administration, cognitive science, HR/employee relations, conflict resolution, negotiations and conflict resolution, statistics.

Table A2
Self-reported academic position of participants in the Researcher Survey.

| Academic position | Frequency |
|---------------------|------------|
| Graduate student | 33.2% (69) |
| Postdoctoral fellow | 11.1% (23) |
| Assistant professor | 21.2% (44) |
| Associate professor | 12% (25) |
| Full professor | 16.3% (34) |
| Teaching faculty | 1.9% (4) |
| Other | 4.3% (9) |
| Total | 208 |

Table A3
Researchers’ expectations for who creates pre-registration documents.

| Who do you think is currently creating pre-registration documents? | Frequency |
|--|-----------|
| Grad students | 87% (169) |
| Postdoctoral fellows | 89% (175) |
| Assistant professors | 73% (143) |
| Associate professors | 38% (74) |
| Full professor | 27% (52) |

Note. Multiple selections were allowed.

Table A4

Costs versus benefits of pre-registration from highest to lowest perceived uncertainty (sorted by unsure column).

| Statement | Agree | Unsure | Disagree | N = |
|--|-------------|-------------|-------------|-----|
| Negative | | | | |
| Pre-registration produces low benefits to me individually | 24.2% (52) | 34.9% (75) | 40.9% (88) | 215 |
| Pre-registration adds substantial work to the research process | 37.5% (81) | 32.9% (71) | 29.6% (64) | 216 |
| Pre-registration does not contribute much to the field | 15% (32) | 25.5% (54) | 59.8% (128) | 214 |
| Pre-registration means there is no room for exploratory analyses | 8.4% (18) | 23.3% (50) | 68.4% (147) | 215 |
| Pre-registration is a waste of time | 9.3% (20) | 23.1% (50) | 67.6% (146) | 216 |
| Pre-registration is not worth it if the analysis is obvious | 12.6% (27) | 22.8% (49) | 64.7% (24) | 215 |
| Positive | | | | |
| Pre-registration can save me money as an individual researcher | 11.2% (24) | 52.1% (112) | 36.7% (79) | 215 |
| Pre-registration frontloads work in relation to writing up results | 50.2% (108) | 35.8% (77) | 14% (30) | 215 |
| Pre-registration helps communication between collaborators | 54% (116) | 33.5% (72) | 12.6% (27) | 215 |
| Pre-registration can help in training new researchers | 68.2% (146) | 26.2% (56) | 5.6% (12) | 214 |
| Pre-registration helps clarify ideas before running a study | 79% (169) | 17.3% (37) | 3.7% (8) | 214 |
| Pre-registration can help signal to others that I do not p-hack | 73.1% (158) | 17.1% (37) | 9.7% (21) | 216 |
| Neutral | | | | |
| Pre-registrations are automatically made public | 11.1% (24) | 38.9% (84) | 50% (108) | 216 |
| Only junior researchers pre-register | 10.6% (23) | 31.5% (68) | 57.9% (125) | 216 |

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