Research note

P | U | S

Public Understanding of Science
2021, Vol. 30(1) 91–102

DOI: 10.1177/0963662520954370
journals.sagepub.com/home/pus
SAGE

The "replication crisis" in the public eye: Germans' awareness and perceptions of the (ir)reproducibility of scientific research

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Abstract

Several meta-analytical attempts to reproduce results of empirical research have failed in recent years, prompting scholars and news media to diagnose a "replication crisis" and voice concerns about science losing public credibility. Others, in contrast, hoped replication efforts could improve public confidence in science. Yet nationally representative evidence backing these concerns or hopes is scarce. We provide such evidence, conducting a secondary analysis of the German "Science Barometer" ("Wissenschaftsbarometer") survey. We find that most Germans are not aware of the "replication crisis." In addition, most interpret replication efforts as indicative of scientific quality control and science's self-correcting nature. However, supporters of the populist right-wing party AfD tend to believe that the "crisis" shows one cannot trust science, perhaps using it as an argument to discredit science. But for the majority of Germans, hopes about reputational benefits of the "replication crisis" for science seem more justified than concerns about detrimental effects.

Keywords

attitudes toward science, replicability, representative survey, secondary analysis, trust in science

1. Science's "replication crisis" and its public perception

Since the early 2000s, scientists have increasingly meta-analyzed the replication validity of scientific research, testing if empirical studies yield the same results when repeated under the same or similar

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conditions. They discovered, for example, that follow-up studies in genetics often failed to confirm effect sizes found in prior research (Ioannidis et al., 2001), and that most findings from 100 landmark psychological studies could not be reproduced (Open Science Collaboration, 2015). Poor reproducibility[1] rates were also found in medicine (Freedman et al., 2015), economics (Camerer et al., 2016), biology (Baker and Dolgin, 2017), and experimental social science (Camerer et al., 2018).

These findings raised concern in several circles. First, scholars expressed doubts about the reliability and public credibility of science (e.g. Białek, 2018; Maxwell et al., 2015) and even spoke of a "replication crisis" or "reproducibility crisis" (Fanelli, 2018), describing concerns that have been widespread in the scientific community according to a much-noticed survey among 1576 researchers (Baker, 2016). Second, the issue of non-replicability was broached by science funders and policy-makers—in Germany, for example, by government-funded research councils (Rat für Sozial- und Wirtschaftsdaten, 2020) or the National Science Foundation (Deutsche Forschungsgemeinschaft, 2017). Third, news media discussed replication failures. High-profile outlets covered the topic (e.g. Sample, 2015), often adopting the crisis narrative and framing science as "broken" (Hilgard and Jamieson, 2017: 85). Both in the United States and in Europe, journalists suggested that non-replicability might initiate an "avalanche of doubt" (Frith and Frith, 2014), cause the general public to feel "led astray" (Fischer, 2019), and damage science's reputation severely. Only few media took a more optimistic stance, arguing that replication efforts would actually demonstrate how science applies quality criteria and self-correction mechanisms (Jamieson, 2018).

Overall, irreproducibility concerns (apart from those of scientists worried about impediments to scientific progress) adressed two dimensions: First, there were fears that large parts of the general population had become aware of the "replication crisis," and second, that this awareness, perhaps fueled by pessimistic media portrayals, may lead to negative public perceptions of science (Białek, 2018; Jamieson, 2018; Liskauskas et al., 2019). Yet some scholars have expressed hope that the "crisis" would stimulate open science practices which might improve (or restore) public confidence in science (e.g. Vazire, 2020).

But evidence backing these concerns and hopes is lacking as empirical research on public awareness and perceptions of the "replication crisis" is scarce (see Rutjens et al., 2018: 154). *Public awareness* remains particularly under-researched. In such a situation, aggregate online information seeking metrics, such as the number of Google search queries, can serve as a proxy measure for public awareness (Scharkow and Vogelgesang, 2011). Google queries for "replication crisis" and related terms increased around 20-fold from September 2015 to November 2019 (Google Trends, 2020a). It is thus reasonable to assume that awareness of the issue has grown substantially after the Psychology Reproducibility Project published its seminal report in August 2015. Yet during that period, Google users researched the topic only 22% as often as they searched for "Open Science" and related terms, for example, which suggests that public awareness of non-replicability may remain rather low (Google Trends, 2020b). An online pilot survey ($n = 201$; age: $M = 31.9$ years, $SD = 11.1$; gender: 48.8% female) by Anvari and Lakens (2018) seems to support this: Only 9.5% of respondents felt well-informed about a "reproducibility crisis in psychology" (i.e. selected scale options 8–10 on a 10-point scale with 1 = "never heard about it" and 10 = "very well-informed"), whereas the majority indicated low or no familiarity ($M = 3.42$, $SD = 2.46$). However, both estimates of public awareness are limited: Google Trends neither gives insights into total search query numbers nor allows conclusions as to how many people are indeed familiar with the "replication crisis," and Anvari's and Lakens' (2018) pilot survey did not use representative data but a small, and likely biased, non-probability sample.

Public perceptions of the "replication crisis" have been analyzed several times—however, often in experimental or quasi-experimental settings. Hendriks et al. (2020) found in an experiment that failure to replicate a study caused people to rate it less credible and its authors less trustworthy.

Correspondingly, Anvari and Lakens (2018) showed that learning about low reproducibility in psychology decreased trust in past research. Other experiments provide additional evidence for negative effects of irreproducibility on the perceived truthfulness of research results (Ebersole et al., 2016) and on trust in scientists (Wingen et al., 2019). These effects appear to be relatively persistent: Neither explanations of irreproducibility reasons and recent transparency efforts (Wingen et al., 2019) nor information on causes, consequences, and resolutions of the "replication crisis" (Chopik et al., 2018) could stop people from losing trust in science. Further research suggests, however, that admitting the wrongness of an irreproducible study (Fetterman and Sassenberg, 2015), responding to a failed replication by conducting a follow-up study (Ebersole et al., 2016), or successful replication (Hendriks et al., 2020) may compensate or alleviate reputational damage. Moreover, learning about replication failure does not appear to affect individuals' trust in future research (Anvari and Lakens, 2018).

Yet overall, nationally representative evidence on the prevalence and predictors of awareness and perceptions of the "replication crisis"—which would be needed to substantiate claims on its implications for public attitudes toward science—is missing. This also applies to Germany, where the issue has continuously received attention in leading legacy media and scholarly discourse. Therefore, we conducted a secondary analysis of nationally representative survey data collected for the German Science Barometer 2018, a survey on Germans' views on science (Wissenschaft im Dialog, 2020). We examined the following research questions:

***RQ1*:** How prevalent is public awareness of the "replication crisis" in Germany and what predicts this awareness?

***RQ2*:** What are public perceptions of the "replication crisis" in Germany and what predicts these perceptions?

2. Method

To examine the German public's awareness and perceptions of the "replication crisis" and sociodemographic and attitudinal predictors thereof, we ran secondary analyses of survey data from the 2018 wave of the German "Science Barometer" ("Wissenschaftsbarometer"),[2] which annually investigates Germans' attitudes toward science and research based on a nationally representative sample of the German population. The 2018 wave was conducted in August, using computer-assisted telephone interviews (80% landline, 20% mobile phones).[3] A total of 1008 respondents completed the interviews (age: $M = 55.8$ years, $SD = 17.7$; gender: 51.3% female). Sampling relied on a large national sampling frame.[4] The sample was weighted regarding landline/mobile probability, gender, age, occupation, education, federal state as well as size of town and household.

Supplemental Table A1 includes the variables we used in the analyses. *Awareness of the "replication crisis"* was measured as follows: First, all respondents were told that it is part of the scientific research process to replicate studies under the same conditions to test if they yield equivalent results. Second, respondents were informed that "it has recently been reported that [. . .] a certain number of replication studies did not deliver the same results." The wording of this sentence was varied using a split-ballot method, that is, respondents were randomly assigned to receive one of four versions of it. Approximately one quarter of the sample were told that "*within biology* a certain number of replication studies did not deliver the same results," the other quarters were told about non-replicability within economics, medicine, and psychology, respectively. Afterwards, all respondents were asked if they have heard or read about this in the media lately (see Supplemental Table A1 for English translations of original question wordings). This measure addresses the notion

that high-profile media reporting has the potential to raise audience awareness of certain issues (such as the "replication crisis"; McCombs, 2001), especially when covering key events (such as the seminal publication of the Psychology Reproducibility Project in 2015; Kepplinger and Habermeier, 1995). The split-ballot procedure allowed us to account for varying medialization degrees of different disciplines (Schäfer, 2009). The neutral wording, which avoided framing irreproducibility as a "crisis," diminished priming biases for subsequent measures.

To measure *perceptions of the "replication crisis*," three items were administered immediately after the awareness measure to all respondents, regardless of whether they had heard of it. The items asked if respondents agree that non-replicability "shows that you cannot trust science and research," that "replication shows that quality assurance takes place in science and research," and that "errors and their corrections are part of science and research." Agreement was measured with 5-point Likert-type scales (1="completely agree," 5="completely disagree"; inverted for analyses). Respondents were allowed (yet not explicitly offered) to answer "don't know." The first of these items captures respondents' perception of a loss of epistemic trustworthiness (Hendriks et al., 2016). As such, it pertains to scholarly and public concerns about detrimental effects of the "replication crisis" on public confidence in science (Białek, 2018), which have already been observed in experimental research (e.g. Wingen et al., 2019). The item also ties in with the assumption that negative media framing of the "replication crisis" may have translated into negative audience perceptions (Jamieson, 2018). Meanwhile, the second and third item address hopes that replication efforts may illustrate the self-correcting logic of science and thus cause people to adopt or maintain favorable attitudes toward science (e.g. Vazire, 2020).

In addition, we selected a number of possible *predictor variables* from the Science Barometer. We opted for age, gender, household income per month, education, region of residence, party preference, religiosity, interest in science, frequency of contact with science (mean index), and proximity to science (score), because previous research has suggested that these variables may influence public opinion about controversial scientific issues such as data fraud (Pickett and Roche, 2018), politicized research topics (Merkley, 2020), or scientific uncertainty (Broomell and Kane, 2017). Importantly, we dichotomized party preference, distinguishing between supporters of the German populist right-wing party Alternative for Germany (AfD) and non-AfD supporters, to obtain a binary proxy measure for populist attitudes (see Loew and Faas, 2019, who found a significant positive relationship between populist attitudes and AfD voting). This measure allowed us to examine if the "replication crisis" resonates with two core ideas of populism, that is, anti-elitism and a preference for common-sense solutions (Mudde, 2004), such as that respondents with populist attitudes have greater awareness and more negative perceptions of the "crisis," because it corresponds with their views of science being a corrupt elite and of common sense being a legitimate alternative to allegedly unreliable and useless scientific knowledge (Mede and Schäfer, 2020).[5]

3. Results

Prevalence and predictors of awareness of the "replication crisis" (RQ1)

A large part of the German population is not aware of the "replication crisis." More than 75% have not heard about replication failures in biology, economics, medicine, or psychology (see Figure 1). Actual awareness may be even lower among the population due to false recognition and social desirability—two biases known for recognition measures such as the one we relied on (Gruneberg et al., 1977; Roediger and McDermott, 1995).

Descriptive analyses suggest that familiarity with failed replication efforts varies by discipline. Germans seem to be most aware of most recent irreproducibility findings (i.e. in biology and economics), and least aware of "replication crises" in fields where first large-scale meta-analyses date back to

2015 (i.e. medicine and psychology). Yet overall, these differences are not significant: Rao-Scott adjusted $\chi^2(3, 998)=8.56$, $p=.36$. Only irreproducibility in biology is significantly better known than irreproducibility in psychology ($b=-1.00$, $p < .05$, OR = 0.37, see regression results in Table 1).

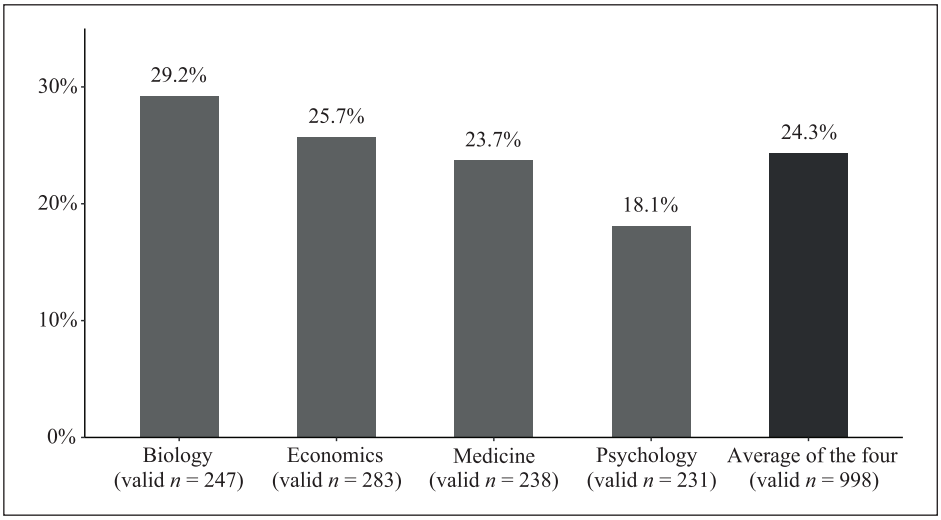

Figure 1. Share of Germans who have heard of replication failures in different fields.
Valid n values are rounded weighted frequencies and percentages are based on these frequencies.

Table 1. Predictors of awareness of replication failures: Binary logistic regression on weighted data.

Predictor	*b*	*SE*	*OR* [95% CI]
(Intercept)	−4.28***	0.99	–
Age	0.03***	0.01	1.03 [1.01, 1.05]
Gender (1 = female)	−0.36	0.28	0.70 [0.40, 1.20]
Household income	−0.05	0.10	0.95 [0.79, 1.15]
Education (1 = university degree)	0.68*	0.33	1.97 [1.03, 3.78]
Region (1 = East Germany)	0.23	0.40	1.26 [0.58, 2.76]
Party preference (1 = AfD)	0.26	0.63	1.29 [0.37, 4.45]
Religiosity	−0.09	0.11	0.91 [0.73, 1.13]
Interest in science	0.13	0.15	1.14 [0.84, 1.54]
Frequency contact with science	0.58*	0.28	1.79 [1.04, 3.08]
Proximity to science	0.14	0.21	1.15 [0.76, 1.74]
Split-ballot group assignment (ref.: replication failures in biology)			
Replication failures in economics	−0.52	0.39	0.60 [0.28, 1.27]
Replication failures in medicine	−0.44	0.37	0.65 [0.31, 1.34]
Replication failures in psychology	−1.00*	0.45	0.37 [0.15, 0.89]

SE: standard error; OR: odds ratio; CI: confidence interval.
Valid $n = 748$. McFadden's Pseudo-$R^2 = .19$***. Akaike information criterion (AIC) = 739.87. Dependent variable: awareness of "replication crisis" in biology, economics, medicine, or psychology (split-ballot procedure; 1 = yes, 0 = no). Analysis used survey weights and was run with the R package survey v4.0. Assumption checks can be retraced in the Supplemental material.
*$p < .05$, ***$p < .001$.

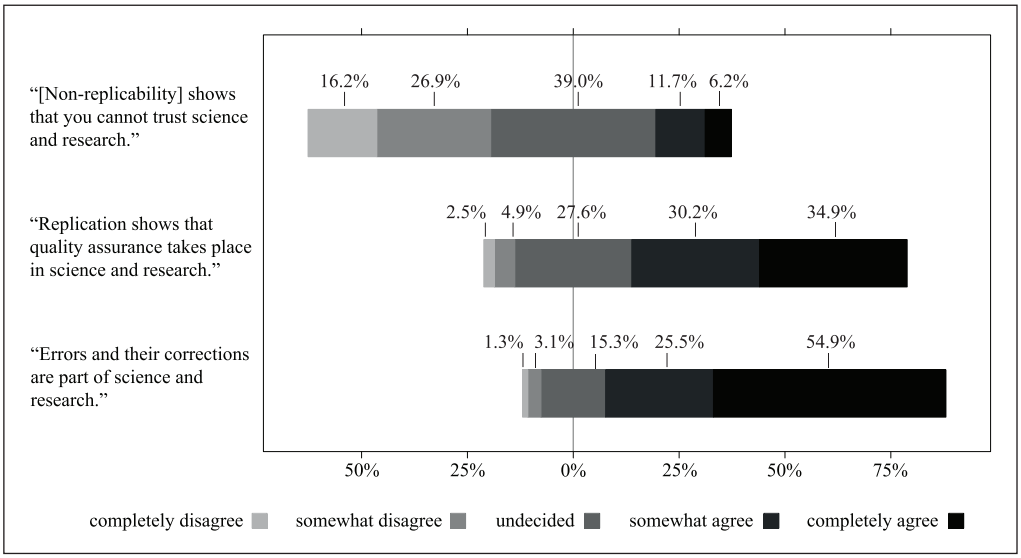

Figure 2. Germans' perceptions of replication failures and replication efforts.
Percentages are based on weighted frequencies.

To explore which segments of the German public are most likely to be aware of the "replication crisis," we investigated sociodemographic, attitudinal, and behavioral predictors of awareness in a binary logistic regression model (see Table 1). Results indicated very good model fit (McFadden's Pseudo-$R^2 = .19$)[6] and revealed that older people with a university degree and frequent contact with science are more likely to have heard of replication failures.

Prevalence and predictors of perceptions of the "replication crisis" (RQ2)

Generally, Germans' perceptions of replication failures and efforts are rather favorable. Only a minority agrees somewhat or completely that irreproducibility "shows that you cannot trust science and research" (17.9%, see Figure 2). Average agreement is just 2.65 on a 5-point Likert-type scale, with higher values indicating stronger agreement ($SD = 1.08$; valid $n = 983$). Yet many people think that "replication shows that quality assurance takes place in science and research" (65.0%; $M = 3.90$; $SD = 1.02$; valid $n = 965$) and that "errors and their corrections are part of science and research" (80.4%; $M = 4.30$; $SD = 0.92$; valid $n = 978$). Notably, these perceptions seem to refer to different underlying concepts as they correlate only moderately (Cronbach's alpha = .39). This suggests that people who see replication failures as a reason for distrusting science are often not those who deny that errors and their corrections are part of science.

Positive perceptions of non-replicability seem to be relatively evenly distributed among the German population, as multiple linear regression models only explain a small part of their variance (Adj. $R^2 = .04$ and .08, respectively). Nevertheless, we find that interest in science and awareness of replication failures predict acknowledgment of the self-correcting nature of science (see Table 2). Analyses also show that university education predicts recognition of verification efforts.

Germans' perception that the "replication crisis" reveals an untrustworthy science, however, can be explained quite well (Adj. $R^2 = .18$). It is particularly prevalent among older people—and among supporters of the German populist right-wing party AfD (see Table 2). Follow-up analyses

Table 2. Predictors of perceptions of replication failures and replication efforts: Multiple linear regressions on weighted data.

Predictor	"[Non-replicability] shows that you cannot trust science and research."				"Replication shows that quality assurance takes place in science and research."				"Errors and their corrections are part of science and research."			
	b	[95% CI]	*SE*	β	*b*	[95% CI][a]	*SE*[a]	β	*b*	[95% CI][a]	*SE*[a]	β
(Intercept)	2.78***	[2.05, 3.50]	0.37	2.64	3.26***	[2.44, 4.02]	0.40	3.95	3.42***	[2.72, 4.10]	0.35	4.36
Age	0.01***	[0.01, 0.02]	0.003	0.50	0.001	[−0.01, 0.01]	0.003	0.04	−0.001	[−0.01, 0.01]	0.003	−0.04
Gender (1 = female)	−0.14	[−0.37, 0.08]	0.12	−0.14	−0.01	[−0.24, 0.22]	0.12	−0.01	0.04	[−0.16, 0.24]	0.10	0.04
Household income	−0.03	[−0.11, 0.05]	0.04	−0.10	−0.001	[−0.09, 0.09]	0.05	−0.002	0.06	[−0.03, 0.13]	0.04	0.16
Education (1 = university degree)	−0.13	[−0.42, 0.16]	0.15	−0.13	0.29*	[0.03, 0.54]	0.13	0.29	0.10	[−0.13, 0.33]	0.12	0.10
Region (1 = East Germany)	−0.10	[−0.39, 0.18]	0.15	−0.10	−0.26	[−0.68, 0.14]	0.21	−0.26	0.17	[−0.09, 0.44]	0.14	0.17
Party preference (1 = AfD)	0.76**	[0.30, 1.23]	0.24	0.76	0.16	[−0.25, 0.63]	0.22	0.16	0.21	[−0.14, 0.60]	0.19	0.21
Religiosity	0.01	[−0.07, 0.09]	0.04	0.03	0.10*	[0.02, 0.19]	0.04	0.25	0.03	[−0.05, 0.11]	0.04	0.07
Interest in science	−0.08	[−0.21, 0.06]	0.07	−0.17	0.02	[−0.12, 0.17]	0.07	0.05	0.13*	[0.02, 0.26]	0.06	0.29
Frequency contact with science	−0.09	[−0.30, 0.12]	0.11	−0.12	0.08	[−0.17, 0.34]	0.13	0.11	0.09	[−0.08, 0.27]	0.09	0.13
Proximity to science	−0.13	[−0.31, 0.05]	0.09	−0.18	−0.06	[−0.24, 0.10]	0.09	−0.09	−0.04	[−0.18, 0.11]	0.07	−0.06
Awareness of "replication crisis" (1 = yes)	−0.12	[−0.38, 0.14]	0.13	−0.12	0.04	[−0.22, 0.30]	0.13	0.04	0.24*	[0.06, 0.44]	0.10	0.24
Split–ballot group assignment (ref.: replication failures in biology)												
Replication failures in economics	−0.09	[−0.39, 0.21]	0.15	−0.09	0.23	[−0.04, 0.52]	0.14	0.23	−0.15	[−0.43, 0.15]	0.15	−0.15
Replication failures in medicine	0.15	[−0.19, 0.48]	0.17	0.15	−0.002	[−0.38, 0.38]	0.19	−0.002	0.06	[−0.20, 0.31]	0.13	0.06
Replication failures in psychology	0.08	[−0.25, 0.41]	0.17	0.08	0.33*	[0.07, 0.62]	0.14	0.33	−0.15	[−0.43, 0.12]	0.14	−0.15
Adj. R^2	.18***				.04***				.08***			
AIC	703.31				702.43				532.22			
N	735				731				740			

CI: confidence interval; SE: standard error; AIC: Akaike information criterion.
Analyses used survey weights and were run with the R package survey v4.0. Standardization of b values follows Gelman's (2008) suggestion to rescale the estimates by dividing them by two standard deviations instead of one. Assumption checks can be retraced in the Supplemental material.
[a]The assumption of normality of the residuals was violated for these regression models (see Supplemental Figures A4-A9). Therefore, confidence interval bounds and standard errors of regression coefficients were bootstrapped. Bootstrapping was done with the R package boot v1.3-25 using non-studentized pivotal confidence interval estimation. Yet bootstrapped confidence intervals and standard errors differed only marginally from original confidence intervals and standard errors.
*$p < .05$, **$p < .01$, ***$p < .001$.

suggest that their opinion on replication failures is significantly more critical than that of supporters of other parties: While AfD voters tend to agree that such failures show that one cannot trust science ($M=3.52$; $SD=1.09$), non-AfD voters disagree ($M=2.61$; $SD=1.05$; $t=4.22(921)$, $p<.001$). Interestingly, however, AfD supporters have not heard of replication failures significantly more often than non-AfD supporters ($t=0.87(933)$, $p=.39$). This suggests that AfD voters may willingly take the "replication crisis," perhaps right after learning about it, as an argument to adopt or justify a critical position toward science. Meanwhile, sociodemographic, attitudinal, or behavioral variables other than age and party preference do not explain Germans' tendency to believe that science is not trustworthy due to irreproducibility. Awareness of replication failures is not a significant predictor either.

4. Discussion

Our secondary analysis of the German "Science Barometer" offers representative evidence on public awareness and perceptions of the so-called "replication crisis." It suggests that broad concerns about its public impact are unjustified. First, only a quarter of the German population has heard about failures to reproduce empirical research. While this is considerable, a large majority of people is *not* aware of it. Second, most Germans do not perceive irreproducibility negatively as they interpret replication efforts as an indication of science's self-correcting nature. Third, awareness of non-replicability does not predict negative perceptions of it. Overall, this indicates that concerns about a public backlash of the "replication crisis" are not justified, at least for Germany. It may rather draw individuals' attention to scientific quality control and thus have positive implications for public attitudes toward science. This result is reassuring insofar as science depends on public confidence and legitimization to fulfill its function in society (Hendriks et al., 2016).

We also found, however, that the "replication crisis" may evoke or reinforce negative attitudes toward science among specific groups of the population. One of these groups are supporters of the German populist right-wing party AfD. They tend to believe that replication failures show that one cannot trust science, yet they had not heard particularly often about such failures before the survey. This indicates that the "replication crisis" accommodates AfD supporters' existing views on science by providing a plausible narrative of an untrustworthy science which bolsters those "anti-scientific sentiments" that many AfD supporters already endorse (Krämer and Klingler, 2020: 256). As such, the "replication crisis" may fuel processes which have been conceptualized as "motivated reasoning" (Kraft et al., 2015) or "cultural cognition" (Kahan et al., 2011) and which have been observed in research showing that exposure to populist arguments can increase the salience of anti-intellectual attitudes (Merkley, 2020). While AfD voters' perceptions of replication failures reflect minority positions, their views may still resonate in the German public as they report liking, sharing, or commenting social media content about science and research more frequently than supporters of other parties (Wissenschaft im Dialog, 2018: 119). From this perspective, concerns about reputational damage to science caused by irreproducibility are at least partly justified, and may be even more justified in the future.

While these findings were drawn from a German survey, some of them may apply to countries whose populations have similar views on science, like the United States, Australia or Northern European countries (Gallup, 2019), and where populist movements also challenge science (Mede and Schäfer, 2020). Future survey research is nevertheless needed to further substantiate this assumption. Such research may still find evidence for negative reputational implications of the "replication crisis"—or, in case of results similar to ours, help current open science efforts gain traction (e.g. Dienlin et al., 2020).

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The Science Barometer Germany 2018 was funded by the Robert Bosch Foundation and methodological advice was provided by GESIS—Leibniz-Institute for Social Sciences, and by an international advisory board that includes Mike S. Schäfer.

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Supplemental material

Supplemental material for this article is available online.

Notes

1. Some scholars argue that replicability and reproducibility refer to different concepts. LeBel et al. (2018), for example, define replicability as the ability of study results to be consistently observed in *new* samples using "methodologies and conditions *similar* to those of the original study," and reproducibility as the ability of results to be consistently observed when "repeating the *same* data processing and statistical analyses on the *original* data" (LeBel et al., 2018: 390; emphasis added). However, other scholars use both terms interchangeably (e.g. Anvari and Lakens, 2018; Chopik et al., 2018; Ebersole et al., 2016). We do that as well, as we are not concerned with the different variants and degrees of replicability (reproducibility) but with public awareness and perceptions of all variants and degrees of non-replicability (non-reproducibility).
2. We share the R Syntax we used for the analyses, a compiled R Markdown file with annotations in HTML format, and a professional English translation of the survey questionnaire on https://osf.io/2h9yx/. The survey data and additional materials (e.g. the questionnaire and a methodological report, both in German) can be accessed/requested via the GESIS Data Archive, doi: 10.4232/1.13241 (Wissenschaft im Dialog, 2019).
3. The survey was carried out by Kantar Emnid as part of an omnibus survey that also contained questions on education, migration, and health.
4. The sampling frame was provided by the ADM, the leading business association for private market and social research institutes in Germany (for details see ADM, 2020).
5. With this secondary analysis, we aimed to explore public awareness and perceptions of the "replication crisis" utilizing an existing nationally representative survey data set. What motivated us to investigate specifically whether AfD support predicts awareness and perceptions was previous theoretical and empirical research suggesting that criticisms of science often interact or coincide with populist ideas (e.g. Huber, 2020; Krämer and Klingler, 2020; Mede and Schäfer, 2020; Merkley, 2020).
6. Values of McFadden's Pseudo-R^2 tend to be considerably lower than R^2 values for OLS regression models, so both should not be evaluated by the same standards. Unlike traditional R^2 values, values of McFadden's Pseudo-R^2 greater than .20 already "represent an excellent fit" (McFadden, 1979: 307).

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