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"Publicationism" and scientists' satisfaction depend on gender, career stage and the wider academic system

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ABSTRACT The biological sciences have experienced a significant increase in journals and hence in publications in recent decades. The increasing number of research contributions reflects the "publish-or-perish" culture of science. The resulting pressure to publish may affect the publishing and working behaviour of researchers. However, the pressure to publish and the satisfaction while publishing scientific results may vary between genders and across career stages. Little effort has been taken to understand how scientists are affected by this pressure and how it may differ among groups of scientists. Therefore, we anonymously interviewed almost 1000 scientists from the field of the biological sciences, including female and male researchers at all career stages, to investigate potential negative effects of the pressure to publish, but also positive feelings (i.e. satisfaction) resulting from publishing. We assessed basic personal attributes (i.e. age, gender, career stage), and the personal attitude and feeling towards publishing. Our data indicates that "publicationism", an index of stress arising from the pressure to publish, depends on age and gender. Female scientists suffered stronger from publicationism (publicationism score = 2.577) than male scientists (score = 2.364). Publicationism decreased with increasing age (drop of 0.19 index points), and was more intense for scientists from the United States (score = 2.91) than for Germans (score = 2.20). Most scientists felt satisfied when contributing to science by publishing their work and satisfaction lasted longer with increasing age. Our data show a weak negative correlation between publicationism and satisfaction. Thus, publishing in the biological sciences produces an ambivalent situation, which positively stimulates older, experienced scientists, but which may stress young researchers, in particular females. Publicationism further depends on the academic system and employer of the scientist.

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Introduction

Career perspectives in science are currently strongly driven by publication pressure as a result of the ongoing publish-or-perish policy. While communicating scientific results was originally based on the publication of key results or overviews in books and scientific journals, the struggle for funding and positions has led to a publication-record driven science business during the past decades (Larsen and von Ins, 2010; Bornmann and Mutz, 2015). The establishment of metrics to rank the quality of a journal (for example, Impact Factor, h-index, Kokko and Sutherland, 1999) has further enforced the urge of publishing in most research fields of natural sciences accelerating the number of articles published. As a consequence, today, scientists attempt to publish many articles in high profile journals being recognized by a broad readership. A high scientific output in well-perceived journals directly affects funding and job opportunities (Marks *et al.*, 2013).

The publication metrics, the pressure to publish and science policy strongly affect the way scientists work today: long-term studies have become rare as they do not provide fast research output, more time is allocated for writing articles rather than conducting experiments and analyses, and researchers start splitting scientific data into smaller sub-sets to fulfil the goal of publishing a large number of articles in constant search of the "least-publishable" unit (McCallum and McCallum, 2006; Dupps and Randleman, 2012; Grossman, 2014). This strong publication pressure may lead to less innovative research (Foster *et al.*, 2015) and increasing scientific misconduct has been identified and interpreted as one result of ongoing publication pressure (Fang *et al.*, 2012). Besides its negative effects on the quality and credibility of science, the constant pressure may also lead to serious psychological problems for many scientists (e.g., the impostor syndrome, Woolston, 2016).

Meanwhile, researchers and science politicians have started to critically reflect on the efficiency of this publication-driven research environment, as it creates a situation counteracting stimulating researchers in positive ways (Stergiou and Lessenich, 2013; Engler and Husemann, 2014), potentially even leading to addictive behaviour (Silverman, 1999) or other psychological dependencies (Woolston, 2016). Recent studies have shown that science policy, particularly publication policy, strongly affects the working behaviour of scientists, who, apart from doing sound research, also struggle for survival in the world of academia and compete for limited funding and (permanent) positions (Stergiou and Lessenich, 2013; Engler and Husemann, 2014).

The arising pressure may be perceived differently depending on a variety of factors, e.g., gender, country, career stage, age and the type of employer (university or non-university). This, however, has not been comprehensively assessed so far. Thus, we performed a global interview-based survey of publication behaviour to test for potential effects of "publicationism", a newly introduced index of mental stress derived from publication pressure. We anonymously interviewed almost 1000 active researchers from different fields of biological science to gain insights in their publication behaviour with specific focus on publicationism and satisfaction derived from publishing. On the basis of the data we aimed to answer the following questions:

(i) Do age, gender, type of employer, or country affect the level of publicationism?
(ii) Do age, gender, type of employer, or country affect the level of satisfaction?
(iii) Are satisfaction and publicationism experienced by an individual researcher correlated with each other?

Material and methods

Questionnaire. The questionnaire consisted of the following main components: basic personal details, information on the career stage and the type of employer, and personal feelings resulting from publishing (publicationism and satisfaction). For most questions asked in our questionnaire we provided five categories of answers with gradual steps, from a negative to a positive reply (that is, agreement to disagreement). These steps were based on a five-point Likert scale, which is widely used to record the level of agreement and disagreement with series of statements that together form a multiple-indicator or time measure (Bryman, 2008). We used this scale as a proxy for the intensity of feelings of the participants concerning specific issues: these values allow for objective comparability.

Personal details included gender, age and the country in which the scientist is currently working. To reflect the career stage, the following parameters were assessed: time working in science (in years) and the currently held position of the participant (PhD, PostDoc, Research fellow, Lecturer, Assistant professor, Associate professor, Junior professor, Full professor, Head of department and so on). For this survey, we exclusively contacted scientists working in the field of biology.

We introduced the new term publicationism, adopted from workaholism, to express the internal pressure of a scientist to publish. To measure the level of publicationism we developed a new index based on 10 questions (see Supplementary material S1.1) and a ranking taken from studies in which the degree of workaholism was analysed (Taris *et al.*, 2005; Andreassen, 2014). Originally, a 17-item scale called "DUWAS" (Dutch Work Addiction Scale) was proposed by Schaufeli *et al.* (2006). A shorter 10-item scale was used in the Netherlands and Japan and has shown to provide valuable psychometric data (Schaufeli *et al.*, 2009). We decided to use the short scale, as Del Líbano *et al.* (2010) suggested that the shorter questionnaire provides better indication of workaholism. We used the original wording of the DUWAS scale, but specifically changed the introduction sentence by asking to rate 10 items (on the original four-point Likert scale) based on feelings beginning with the statement "During the publishing process, I...". The detailed statements and the respective means and standard deviations are given in the Supplementary material S1.1.

In the following, we asked for the number of articles published (by providing five categories: 1 = < 5, 2 = 5–10, 3 = 11–20, 4 = 21–50, 5 = > 50), and the feeling of satisfaction resulting from publishing (five-point Likert scales), as well as reasons for satisfaction (that is, reasons to publish—multiple answers possible). We asked for the duration of being satisfied after an article becomes accepted (five categories ranging from < 1 h to > 1 month) and, whether the feeling of satisfaction lasted longer at the beginning of the career compared with later career stages (five-point Likert scale ranging from "not at all" to "very strongly").

Quality control and data assessment. Twenty pre-test questionnaires were filled out by departmental colleagues and researchers from other fields of science. Comments have been used to further adjust and improve the questionnaire. Moreover, technical pre-tests have been done by the authors to guarantee that entries of online answers of participant's were recorded as the correct values in the online data set, which was used for statistical analyses.

The questionnaire was composed as structured online website using the SoSci-Survey online tool (Leiner, 2014). We performed the survey for a total of 119 days (from 3 August 2015 to 30 November 2015). The web link was spread to colleagues from the

same and related research fields of biological sciences in several ways: first, we send the link to colleagues by personal email and asked them to forward it to further colleagues. This approach is known as snowball sampling and is frequently used in social sciences (Bryman, 2008). To reduce potential bias in sampling (see also the discussion section) we gained additional participants by approaching department leaders of a number of universities, by posting the link on different social media platforms (Facebook, Twitter, Researchgate) and by using scientific and societal list servers (EvolDir, Ecolog-L, Ecological Society of Germany, Switzerland and Austria (GfÖ), German Zoological Society (DZG), Society for Biological Systematics (GfBS)).

We received 930 completed surveys in total. After deleting interviews of undergraduates and technical staff (as they were not our target audience), 918 interviews remained in our data set and were used in further analyses. As we did not force participants to answer every item, the sample size varied across questions due to missing answers. Therefore, sample sizes are reported for each analysis.

The full data sets analysed in this study are available in figshare (https://figshare.com/s/89fdb482b6ea810407c7).

Statistics. To simplify the data obtained from the DUWAS questions we condensed the 10 items into a single index of publicationism. The internal consistency of the items for the index was computed and suggested good consistency (Cronbach's $\alpha = 0.81$). Cronbach's α is a commonly used test for internal reliability. It essentially calculates the average of all possible split-half reliability coefficients and varies between 0 (denoting no internal variability) and 1 (denoting perfect internal reliability). A value of 0.80 is frequently used as a threshold to denote an acceptable level of internal reliability (Bryman, 2008).

To evaluate the effects of different variables on publicationism and satisfaction, we first tested potential explanatory variables for autocorrelation. Here, the following parameters were taken into consideration: age, career stage, years in science, and number of publications. Career stage was grouped as follows: A = PhD, B = PostDoc/ Research fellow/ Lecturer; C = Assistant/ Associate/ Junior professor, D = Full professor/ Head of department; E = Emeritus, and F = Non-university researcher. All categorical variables were transformed into ordinal categories and coded by numbers.

We found strong correlations between all potential explanatory variables (r-values: 0.54–0.89; see Supplementary material S1.2). Thus, from the four variables (age, career stage, years in science and number of publications), we selected only age as explanatory variable for further analyses, as this variable was showing the least missing values (about 100 additional participants stated age compared to years in science). Furthermore, we separated the type of employer from the career stage by creating two categories of employers: A = university, B = non-university, which were independent of the age of the participants in the sample. Researchers from 54 countries participated in the study. However, participants were not randomly distributed across the world, but showed a strong bias to the United States and Germany. Therefore, in a second analysis, we restricted our analyses to responses from the United States and Germany to test for an effect of country as a proxy for the academic system.

To test for the effects of specific demographic variables (age, gender, type of employer) and their interactions on the index of publicationism we used a linear mixed effect model with a random intercept for the country of origin (function *lme* from the package *nlme*; Pinheiro *et al.*, 2012). In a second analysis we used the reduced data set (the United States and Germany only) to test for effects of the same demographic variables and their interactions with the country of origin in a linear model. In these models categorical variables were coded as follows: Gender, "male" = 1, "female" = 2; Employer, "non-university" = 1, "university" = 2; Country, "Germany" = 1, "USA" = 2. Reported parameter estimates are differences of means compared to the reference level of 1 for each factor included in the final model.

To test for potential effects of demographic variables on the expressed satisfaction after publishing, we calculated multinominal regressions based on the entire data set (function *multinom* from the package *nnet*; Venables and Ripley, 2002). These models quantify the probability that a participant selects a category of the Likert scale as a function of his / her demographic attributes.

Finally, we tested for correlations between publicationism and satisfaction. For these correlations, satisfaction scores were treated as ordinal variable. All analyses were performed using R version 3.3.0 (R Development Core Team, 2016).

Results

Data composition. A total of 930 completed surveys were returned; 918 of these surveys were provided by participants representing our target group. Surveys originated from 53 countries, with the majority coming from Germany ($N = 297$, 32%), the United States ($N = 222$, 24%), and the United Kingdom ($N = 43$, 5%). 35 (4%) of the participants did not indicate their country of current employment. The sex-ratio was relatively balanced, with $N = 514$ (56%) male scientists and $N = 364$ (40%) female scientists; $N = 40$ (4%) of the participants provided no gender information.

Effects on publicationism. On the basis of data of all participating scientists irrespective of their country of origin, gender and age showed significant effects on the level of publicationism (Table 1). Female scientists showed a publicationism score of 2.577 at the median age of participants (38 years), which is 0.213 index points higher than the respective score for males (2.364; Fig. 1). Publicationism significantly decreased with increasing age, dropping by 0.19 index points for each doubling of age of participating researchers (Fig. 1). The type of employer (university / non-university) had no significant effect, and no interactions between any of the explanatory variables were detected (Table 1).

In our second analyses only answers from German and American scientists were included to evaluate potential effects resulting from the two divergent academic systems and cultures in both countries. We tested for the same demographic variables as above and included the country-specific explanatory variable (the United States and Germany) together with all potential interactions in the model. We found significant effects of country on publicationism, with, on average, 0.71 index points higher levels in the United States (2.91 as predicted from the model; median age of 39 for participants of the United States and Germany; accounting for covariates) compared with Germany (2.20; Table 2, Fig. 2). However, the effect of country interacted with the type of employer. For scientists working in the United States, we observed higher levels of publicationism for employees at non-university institutions (3.21 versus 2.61 for university employees), while for scientists working in Germany, publicationism was higher for employees at universities (2.42 versus 1.99 at non university employers; Fig. 2). Overall, similar to the analysis of the complete data set, female scientists suffered from higher levels of publicationism compared to males ($F_{1,467} = 20.25$; $p < 0.001$; Table 2, Fig. 2). However, the effect of gender interacted with age and type of employer in the country specific analysis ($F_{1,467} = 4.581$; $p = 0.033$; Table 2). Male scientists showed a slight decrease in publicationism of 0.25 index points

Table 1 | Effects of demographic variables on the index of publicationism in a linear mixed effect model based on all data including a random effect for the country of origin of participants

Explanatory variable	*Parameter estimates (± SE)*	*Significance*
Intercept	3.36 ± 0.29	**$F_{1,766} = 34.78$; $p < 0.001$**
Gender	0.21 ± 0.04	**$F_{1,766} = 40.08$; $p < 0.001$**
Age*	−0.19 ± 0.05	**$F_{1,766} = 12.71$; $p < 0.001$**
Employer		$(F_{1,760} = 0.202;\ p = 0.654)^5$
Gender:Age*		$(F_{1,759} = 2.627;\ p = 0.106)^4$
Gender:Employer		$(F_{1,758} = 0.285;\ p = 0.594)^3$
Age*:Employer		$(F_{1,757} = 0.087;\ p = 0.768)^2$
Gender:Age*:Employer		$(F_{1,756} = 0.533;\ p = 0.466)^1$

*$\log_2$ transformed; random effect of coutnry = 0.173 sd.
Terms in parenthesis have been removed from the model in the order given by the superscripts. Terms shown in bold are significant in the minimum adequate model. For all terms contained in the minimum adequate model parameter estimates together with their standard errors are given.

Table 2 | Effects of demographic variables on the index of publicationism for the reduced data set restricted to participants from the United States and Germany

Explanatory variable	*Parameter estimates (± SE)*	*Significance*
Intercept	8.03 ± 2.79	
Country	1.21 ± 0.27	**$F_{1,467} = 33.67$; $p < 0.001$**
Gender	−9.05 ± 3.75	**$F_{1,467} = 20.25$; $p < 0.001$**
Age*	−1.13 ± 0.51	**$F_{1,467} = 8.364$; $p = 0.004$**
Employer	−4.35 ± 2.82	$F_{1,467} = 2.202;\ p = 0.138$
Country:Gender		$(F_{1,465} = 0.004;\ p = 0.949)^5$
Country:Age*		$(F_{1,466} = 1.749;\ p = 0.187)^6$
Gender:Age*	1.69 ± 0.68	$F_{1,467} = 2.036;\ p = 0.154$
Country:Employer	−1.02 ± 0.27	**$F_{1,467} = 9.425$; $p = 0.002$**
Gender:Employer	8.14 ± 3.83	$F_{1,467} = 0.003;\ p = 0.955$
Age*:Employer	0.88 ± 0.51	$F_{1,467} = 0.056;\ p = 0.813$
Country:Gender:Age*		$(F_{1,462} = 0.067;\ p = 0.796)^2$
Country:Gender:Employer		$(F_{1,463} = 0.129;\ p = 0.720)^3$
Country:Age*:Employer		$(F_{1,464} = 1.134;\ p = 0.288)^4$
Gender:Age*:Employer	−1.48 ± 0.69	**$F_{1,467} = 4.581$; $p = 0.033$**
Country:Gender:Age*:Employer		$(F_{1,461} = 0.379;\ p = 0.538)^1$

*$\log_2$ transformed.
Terms in parenthesis have been removed from the model in the order given by the superscripts. Terms shown in bold are significant in the minimum adequate model. For all terms contained in the minimum adequate model parameter estimates together with their standard errors are given.

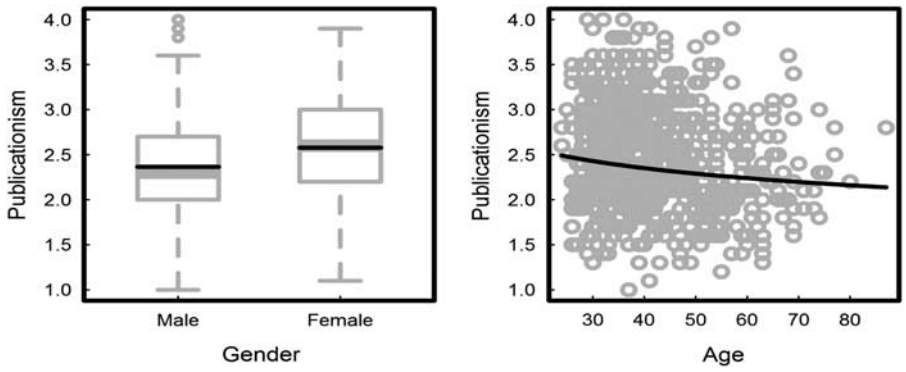

Figure 1 | Effects of demographic variables on levels of publicationism. Only significant effects in a linear mixed-effect model indicated in Table 1 are shown. Left: boxplots (with means, quartiles as box and 1.5 inter-quartile ranges as whiskers. Outlier values are shown as dots) summarizing the measured data. Black lines show average values predicted from the model controlling for co-variables and estimated for an age of 38 (the median age of participants). Right: Relationship of publicationism and age; the line visualizes the significant reduction of publicationism with increasing age as predicted by the model.

with every doubling of age when employed at universities; this effect was more pronounced when males were employed at non-university institutions (decrease of 1.13 index points with each doubling of age). Female scientists, in contrast, exhibited only very slightly decreasing publicationism with age when employed at universities (decrease of 0.04 index points with each doubling of age) and an increasing publicationism with age when employed at a non-university institution (increase of 0.56 index points with

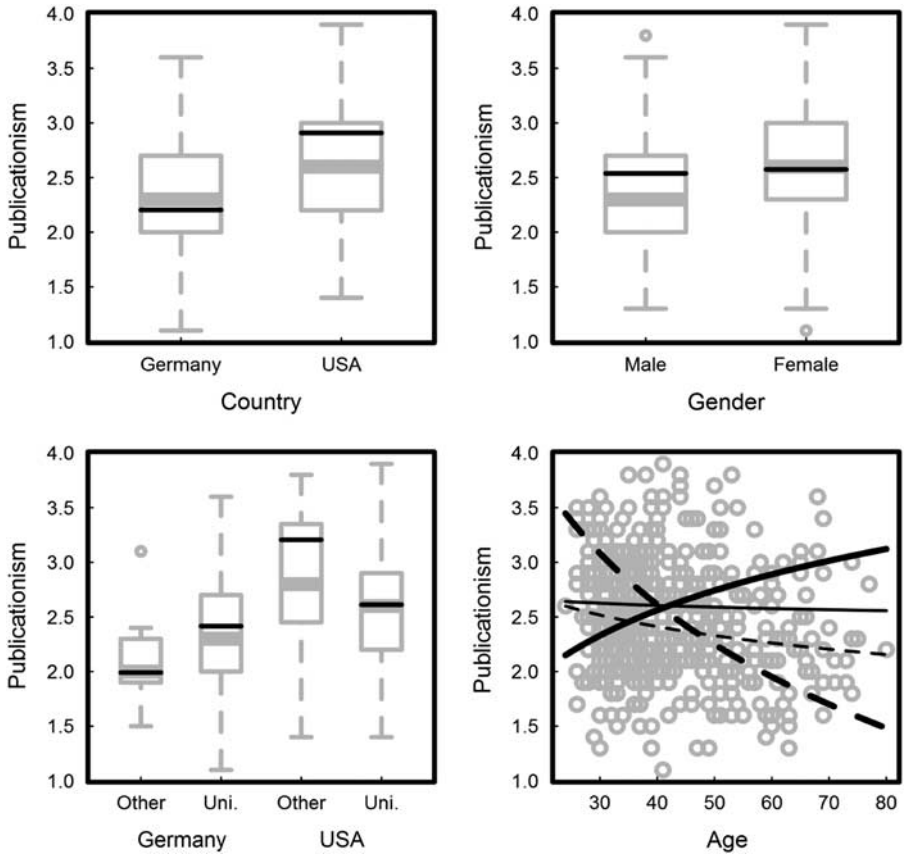

Figure 2 | Effects of demographic variables on levels of publicationism comparing between the United States and Germany. Only significant effects in a linear model indicated in Table 2 are shown. Boxplots show means and quartiles as box and 1.5 inter-quartile ranges as whiskers; outlier values are shown as dots summarizing the measured data. Black lines show average values predicted from the model controlling for co-variables and estimated for an age of 39 (the median age of participants from the United States and Germany). On the bottom left the interaction of country and type of employer (non-university / university) is shown. On the bottom right, the interaction of age, gender, and type of employer is shown. Here again, lines visualize predictions from the model with solid lines representing female scientist and dashed lines male scientist. Thin lines represent university employees and thick lines employees outside of universities.

each doubling of age) (Fig. 2). As a result of these interacting effects publicationism is predicted to be higher for males (3.02) than females (2.40) among young scientists (age 24). At a median age of 39 years, male and female scientists show almost the same level of publicationism (male: 2.54 vs. female: 2.57; Fig. 2). Among senior scientists (age 60) females are predicted to show higher publicationism (2.73) than males (2.11).

Effects on satisfaction. Most participants indicated to feel satisfied ($N=229$, 25%) or very satisfied ($N=579$, 63%) after publishing a manuscript. The most important reason affecting the feeling of satisfaction was the contribution to science ($N=800$, 87%), to improve her/his performance and thus having better career perspectives ($N=471$, 51%), recognition by other scientists ($N=535$, 58%), and a feeling of completion ("not to see the paper anymore") ($N=412$, 45%). Almost a quarter of all participants ($N=221$, 24%) stated that the IF is one of the reasons being satisfied after publishing. 86 (9%) of all participants added extra reasons, for example, "a feeling of accomplishment", "getting permanent records of work quality", "being proud of the work", "contributing to the output of their research group, department and university", "providing evidence of work", or "unfortunate, but necessary, the need to publish in regard of current and future funding".

A multinominal regression indicated that age changed the stated levels of satisfaction after publishing a paper. Increasing age lead to a higher probability of being very satisfied after publishing a paper (Table 3). Lower levels of satisfaction stayed at constantly very low probabilities (Fig. 3, Table 3). The youngest participating scientists (age 24) had a probability of 0.32 of stating to feel satisfied and a 0.54 probability to state they feel very satisfied after publishing a paper. For senior scientists (age 60) the probability to state feeling satisfied decreased to 0.20, while the probability to state feeling very satisfied increased to 0.72. No other demographic variable or any interaction showed significant effects on the level of satisfaction (Table 3). For the time of being satisfied after publishing a paper, the model showed significant effects of age and type of employer (Table 3, Fig. 4); the older the participant the higher the probability that the expressed time of satisfaction is longer. For 24 years old scientists the probability to state that their satisfaction after publishing a paper lasted a week or a month were 0.17 and 0.21, respectively. These probabilities decreased to 0.11 and 0.12 for 60 year old scientists. Over the same period the probability to state that satisfaction lasts longer than a month increased from 0.09 to 0.24. Furthermore, scientists employed at a university stated most often to be satisfied for a week after publishing a paper, while scientists employed at non-university institutions stated most often to be satisfied for more than a month after publishing a paper (Table 3, Fig. 4). Finally,

Table 3 | Effects of demographic variables on the expressed satisfaction after publishing a paper based on the entire data set

Explanatory variable	*Level of satisfaction*	*Time of satisfaction*	*Comparison to earlier satisfaction*
Gender	$(Chi^2_5 = 6.493;\ p = 0.261)^5$	$(Chi^2_4 = 6.163;\ p = 0.187)^5$	$(Chi^2_4 = 2.669;\ p = 0.615)^5$
Age*	**$Chi^2_5 = 17.08;\ p = 0.004$**	**$Chi^2_4 = 25.31;\ p < 0.001$**	$Chi^2_4 = 9.380;\ p = 0.052$
Employer	$(Chi^2_5 = 6.363;\ p = 0.272)^6$	**$Chi^2_4 = 13.69;\ p = 0.008$**	$(Chi^2_4 = 5.501;\ p = 0.240)^6$
Gender:Age*	$(Chi^2_5 = 1.331;\ p = 0.932)^4$	$(Chi^2_4 = 5.055;\ p = 0.282)^4$	$(Chi^2_4 = 2.123;\ p = 0.713)^2$
Gender:Employer	$(Chi^2_5 = 1.769;\ p = 0.880)^3$	$(Chi^2_4 = 2.526;\ p = 0.640)^3$	$(Chi^2_4 = 9.017;\ p = 0.061)^3$
Age*:Employer	$(Chi^2_5 = 0.536;\ p = 0.991)^2$	$(Chi^2_4 = 0.234;\ p = 0.994)^2$	$(Chi^2_4 = 4.881;\ p = 0.300)^4$
Gender:Age*:Employer	$(Chi^2_5 = 0.155;\ p = 0.999)^1$	$(Chi^2_4 = 0.726;\ p = 0.948)^1$	$(Chi^2_4 = 0.929;\ p = 0.920)^1$

*log transformed.
Terms in parenthesis have been removed from the model in the order given by the superscripts. Terms shown in bold are significant in the minimum adequate model.

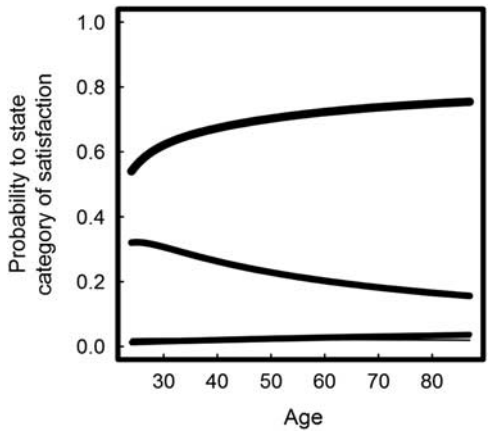

Figure 3 | Effects of age on the level of satisfaction. Lines show predicted probabilities from a multinomial model (Table 3). The thicker the line, the higher the category of the Likert scale (thinnest line: feel not satisfied at all—thickest line: feel very satisfied). Note that the three thinnest lines are overlaid at the bottom of the graph.

we asked scientists to compare their current level of satisfaction to satisfaction at earlier stages in their scientific careers. There was a marginal significant trend ($Chi^2_4 = 9.380$; $p = 0.052$; Table 3) for an increased probability of older scientists to state that earlier in their careers the feeling of satisfaction after publishing lasted longer (Fig. 5).

Correlation of publicationism and satisfaction. We performed a correlation of publicationism with satisfaction, time of satisfaction and earlier time of satisfaction to test for potential relationships of these parameters. Our data indicated a significant, but weak negative correlation between the level of satisfaction and publicationism ($r = -0.11$), as well as between the time of satisfaction and publicationism ($r = -0.09$, Fig. 6). This translates into high publicationism going along with lower satisfaction and shorter time of satisfaction after publishing an article. Furthermore, we detected a weak positive correlation between publicationism and the perception that earlier in their career participants were satisfied for a longer time ($r = 0.13$, Fig. 6). However, variability of the data was high, potentially obscuring additional trends.

Discussion

The analyses of our survey data targeting publication behaviour of researchers in biological sciences suggested that publishing scientific findings generally results in positive feelings. On the other hand, the level of stress derived from publication pressure—publicationism—is particularly high for young and female scientists, and decreases with age. The variability of publicationism is high in early career stages, and decreases with age, that is, advanced career stages. The high variability further implies a strong personality effect. Publicationism is significantly higher in the United States compared with Germany and further differs between types of institutions in these countries, but in opposite directions. Finally, our results clearly demonstrate the negative effects of publicationism as it was negatively correlated with satisfaction. In the following we critically reflect on the causes of publicationism and satisfaction, and discuss how publicationism may influence our work and publishing behaviour.

Satisfaction through publishing. Researchers have positive feelings after publishing an article. This has several non-exclusive reasons. While the contribution to science appears to be the most important factor, about 10% of the participants of our survey took the extra effort in stating that publishing provides a feeling of completion, a chance to review a project before terminating it, and to generate final conclusions. Publishing gives scientists feedback, recognition, creates better career perspectives, and a feeling of personal accomplishment. Publishing further offers the opportunity to present one's own work to the community and is therefore creating self-esteem. Our data indicate that older researchers in biological sciences show higher probabilities of satisfaction, but at the same time this group of scientists also perceives that earlier in their career satisfaction lasted even longer. It is not possible from our data to determine if this really represents an age effect or may rather be an effect of times when publication pressure generally was lower. The latter, however, seems more likely and points toward a cohort effect. Interestingly, age was strongly correlated with the number of publications, hence suggesting that older researchers were not less productive despite potentially lower publication pressure. If the trend represents an age effect rather than a cohort effect, the pattern may be the result of fixed-term contracts, particularly at the beginning of a career, which might lead to higher stress for younger scientists reducing satisfaction until receiving a permanent position, which may produce higher levels of satisfaction. This coherence becomes further underlined by the negative correlation between satisfaction and publicationism.

Besides age, the type of employer also affected satisfaction. Generally, researchers employed at non-university institutions showed a longer lasting satisfaction compared to scientists at universities. This, again, may be strongly correlated with job security on the one hand, but even more likely with different tasks being more important at the different institutional types. While at universities, publications often represent the most important currency, at non-university institutions other tasks may be rated as high or even more importantly and publishing becomes more exclusive, as not everybody does it on a regular basis. In this case

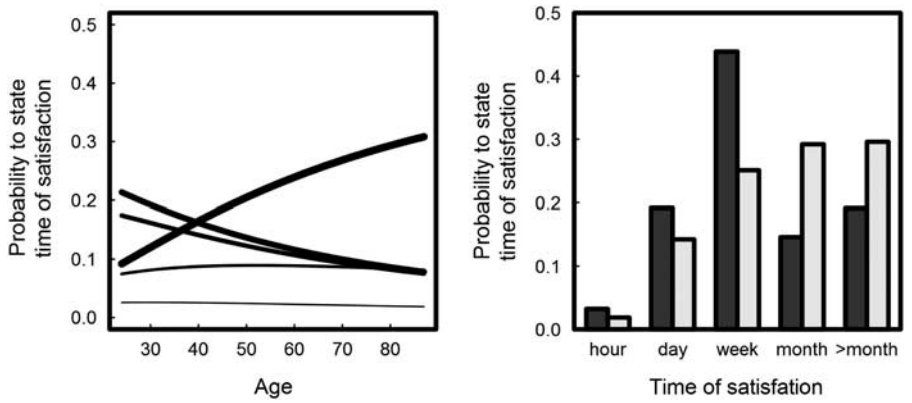

Figure 4 | Effects of age and type of employer on the time of satisfaction. Lines and bars show predicted probabilities from a multinomial model (Table 3); the thicker the line, the higher the category of the Likert scale (thinnest line: feel satisfied <1 h—thickest line: feel satisfied >1 month). Dark grey bars show scientists employed at a university, light grey bars scientists employed at non-university institutions.

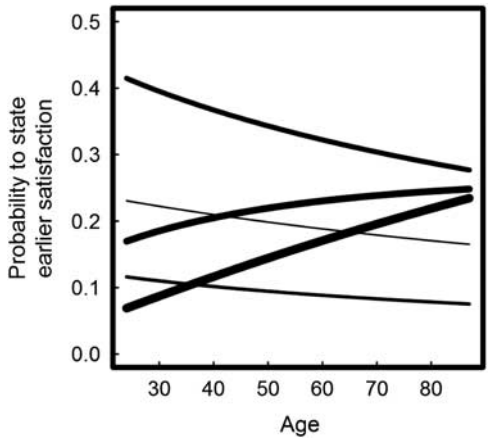

Figure 5 | Effects of age on the level of current satisfaction compared to satisfaction earlier in the scientific career. Lines show predicted probabilities from a multinomial model (Table 3); the thicker the line, the higher the category of the Likert scale (thinnest line: agreeing with the statement: earlier in my career satisfaction did not last longer—thickest line: agreeing with the statement: earlier in my career satisfaction lasted much longer).

publishing may become an additional way, rather than the standard, to display ones achievement, resulting in higher satisfaction. This may also point to an inflation of publishing at universities; publishing is assumed to be normal, rather than being seen as an important accomplishment. The results of our question regarding satisfaction at earlier career stages point towards a similar pattern. Many researchers, especially older scientists indicated that satisfaction lasted longer earlier in the careers. This again, points towards an inflation in publishing, as well as to habituation.

Maybe the most important result of our study of satisfaction is the negative correlation of satisfaction and publicationism. High publicationism reduces the level and time of satisfaction. While this is an intuitive result, it is important to realize for researchers, that the stress level caused by their publication behaviour reduces their satisfaction.

Stress through publishing. Our data supported that the current publication culture strongly affects the working behaviour of scientists and creates stress through publishing. The impact of stress on the productivity and health has already been confirmed in previous studies: Del Líbano *et al.* (2010) showed that workaholism, a more general concept to measure stress caused by work, was negatively related with psychological well-being measured as perceived health and happiness. In extreme cases, the feedback spiral caused by pressure and positive feedback can even lead to a behaviour of addiction (Silverman, 1999); in turn, the constant rejection within the process may lead to psychological problems such the impostor syndrome (Woolston, 2016).

The high relevance of a strong publication record particularly at the beginning of a career might aggravate publicationism, and thus young researchers are more affected by negative feelings compared to advanced researchers. This trend might become accelerated by tools like the PIPredictor software, an online application to calculate the likelihood of becoming a PI in the future, based solely on publication metrics (authorships, IF, etc.) (van Dijk *et al.*, 2014). Publication pressure becomes strongly enhanced by such tools, which are misleading and dangerous (Engler and Husemann, 2014). Increasing publicationism may lead to increased mental health problems observed in the world of academia (Kinman, 2001; Winefield *et al.*, 2008; Woolston, 2016). An online survey targeting researchers from the field of medicine showed negative effects of publication stress resulting in declining research quality (24% of participants) and suggested signals of burn-out syndrome for a high number of participants (Tijdinke *et al.*, 2013). Afonso (2014) even compared the scientific system with a "drug gang": newcomers are motivated by future wealth rather than current income or working conditions. The author describes science as a system of a dual labour market, consisting of a mass of outsiders (with temporary positions) and some few insiders (in secure, stable employment). However, an additional important factor is the personality of people as indicated by the high variance in our data, particularly among participants of our survey representing early career stages. Here, candidates may react differently on future uncertainties, that is, job security. Further, we may have missed additional predictors in our questionnaire (specifically related to personality). Such factors should be included in future analyses.

Besides age, gender was the strongest variable explaining publicationism in our analyses. This coincides with other studies on gender-specific workaholism: Burke (1999) showed that females suffer in particular under workaholic syndromes (perfectionism, job stress), which is assumed to be associated with lower levels of satisfaction and well-being. A study of male and female professors in Turkey indicated that workaholic behaviours, work and outside-of-work satisfaction and psychological well-being are not gender-specific, with one exception:

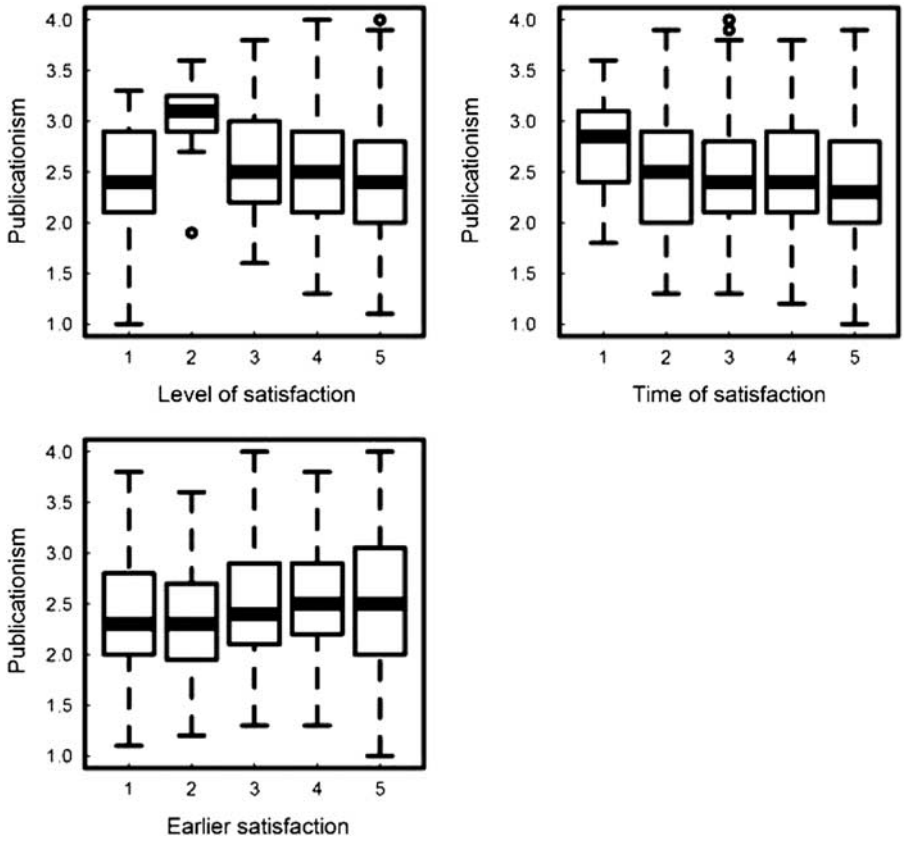

Figure 6 | Publicationism correlated with the level of satisfaction, the time of satisfaction after publishing a paper and the perception that earlier in the career satisfaction lasted longer.

female professors reported more psychosomatic symptoms. Our results provide further support for the higher pressure females may face in science. Science still is often regarded a male domain and females may face severe disadvantages in receiving permanent positions. One of the most decisive factors remains the formation of a family. Pregnancy and child care are still mostly depending on women and may take several years. In this time a publication gap will almost certainly arise leading to severe disadvantages in the search for funding as well as for permanent positions. Accordingly, specifically young females are under extreme pressure to generate a good publication record, to receive a permanent position at an early career stage; the alternative often is to either give up on family or a career in science. This is still reflected in few females being in high academic positions and only a reformation of the scientific system will solve this problem. However, in contrast to our study, other authors did not indicate gender-specific baselines of workaholism, work stress and work-life imbalance (Aziz and Cunningham, 2008).

Finally, our analyses of the reduced data set revealed differences in publicationism between researchers in the United States and Germany. The academic systems in both countries strongly differ in their career paths. While in Germany, no formal evaluation system is established at universities, few teaching positions are available, and professors are employed in normal job interview processes, the United States has established the tenure track system with yearly evaluations, and clear career perspectives.

Our results indicate higher publicationism in the United States than in Germany; we suggest that the tenure track system with its regular evaluations in the United States may impose higher pressure on performance than the German system without such evaluations, but with less clear career perspectives. An additional aspect not evaluated in this study may be cultural differences.

Our analyses further revealed a country specific difference in publicationism between university and non-university institutions. Here, the effects had opposite directions: in the United States, scientists at non-university institutions exhibited higher publicationism, whereas in Germany publicationism was higher at universities. The reasons for this pattern are not clear, but may be related to the importance publications have at non-university institutions in both countries, where additional parameters may be used to evaluate the individual performance.

Publication policy shapes scientific work. Our data underline that advanced researchers are more satisfied and suffer less under publicationism, but also suggest a habituation effect. This all may lead to higher publication output at higher ages. Accelerated publishing at advanced career stages was also found in other studies from the field of biological sciences (McCallum, 2010). Two non-exclusive reasons may explain this: either, the system selects the best publishers (not necessarily equivalent with best researchers); or, researchers become adapted to the pressure to publish (or addicted to publish) at early career stages and hence at later stages write large numbers of articles. This trend of increasing number of articles by neglecting quality finds support in the current academic policy. For example, the Institute of Scientific Information (ISI) provides software packages to help users to calculate essential science indicators that promise to evaluate potential employees, collaborators, reviewers and peers (see Adam, 2002). While publication output and publication

metrics are simple indices to rank journals (and scientist), the extensive use of them may negatively affect science itself, for example by supporting splitting data into the least publishable unit, instead of publishing large data sets. Several papers and online blogs are addressing these problems (Fanelli, 2009; Dupps and Randleman, 2012; Fang *et al.*, 2012; Marks *et al.*, 2013; Streen *et al.*, 2013; Foster *et al.*, 2015). In particular young scientists should be granted an opportunity to develop their skills in a lower pressure environment, rather than being constantly pushed towards higher publication rates (Laurance *et al.*, 2013, 2014; Bruna, 2014).

The academic system appears to have a strong effect on publicationism. The tenure track system realised in the United States seems to impose stronger pressure on young scientists, despite providing a clearer career path. This system is currently tested or being established in several countries, including Germany. Our results suggest that this system, while providing a clearer perspective, may have negative effects on the stress level of people and hence may have to be evaluated with caution. The results point out, that indices, such as publicationism may help to evaluate the benefits and disadvantages of academic systems for scientists more comprehensively. First positive signals against further acceleration of publicationism are boycotts; an example comes from the German Centre for Higher Education (CHE), which now avoids the evaluation of potential employees, departments and proposals by using IFs (Stergiou and Lessenich, 2013). We hope that our study is an additional critical signal against the publish-or-perish policy.

Caveats. While our study is based on a comparatively large sample size and shows some clear results we have to address several shortcomings. Data collection was performed partially by snowball sampling, and the questionnaire was randomly distributed via list servers, and social media. This produced a country bias (more biologists from Germany, the United States and the United Kingdom than from other countries). We used this bias subsequently and tested for potential differences in publicationism and satisfaction between Germany and the United States. Yet, while these countries currently represent strongholds of science, it would be important to identify differences across a larger number of countries, also increasing the sample size of our comparison of academic systems. This leads to a second caveat: systems in academia differ among countries, and academic positions are associated with diverging tasks and functions in different countries. This may complicate identifying "homologue" career stages; thus, we used "age" as explanatory variable (which strongly correlates with "career stage"), and added another, general variable "institutional type" (university and non-university). However, future studies need to develop better ways to evaluate career stages, as these may have important effects on satisfaction and publicationism. This also means our data could have been grouped differently for some analyses (for example, associate with full professors). Further, the variance in our data was high. Even significant effects may be an artifact of the data structure in some cases. Finally, different sub-disciplines in biological sciences may differ in their publication requirements and related pressure. Adding this factor to the analyses would lead to too many categories and hence may blur important general effects. Yet, future studies with even higher sample sizes and clear categorization of sub-disciplines may help to untangle these effects.

Our study, while offering room for improvement in the sampling strategies and questionnaire design points out some important aspects influencing our publication behaviour and publicationism. We hope that this study will encourage further work on this topic as it represents an important field of research in times where scientists face new challenges in the struggle for survival in the science arena.

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Data availability

The data sets analysed in this study are available in figshare: https://figshare.com/s/89fdb482b6ea810407c7 (DOI: 10.6084/m9.figshare.4806667).

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