**Caution, Preprint! Brief Explanations Allow Non-Scientists to Differentiate Between
Preprints and Peer-Reviewed Journal Articles**

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Abstract

A growing number of psychological research findings are initially published as preprints. Preprints are not peer-reviewed and thus did not undergo the established scientific quality control process. Many researchers hence worry that these preprints reach non-scientists, such as practitioners, journalists, and policymakers, who might be unable to differentiate them from the peer-reviewed literature. Across 5 studies in Germany and the US, we investigated whether this concern is warranted and whether this problem can be solved by providing non-scientists with a brief explanation of preprints and the peer-review process. Studies 1 and 2 showed that without an explanation, non-scientists perceive research findings published as preprints as equally credible as findings published as peer-reviewed articles. However, an explanation of the peer-review process reduces the credibility of preprints (Studies 3 and 4). In Study 5, we developed and tested a shortened version of this explanation which we recommend adding to preprints. This explanation again allowed non-scientists to differentiate between preprints and the peer-reviewed literature. In sum, our research demonstrates that even a short explanation of the concept of preprints and their lack of peer-review allows non-scientists who evaluate scientific findings to adjust their credibility perception accordingly. This would allow harvesting the benefits of preprints, such as faster and more accessible science communication while reducing concerns about public overconfidence in the presented findings.

Keywords: preprints; peer-review; credibility, science communication, publishing

Caution, Preprint! Brief Explanations Allow Non-Scientists to Differentiate Between Preprints and Peer-Reviewed Journal Articles

Scientific findings, in psychology and beyond, are rapidly becoming more open and accessible. As part of this open science movement, preprints—that is, scientific manuscripts preceding formal peer-review and publication—have gained popularity and their number is growing exponentially (see Figure 1). This development has been accelerated by the COVID-19 crisis, where researchers aim to rapidly disseminate their findings instead of going through the traditional peer-review process (Kwon, 2020; Polka et al., 2021; Rahal & Heycke, 2020). Moreover, this development was facilitated by an increasing availability of preprint servers in general (e.g., *OSF Preprints*) but also for specific disciplines (e.g., *PsyArXiv* for psychological research).

Figure 1. Development of the number of manuscripts published per year on two major preprint servers for psychology and the social sciences since 2017. Numbers were derived by searching for available preprints on *Google Scholar*, filtering for each year, and server.

The fact that preprints are typically not peer-reviewed does not seem to be a significant barrier to their success. One reason for this may be that the peer-review process has several drawbacks. First, the peer-review process is time-consuming and contributes to a substantial delay between the discovery and the publication of research findings (Cooke et al., 2016; Huisman & Smits, 2017). Second, peer-reviewers are humans, and thus their judgments can be biased and influenced by other factors than scientific quality (Helmer et al., 2017; Jukola, 2017; Okike et al., 2016). Finally, peer-review may further hinder scientific progress because some reviewers oppose unconventional theories, methods, and practices, such as publishing non-significant findings or failed replications (Eisenhart, 2002; Elson et al., 2020; French, 2012; Olson et al., 2002). For these reasons, some scholars even argue that peer-review is a deeply flawed process and should be abolished (Heesen & Bright, 2019; Smith, 2006).

Nevertheless, peer-review is currently the established standard quality control process for scientific publications (e.g., Elson et al., 2020; Nosek & Bar-Anan, 2012). Indeed, there is empirical evidence that peer-reviewed manuscripts have a higher quality of reporting compared to their non-peer-reviewed version (Carneiro et al., 2019; Cobo et al., 2011; Goodman et al., 1994). Moreover, various studies show that peer-reviewers usually detect (some) errors in manuscripts (Godlee et al., 1998; Okike et al., 2016; Schroter et al., 2004). Hence, researchers across disciplines consider peer-review as a guiding principle on which work they read and cite. For example, a large international survey found that scientists considered peer-review as the most significant factor for determining the quality and trustworthiness of research (Tenopir et al., 2016), and most

scientists emphasize that it is important that preprints are ultimately submitted to a peer-reviewed journal (Soderberg et al., 2020).

However, preprints are not only available to scientists (who, in general, can be assumed to know that preprints are not peer-reviewed). Instead, because preprints typically are published in open access, they are also openly available to the general public, who might not be aware that preprints are usually not peer-reviewed. In fact, especially during the COVID-19 crisis, many preprints became part of the public discourse through traditional and social media (Fraser et al., 2021). For example, a now-retracted preprint describing an “uncanny similarity” between SARS-CoV-2 and HIV spurred discussion on social media on whether SARS-CoV-2 is a genetically engineered bioweapon (Koerber, 2021), which later on became one of the leading Coronavirus-related conspiracy theories (Imhoff & Lamberty, 2020). Presumably because of this incident, the preprint server *bioRxiv*, who provided this questionable preprint, added a warning to their website, stating that preprints are preliminary, non-peer-reviewed reports (Forster, 2020). In another example, a preprint on the SARS-CoV-2 viral load in children was disparaged on the title page of the largest German newspaper (Niggemeier, 2020). The newspaper, however, ignored that the work was a preprint and heavily criticized some preliminary analyses. This public debate over a preprint might have damaged trust in science in Germany (Lindner, 2020), which could have had serious consequences for the adherence and adoption of recommended protective behaviors (Dohle et al., 2020). These examples illustrate what many researchers fear: Members of the general public treating non-peer-reviewed preprints as established evidence, leading to ill-advised

decisions and potentially damaging public trust in science (Fox, 2018; Heimstädt, 2020; Rahal & Heycke, 2020; Sheldon, 2018).

This concern about preprints, which has been described as the most frequent argument against them (Vazire, 2020), goes beyond COVID-19 related research and is highly relevant for all research findings of public interest. Indeed, media outlets and public science-communication blogs also cover preprints on psychological topics such as climate change anxiety (Chow, 2021), personality (Adam, 2019), or even the trustworthiness of psychological research as a whole (Chivers, 2020). Preprints in psychology may be especially likely to catch the public eye, as they deal with questions related to human behavior and society. It thus seems likely that (some) non-scientists even directly seek out psychological preprints, as they often address topics highly relevant to their lives.

The central assumption underlying concerns about the public availability of preprints is that non-scientists fail to differentiate between preprints and peer-reviewed literature and thus treat them as equally credible sources. However, this assumption currently lacks empirical evidence. As preprints are often presented with no or very little accompanying information (e.g., simply stating that the results stem from a preprint), we believe that in such a situation, non-scientists will indeed fail to incorporate this information in their credibility judgment. This is because they lack the necessary background knowledge that preprints are not peer-reviewed. We hypothesize that without an additional explanation of preprints and their lack of peer-review, people will perceive

research findings from preprints as equally credible compared to research findings from the peer-reviewed literature (Hypothesis 1).

However, recent research suggests that even very brief explanations (e.g., warning labels) allow non-scientists to adjust their credibility ratings (Koch et al., 2021), even for complex scientific topics (Anvari & Lakens, 2018; Hendriks et al., 2020; Wingen et al., 2020). If such a brief explanation of preprints includes that they are not peer-reviewed and thus did not undergo the established standard quality control process for psychological publications, non-scientists might perceive preprints as less credible. Emphasizing increased quality control, for example through consumer reviews or quality management systems (Adena et al., 2019; Boiral, 2012; Resnick et al., 2006; Silva & Topolinski, 2018), as well as highlighting adherence to community norms and standards (Bachmann & Inkpen, 2011; Blanchard et al., 2011; Wenegrat et al., 1996), are linked to increased credibility and trustworthiness. We thus hypothesize that, after receiving an explanation of preprints and their lack of peer-review, non-scientist would perceive preprints as less credible than peer-reviewed articles (Hypothesis 2).

Overview of Studies

We conducted five experimental studies to test whether non-scientists perceive preprints as less credible than peer-reviewed literature and if this depends on whether they receive an explanation of the peer-review process. We focused on preprints covering research findings from psychology and the social sciences, as they seem particularly likely to be comprehensible and interesting to the general public. In the pilot study, we explored whether preprints in psychology and the social sciences typically provide an explanation of preprints and the peer-review process. We coded 200 recent preprints and

examined whether they sufficiently explain their lack of peer-review. Study 1 (German sample) and Study 2 (US sample) tested whether, without an explanation of preprints and the peer-review process, non-scientist would be able to differentiate between peer-reviewed literature and preprints. Study 3 (within-subjects design) and Study 4 (between-subjects design) tested whether after receiving an explanation of preprints and their lack of peer-review, non-scientist would perceive preprints as less credible than peer-reviewed articles. Finally, in Study 5, we developed a shortened version of this explanation and tested whether this very brief explanation allowed non-scientists to differentiate between preprints and peer-reviewed literature. We moreover cross-sectionally explored how this explanation may work (mediation) and whether the effect of this explanation depends on education and familiarity with the publication process (moderation).

Preregistration

Studies 1 to 5 and the Supplemental Study 1 have been preregistered. All preregistration forms are shared on the Open Science Framework (<https://osf.io/egkpb/>). The pilot study, which focused on coding existing data, was not preregistered.

Data, materials, and online resources

All materials, anonymized datasets, and analyses code are shared on the OSF. Statistical analyses were conducted using R 4.0.4 (R Development Core Team, 2021), and for the main analyses, we relied on the packages *effsize* (Torchiano, 2020), *lavaan* (Rosseel, 2012), *psych* (Revelle, 2021), *pwr* (Champely et al., 2018), *yarr* (Phillips, 2017), and *TOSTER* (Lakens, 2017). Details regarding our recruitment strategy and

regarding one additional study (see section “Reporting”) are reported in the Supplemental Materials.

Reporting

For each study, we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

The studies are numbered 1–5 for narrative style. Chronologically, the studies were run in the following order: 3, 4, 1, 5, 2. Coding for the pilot study was completed shortly after Study 3. We conducted one further study, prior to Study 5. We found that this study likely contains a high percentage of inattentive respondents (see Supplemental Materials for details), which render the obtained null results largely uninterpretable. We thus refrain from discussing this study in the main text, but to increase transparency, we provide details about this study in the Supplemental Materials and on the OSF. All analyses with a preregistered hypothesis are tested with one-sided p -values. In all studies where we predicted the absence of an effect, we rely on equivalence tests with preregistered equivalence bounds. This is a commonly recommended frequentist method to provide evidence for the absence of a meaningful effect (Lakens, 2017; Lakens et al., 2018).

All participants who completed our studies were included in the analyses except if they met preregistered exclusion criteria or if they did not respond to our central dependent variable (i.e., perceived credibility, not explicitly preregistered). Participants were blocked from participating in more than one study to avoid nonnaïveté (Chandler et al., 2015). Sample sizes were preregistered in Studies 1 to 5, however, some deviations occurred because we recruited participants online and thus had limited control over the

final sample size (for details regarding sample sizes and deviations, see Supplemental Materials). However, in no case was the final sample size determined based on the obtained results.

Ethical approval

All studies were conducted consistent with the Declaration of Helsinki, and all are exempt from Institutional Review Board approval by guidelines of the German Psychological Society DGPs (German Society for Psychology, 2018)

Pilot study

Method

For the pilot study, we collected the information presented in the 303 most recent manuscripts (at the time of coding; June 2020) on two popular social science preprint servers, commonly used by psychological scientists. These servers were *PsyArXiv* (<https://psyarxiv.com>) and the social and behavioral sciences section at *OSF Preprints* (<https://osf.io/preprints>). We first collected general bibliographic information (authors, publication date, language, doi, whether the manuscript was a postprint). We excluded 63 manuscripts from our analyses, because they appeared to be accepted versions of articles (postprints) and thus peer-reviewed, thereby not meeting our definition of preprints. We furthermore excluded 33 non-English preprints, and finally, 7 documents that were not preprints (e.g., supplemental materials, book chapter scans).

In light of these necessary exclusions, the coders continued coding (by going back further in time and coding earlier preprints) until eventually, two hundred suitable manuscripts (100 from each server) were included. We coded whether the authors of the preprint: a) mentioned that it is a preprint b) mentioned that it is thus not peer-reviewed,

c) explained that peer-review serves as a quality control process, d) explained that peer-review is the standard procedure for scientific publication, e) and/or added another indication that the findings might be preliminary or less credible.

Results

The results showed that only 27.50 % of the preprints explicitly stated that they were preprints. Even fewer preprints (15.50 %) contained information that they had not undergone peer-review yet. Finally, not a single preprint provided information explaining that peer-review serves as a quality control measure. Detailed results for each preprint server are presented in Table 1.

Table 1. Information about peer-review in recent preprints on two major preprint servers.

Number of preprints informing their readers that:	OSF Preprints	PsyArXiv	Overall
They are a preprint (or similar).	30.00%	25.00%	27.50%
Are not peer-reviewed (or similar).	13.00%	18.00%	15.50% ^a
Peer-review is typically part of the scientific publication process.	1.00%	0.00%	0.50%
Peer-review serves as a quality control measure.	0.00%	0.00%	0.00%
Their findings might be preliminary (or similar).	6.00%	0.00%	3.00%

^aThe overall number includes 9 publications mentioning that they are “under review”, but not 11 publications mentioning that they have been “submitted for publication”, as we believe the latter does not clearly indicate to non-scientists that the work has not yet been peer-reviewed.

Study 1

In Study 1, we tested whether participants would evaluate psychological research findings that were published as peer-reviewed articles as equally credible as research findings published as preprints.

Method

Participants and design. Participants were German university students recruited online in exchange for course credits, as well as individuals recruited through postings in public German social media groups for voluntary research participation. The study employed a between-subjects experimental design. We randomly assigned participants to one of two between-subject conditions (preprint condition, peer-review condition). Sample size considerations were made in relation to Study 4, which chronologically took place before Study 1; compared to Study 4, we aimed to double our sample size. The recruited sample was slightly larger and consisted of 277 participants (after excluding 35 participants who already took part in Study 4, as preregistered), out of which 204 provided responses to all credibility ratings and were therefore included in the main analysis (74.5 % female; age: $M = 25.41$, $SD = 7.09$ y). Power analyses revealed that the sample size of 204 had a 99.87 % power to detect the effect observed in Study 4 ($d = .70$, α of .05) and a 95% power to demonstrate in an equivalence test that an observed effect is considerably smaller than the effect observed in Study 4 (preregistered equivalence bound of $d < .5$, compared to $d = .70$ in Study 4).

Procedure. Participants were presented with five different research findings (for an overview of research findings used as stimuli, see Table 2). The findings were described as either being published as a peer-reviewed journal article, or as a preprint,

depending on condition. For each research finding, participants indicated their perceived credibility (“How credible is this study result?”) on a 7-point rating scale (ranging from 1 = “not at all credible” to 7 = “very credible”). Participants received no further information (e.g., an explanation of the peer-review process). In fact, all five findings (Gervais & Norenzayan, 2012; Hauser et al., 2014; Nishi et al., 2015; Shah et al., 2012; Wilson et al., 2014) were published in the peer-reviewed journals *Nature* or *Science*. Descriptions of these findings were adapted from prior work, where they proved to be comprehensible to non-scientists (Hoogeveen et al., 2020). Findings covered various psychological and economic behavioral science topics, and participants judged the credibility of these five research findings. An average credibility score across all five ratings was computed and served as the dependent variable.

Table 2. Overview of research findings used as stimuli in Studies 1, 2, 4, and 5.

Authors	Short Description
Gervais et al. (2012)	Analytical thinking promotes religious disbelief.
Hauser et al. (2014)	When making collective decisions people share more common resources for future generations.
Nishi et al. (2015)	Financial inequality between group members remains when people are informed about each member's wealth.
Shah et al. (2012)	Poverty drains people's attention.
Wilson et al. (2014)	People dislike doing nothing and prefer an engaged mind.

Results

In line with our preregistration, we computed an average credibility score across all five credibility ratings. As predicted, without a brief explanation, participants considered research findings published as preprints ($M = 4.09$, $SD = 0.80$) to be equally credible compared to findings published as peer-reviewed journal articles ($M = 4.24$, $SD = 0.88$), $t(202) = 1.25$, $p = .211$, $d = 0.18$, 95% CI[-0.10, 0.46]. This finding is presented in Figure 2. A preregistered equivalence test, a test that provides support for the absence of a meaningful effect, showed that the observed effect size, which is conventionally considered very small, was equivalent with an interval containing only small to medium effects ($d < .5$), $t(202) = 2.29$, $p = .012$. Descriptive statistics for the perceived credibility across studies and conditions throughout this article are presented in Table 3.

Figure 2. Pirate plot showing perceived credibility as a function of publication mode, in Study 1 (German participants), in which participants received no explanation of preprints. The black dots represent the jittered raw data which is shown with smoothed densities indicating the distributions in each condition. The central tendency is the mean, and the intervals represent two standard errors around the mean.

Table 3. Perceived credibility of research findings depending on source and explanation across all studies presented in this article.

Study	Mean	Standard Deviation	<i>t</i> -value ^a	Degrees of freedom	<i>p</i> -value ^b	Cohen's <i>d</i> [95%- CI]
Study 1 (Without Explanation)						
Peer-Reviewed Article	4.24	0.88				
Preprint	4.09	0.80	1.25	202	.211	0.18 [-0.10;0.46].
Study 2 (Without Explanation)						
Peer-Reviewed Article	4.73	1.11				
Preprint	4.58	1.00	1.50	464	.136	0.14 [-0.04;0.32]
Study 3 (With Explanation)						
Peer-Reviewed Article	5.63	1.34				
Preprint	4.00	0.93	10.06	51	<.001 (one-sided)	<i>dz</i> = 1.39.
Study 4 (With Explanation)						
Peer-Reviewed Article	4.15	0.65				
Preprint	3.67	0.72	3.74	111	<.001(one-sided)	0.70 [0.32;1.09]
Study 5 (With Explanation)						
Peer-Reviewed Article	4.65	1.00				
Limited Information	4.42	1.15	2.02	379	.044	0.21 [0.01;0.41]
Authors' Explanation	4.39	1.07	2.31	359	.010 (one-sided)	0.25 [0.04;0.45],
External Explanation	4.31	1.02	3.25	379	<.001 (one-sided)	0.33 [0.13;0.54]

^aThe *t*-tests results refer to the comparison of the respective condition with the peer-review-condition in each study. These are *t*-tests for dependent samples in Study 3, and for independent samples in the other studies.

^bOne-sided *p*-values are reported for directional hypotheses

Study 2

Study 2 aimed to replicate the findings from Study 1 in a different population using an even larger sample size ($N = 466$; US sample) and a stricter preregistered criterion of what constitutes a negligible difference ($d < .3$). The design was identical to Study 1, with the only difference that Study 2 also included a basic text comprehension check which had to be answered correctly to ensure that participants were aware that the five research findings were published as preprints or peer-reviewed journal articles, respectively.

Method

Participants and design. Participants were US-based individuals recruited on the Amazon MTurk platform in exchange for \$0.50. The target sample size was set to 578, which allowed us to detect group differences of $d = .30$ ($1 - \beta = .95$, α of .05) and moreover provided sufficient power for an equivalence tests ($1 - \beta = .95$, equivalence bounds of $d = .3$). To increase data quality, we opted to exclude participants who failed a basic text comprehension check (see below). This decision was based on previous research raising concerns about MTurk workers not reading study materials or even being bots (Chmielewski & Kucker, 2020). To compensate for potential exclusions, we recruited 753 participants, of which 476 passed the preregistered comprehension check. Finally, 466 participants answered all credibility items and were therefore included in the main analysis (42.15% female; age: $M = 37.00$, $SD = 11.97$ y). Despite this reduced

sample size, a sensitivity analysis revealed that the final sample size had an 80% power (with $\alpha = .05$) to detect an effect of $d = 0.26$ and a 95% power to detect $d = 0.33$.

Procedure. For the text comprehension check, participants had to answer how the research findings were published and were presented with eight options (e.g., “as textbooks”, “as preprints”). If participants answered the text understanding question incorrectly, they were asked to carefully read the text again. If they failed the text understanding question again, they were excluded from our analyses. We also added a few exploratory questions about whether participants perceived the research findings as strictly quality controlled, whether they believed that the researchers adhered to the standard publication procedure, and participants’ education and familiarity with the publication process (to ensure comparability with Study 5). Apart from this, the procedure and design were identical to Study 1.

Results

We computed an average credibility score across all five credibility ratings. As predicted and in line with Study 1, participants rated research findings from preprints ($M = 4.58$, $SD = 1.00$) as equally credible as research results from peer-reviewed journal articles ($M = 4.73$, $SD = 1.11$), $t(464) = 1.50$, $p = .136$, $d = 0.14$, 95% CI[-0.04, 0.32]. This finding is presented in Figure 3. An equivalence test showed that this observed effect

size, which is conventionally considered very small, was equivalent with an interval containing only small effects ($d < .3$), $t(464) = 1.741$, $p = .041$.

Figure 3. Pirate plot showing perceived credibility as a function of publication mode in Study 2 (US-participants), in which participants received no explanation of preprints.

Study 3

Studies 1 and 2 found that, without an explanation, non-scientists rated research findings from preprints as equally credible as research findings from peer-reviewed journal articles. Study 3 tested whether non-scientists truly believe that the two types are equally credible, or whether they start to differentiate once they get an explanation of preprints and the peer-review process and can directly compare these two options. Study 3 straightforwardly tested this by employing a within-subject design where participants rated research findings in general.

Method

Participants and design. Participants were recruited through postings in public German social media groups for voluntary research participation. The targeted sample size was set to $N = 45$, based on an a priori power analysis for 95% power (one-sided α of .05) to detect a moderate effect of $d_z = 0.5$ that would be typical for similar social-psychological research. The recruited sample was slightly larger as is often the case in online studies and consisted of 65 participants. Of these, 52 responded to all credibility items and were therefore included in the main analysis (73.08% female; age: $M = 30.83$, $SD = 9.71$ y).

Procedure. This study employed a within-subjects design. Participants read a short, jargon-free description of the peer-review process, which highlighted that peer-review serves as a quality control process, and that peer-review currently is the standard procedure for scientific publication. They were also informed that some research findings are initially published before the peer-review process as preprints, in order to achieve

rapid dissemination of results. The full description reads as follows (translation by authors):

Usually, scientific articles are subject to an extensive peer-review process. This means that other scientists anonymously review articles submitted to a scientific journal. They then speak out for or against a publication and provide important suggestions for article improvement. This procedure is considered the gold standard of scientific journals. Only articles that receive positive reviews have a chance of being published. This procedure is intended to ensure that the articles are of particularly high quality. However, some articles are now published online as preprints without having been peer-reviewed. This allows scientists to make their results available to the public very rapidly, whereas the time-consuming peer-review process can take several months. Normally, peer-review is then carried out after the article has been submitted to a scientific journal.

Afterward, participants reported the perceived credibility of research findings published as peer-reviewed articles (“How credible are research findings that are published as journal articles [with peer-review]?”) and as preprints (“How credible are research findings that are published as preprints [without peer-review]?”) on a 7-point rating scale (ranging from 1 = “not at all credible” to 7 = “very credible”). Finally, participants indicated whether they had heard about preprints and peer-reviewed articles prior to the study, completed demographics, and were debriefed.

Results

As predicted, participants rated research findings from preprints ($M = 4.00$, $SD = 0.93$) as less credible than research results from peer-reviewed journal articles ($M = 5.63$, $SD = 1.34$), $t(51) = 10.06$, one-sided $p < .001$, $d_z = 1.39$ (see Fig. 4).

Figure 4. Pirate plot showing perceived credibility as a function of publication mode, in Study 3 (German participants), in which participants received an explanation and directly compared the two options.

Study 4

Study 4 tested whether the finding of Study 3 generalizes to a more realistic situation where participants do not directly compare preprints and peer-reviewed articles with each other. Instead, participants judged specific research findings, and the design was largely identical (and thus directly comparable) to Studies 1 and 2.

Method

Participants and design. Participants were German university students recruited online in exchange for course credits. The study employed a between-subjects experimental design. We randomly assigned participants to one of two between-subject conditions (preprint condition, peer-review condition). The target sample size was set to 102, based on an a priori power analysis for 80% power (one-sided α of .05) to detect a moderate effect of $d = 0.5$. The recruited sample consisted of $N = 140$ participants, of which 113 responded to all credibility items and were therefore included in the main analysis (76.11% female; age: $M = 23.75$, $SD = 5.10$ y).

Procedure. Participants read the same short descriptions of the peer-review process and preprints as in Study 3 and answered two exploratory text comprehension questions. Participants judged the credibility of five research findings (the same research findings used in Studies 1 and 2). The findings were described as either being published as peer-reviewed journal articles or as preprints. Ratings were given on a 7-point rating scale (ranging from 1 = “not at all credible” to 7 = “very credible”). Participants also indicated whether they had heard about preprints and peer-reviewed articles prior to the

study, received an exploratory open-entry question on how they made their credibility judgments, completed demographics, and were debriefed.

Results

In line with our preregistration, we computed an average credibility score across all five credibility ratings. As predicted, participants rated research findings from preprints ($M = 3.67$, $SD = 0.72$) as less credible than research findings from peer-reviewed journal articles ($M = 4.15$, $SD = 0.65$), $t(111) = 3.74$, one-sided $p < .001$, $d = 0.70$, 95% CI[0.32,1.09]. This pattern is depicted in Figure 5.

Figure 5. Pirate plot showing perceived credibility as a function of publication mode in Study 4 (German participants). This study provided participants with an explanation of preprints and the peer-review process.

Study 5

In Study 5, we developed a shortened version of the explanation utilized in Studies 3 and 4 which could be easily added to preprints. We tested whether this explanation allows non-scientists to differentiate between preprints and the peer-reviewed literature. We further tested whether it matters if this brief explanation is provided by the

authors, or by an external source, but expected the explanation to be effective in both cases. As most preprints are published in English, we tested this in an English-speaking population ($N = 727$; US sample). We also aimed to explore the underlying mechanism of our explanation and tested preregistered mediators (perceived quality control and perceived adherence to publication standards), and moderators (education and familiarity with the publication process).

Method

Participants and design. Participants were US-based individuals recruited on the Amazon MTurk platform in exchange for \$0.50. We randomly assigned participants to one of four between-subject conditions (peer-review condition, preprint: limited information condition, preprint: authors' explanation condition, preprint: external explanation condition). The target sample size was set to 1,000, which allowed us to detect group differences of $d = 0.29$ ($1 - \beta = .95$, one-sided α of .05) and moreover provided sufficient power for an equivalence tests ($1 - \beta = .91$, equivalence bounds of $d = 0.3$). We recruited 1,051 participants, of which 739 passed the preregistered text comprehension check. For the text comprehension check, participants had to answer how the research findings were published (see Study 2). If an additional explanation of peer-review and preprints was given, they also indicated for three additional text comprehension questions whether they were true or false ("Scientific articles are usually peer-reviewed.", "As part of the peer-review process, independent researchers evaluate the quality of the work.", and "Preprints have been peer-reviewed"). If participants answered any of the questions incorrectly, they were asked to read the text carefully again. If they again failed any of the text comprehension questions, they were excluded

from our analyses. Finally, 727 participants responded to all credibility items and were thus included in the main analyses (43.39 % female; age: $M = 39.24$, $SD = 12.68$ y). One participant did not respond to the remaining items, reducing the sample size for secondary analyses to 726. Despite this reduced sample size, a sensitivity analysis revealed that for all possible group comparisons, our sample had at least an 80% power (with $\alpha = .05$) to detect an effect of $d = 0.30$ and a 95% power to detect $d = 0.39$.

Procedure. Participants learned that they would judge the credibility of five research findings and were randomly assigned to one of four conditions. In the *peer-review condition*, participants were informed that the findings went through a peer-review process and were published in a scientific journal. The *preprint: limited information condition* stated that the findings were preprints but in contrast to Studies 1 and 2, it was also added that preprints are not peer-reviewed (without further information, however, what is meant by peer-review). In the other two conditions, the research findings were presented as non-peer-reviewed preprints, but participants received an additional explanation of preprints and the peer-review process. This additional explanation was allegedly either provided by the authors of the preprint (*preprint: authors' explanation condition*) or without any reference to the source in the introduction of the study (*preprint: external explanation condition*).

The explanation was drafted building on the information provided in Studies 3 and 4 but incorporated further feedback from colleagues from various disciplines (anthropology, biology, psychology, and sociology), as well as from non-scientists, to ensure an interdisciplinary perspective and comprehensibility. The explanation highlighted two important aspects, namely that peer-review serves as a quality control

process, and that peer-review currently is the standard procedure for scientific publication. Compared to Studies 3 and 4, we aimed to keep this explanation as comprehensive as possible. This explanation read:

Scientific articles usually go through a peer-review process. This means that independent researchers evaluate the quality of the work, provide suggestions, and speak for or against the publication. Please note that the present article has not (yet) undergone this standard procedure for scientific publications.

After judging the credibility of the research findings, participants were also asked about the perceived quality control of the research findings, the perceived adherence to scientific publication standards, their education, and their familiarity with the publication process. Credibility ratings were given on a 7-point rating scale (ranging from 1 = “not at all credible” to 7 = “very credible”). Familiarity with the publication process (“I am familiar with the scientific publication process”), perceived quality control of the research findings (“The quality of the research findings has been strictly controlled”), and perceived adherence to scientific publication standards (“When publishing their findings, the researchers followed the standard procedure of the research community”) were measured on a 7-point rating scale (1 = “strongly disagree” to 7 = “strongly agree”).

Results

Main analyses. We again computed an average credibility score across all five credibility ratings. As predicted, across both preprint explanation conditions, participants reported lower credibility of research findings compared to the peer-review-condition ($M = 4.65$, $SD = 1.00$). This was the case when participants received the explanation by the

authors ($M = 4.39$, $SD = 1.07$), $t(359) = 2.32$, one-sided $p = .010$, $d = 0.25$, 95% CI[0.04,0.45], as well as by an external source ($M = 4.31$, $SD = 1.02$), $t(379) = 3.25$, one-sided $p < .001$, $d = 0.33$, 95% CI[0.13,0.54], see Figure 6. Interestingly and unexpectedly, this was also the case when participants only received very limited information ($M = 4.42$, $SD = 1.15$), $t(379) = 2.02$, $p = .044$, $d = 0.21$, 95% CI[0.01,0.41]. The three preprint conditions did not significantly differ from each other (all $ps > .317$, all $ds < .10$), and the observed differences between these conditions were all equivalent with an interval containing only small effects ($d < .3$), all $ps < .031$ (see OSF analyses for details).

Figure 6. Pirate plot showing perceived credibility as a function of publication mode and explanation in Study 5 (US participants).

Raw data is not visualized in the figure due to the large number of data points.

Quality Control and Adherence to Scientific Publication Standards. However, the three preprint explanations differed regarding the perceived quality control of the research findings and the perceived adherence to scientific publication standards. Participants who received an explanation reported lower perceived quality control of preprints compared to the limited information condition ($M = 4.27$, $SD = 1.79$). This was the case no matter whether participants received this explanation by the authors ($M = 3.72$, $SD = 1.63$), $t(344) = 2.97$, one-sided $p = .002$, $d = 0.32$, 95% CI [0.11,0.53], or by an external source ($M = 3.81$, $SD = 1.71$), $t(363) = 2.51$, one-sided $p = .006$, $d = 0.26$, 95% CI [0.06, 0.47]. Likewise, after receiving an explanation, participants reported lower perceived adherence to scientific publication standards compared to the limited information condition. This was again the case no matter whether participants received this explanation by the authors ($M = 3.83$, $SD = 1.72$), $t(344) = 3.15$, one-sided $p < .001$, $d = 0.34$, 95% CI [0.13,0.55], or by an external source ($M = 3.95$, $SD = 1.79$), $t(363) = 2.50$, one-sided $p = .007$, $d = 0.26$, 95%-CI [0.05, 0.47].

Moderation Analyses. In line with our preregistration, we also tested whether education or familiarity with the scientific publication process moderated the effect of our explanation on the perceived credibility of research findings (compared to the peer-review condition). For these analyses, we merged the preprint: authors' explanation-condition and the preprint: external explanation-condition, as they did not differ on any of the relevant variables. We conducted multiple linear regression analyses to test whether any of our potential moderator variables moderated the relationship between explanation (detailed explanation vs. peer-review) and credibility. Indeed, whereas centered education did not significantly interact with our explanation ($b = -0.22$, $SE = 0.14$, $t(539) = 1.58$, p

= .115), centered familiarity with the publication process was a significant moderator, indicating that our explanation was more effective for people who indicated a higher familiarity with the scientific publication process ($b = -0.12$, $SE = 0.05$, $t(539) = 2.49$, $p = .013$; see Table 4).

Table 4. Multiple linear regression predicting perceived credibility from condition, centered familiarity with the publication process, and their interaction term.

Predictor	<i>B</i>	<i>SE B</i>	<i>t</i> (539)	<i>p</i>
Condition (0 = <i>peer-review</i> , 1 = <i>explanation</i>)	-0.22	0.09	2.46	.014
Familiarity (Centered)	0.23	0.04	5.85	<.001
Condition * Familiarity (Centered)	-0.12	0.05	2.49	.013

Mediation Analyses. Finally, we explored preregistered mediators of the effect of our explanation on credibility (compared to the peer-review condition). For these cross-sectional analyses, we again merged the authors' explanation-condition and the external explanation-condition, as they did not differ on any of the relevant variables. We investigated whether perceived quality control or perceived adherence to publication standards mediated the negative effect of explaining preprints on perceived credibility. To test this, we ran a parallel mediation model (see Figure 7) with 10,000 bootstrap resamples, using the R package lavaan (Rosseel, 2012). This model revealed that both perceived quality control ($b = -0.23$, 95% CI [-0.14, -0.33]), as well as perceived

adherence to publication standards ($b = -0.25$, 95% CI $[-0.15, -0.35]$) simultaneously mediated the effect.

As this mediation model relied on cross-sectional data, these results should be considered with caution because the mediating variables were not experimentally manipulated and may be biased (Bullock et al., 2010). An observed statistical mediation cannot conclusively prove actual mediation (Fiedler et al., 2011) and should rather be seen as a tentative hint for mediation.

Figure 7. Parallel mediation analyses involving perceived quality control and adherence to publication standards as dual, simultaneous mediators for the link between explanations (0 = peer-review condition, 1 = merged explanation conditions) and perceived credibility. Values represent standardized path coefficients. The total effect is presented in parentheses.

* indicates significance at the $p < .05$ level, ** at the $p < .01$ level, and *** at the $p < .001$ level.

General Discussion

A central argument against preprints is that non-scientists might fail to differentiate them from the peer-reviewed literature (Fox, 2018; Vazire, 2020). Indeed, non-scientists from Germany (Study 1) and the US (Study 2) perceived research findings published as preprints as equally credible as research findings published in peer-reviewed journals. However, a brief explanation of the peer-review process, combined with the information that preprints are not peer-reviewed, led non-scientists to perceive identical research findings published as preprints as less credible than the peer-reviewed literature. This effect was observed for research findings in general (Study 3), and specific psychological research findings (Studies 4 and 5). Study 5 further suggested that even a very brief explanation, which could be added to all preprints, allowed non-scientists to differentiate them from the peer-reviewed literature. Importantly, this effect emerged independently of whether this explanation was allegedly provided by the preprints' authors, or by an external source, even though the effect was descriptively smaller in the former situation. The explanation seemed to be especially effective for individuals who are rather familiar with the scientific publication system, and it seems to work by influencing whether non-scientists see preprints as quality-controlled and as adhering to publication standards. In other words, when non-scientists are well-informed about the source of information, they are able to adjust their credibility ratings accordingly.

In practice, however, most psychological preprints do not contain such an explanation. The pilot study, in which we coded recent preprints from two popular psychological preprint servers, revealed that less than 30% of preprints contained information that they are a preprint. Even fewer mentioned that they are not peer-

reviewed and virtually none provided an explanation similar to the one used in our studies. Taking this current status quo into account, our findings suggest that non-scientists might currently be unable to differentiate between preprints and the peer-reviewed literature.

Some scholars (e.g., Elmore, 2018) have pointed to the fact that the term preprint is a misnomer because there may never be a future print version in a scientific journal (e.g., if the preprint does not pass the peer-review process). Non-scientists might, however, believe that preprints are in fact earlier versions of already published and peer-reviewed articles. This discrepancy could explain why Study 5 found that simply stating that preprints have not yet passed peer-review—something that many individuals are probably not aware of—already reduced perceived credibility. The same study, however, also demonstrated that a more detailed explanation led to a stronger differentiation between preprints and peer-reviewed literature regarding their perceived quality control and their perceived adherence to publication standards, which were relevant mediators. We thus recommend that future authors of preprints, but also preprint servers or science journalists covering preprints, should briefly explain the peer-review process and highlight that preprints are non-peer-reviewed. Our research suggests that such an explanation might be especially effective if it includes elements that indicate that peer-review serves as a quality control process and that it is the standard procedure for scientific publication.

One important discussion point, however, is whether it is desirable that non-scientists differentiate between preprints and peer-reviewed literature in terms of credibility. Even though the peer-review system leads to improvements of a manuscript

(Carneiro et al., 2019; Godlee et al., 1998; Goodman et al., 1994; Schroter et al., 2004), it also has serious drawbacks (Heesen & Bright, 2019; Huisman & Smits, 2017; Jukola, 2017), and one might argue that preprints are not necessarily less credible than peer-reviewed articles. Regardless of whether peer-reviewed papers are objectively more credible, we find that if provided with information about the differences between preprints and peer-reviewed articles, participants used this information to inform their credibility judgments. We, therefore, argue that this information should not be withheld. In contrast to more patronizing statements, such as the statement by *BioRxiv* (preprints “should not be regarded as conclusive, guide clinical practice/health-related behavior, or be reported in news media as established information”), our approach leaves it up to the reader to decide whether a preprint is less credible.

Even if one agrees that preprints are on average less credible than peer-reviewed articles, it could be argued that it is not desirable to reduce the perceived credibility of all preprints, as some preprints may be in fact highly credible. However, as psychological research findings are often non-replicable (Open Science Collaboration, 2015) and context-sensitive (Van Bavel et al., 2016), we argue that it is better to err on the side of caution by increasing non-scientists vigilance towards preprints, even if this may not always be necessary. This does not imply, of course, that non-scientists (should) rely solely on whether a manuscript is a preprint when evaluating its content. In fact, recent work suggests that non-scientists are also sensitive to other important aspects of scientific research, such as the strength of evidence (Hoogeveen et al., 2020) or successful replications of the presented work (Hendriks et al., 2020).

It is also important to discuss the generality of our findings (Simons et al., 2017). First, as we replicated our findings in rather different samples (US-MTurk users and German students), we expect our findings to replicate also in more representative samples for these and other (Western) countries. Notably, however, we found that our explanation was more effective for participants who reported a high familiarity with the publication process. This might explain why we observed substantially larger effects in Germany: As the German samples mostly consisted of undergraduate students, they might be more familiar with the publication process, compared to the US-samples of Amazon MTurk users. Thus, familiarity with the publication process might constrain the generality of our findings. From an applied perspective, it seems likely that non-scientists seeking out preprints might be rather familiar with the publication process (e.g., journalists), which means that our explanation would be rather effective in such a situation. However, it is also possible that this is a methodological artifact: participants who read our materials more closely might consequently report a higher familiarity with the publication process, as well as being more strongly affected by the manipulation.

Moreover, it seems likely that the effectiveness of our explanation depends on participants' general trust in science, because our explanation highlights that preprints do not follow the established scientific publication procedure. If, however, participants' trust in the established scientific knowledge is generally low, a deviation from established standards might not reduce, but even increase, trust. This could for example be the case for politically highly conservative participants, who are contemporarily characterized by relatively low trust in science (Gauchat, 2012).

Finally, it would also be vital to test whether our findings generalize to other forms of non-peer-reviewed science communication, such as blogs, podcasts, or popular science magazines. For example, during the COVID-19 crisis, some scientists shared their findings through non-peer-reviewed podcasts and even press conferences (Kupferschmidt, 2020). In such a situation, it might also be desirable to inform the public that the presented research findings have not been peer-reviewed to avoid public overconfidence in the presented research. It however remains possible that the public already perceives such publication formats as rather uncommon and thus less credible, leaving no room for such an explanation to have an additional effect. This remains an interesting question for future research.

In sum, our work suggests that concerns about non-scientists not differentiating between preprints and peer-reviewed psychological literature are legitimate. However, we also suggest and test a solution: preprint authors, preprint servers, and other relevant institutions can likely mitigate this problem by briefly explaining the concept of preprints and their lack of peer-review. This would allow harvesting the benefits of preprints, such as faster and more accessible science communication while reducing concerns about public overconfidence in the presented findings.

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