How do Research Faculty in the Biosciences Evaluate Paper Authorship Criteria?

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Short title: Authorship Criteria in the Biomedical Sciences and Engineering

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Abstract

Authorship on peer-reviewed journal articles and abstracts has become the main currency and reward unit in academia. Such a reward has become a crucial component for students and postdocs who are often under-compensated and thus value authorship as their primary reward mechanism. While numerous scientific and publishing organizations have attempted to write guidelines for defining who gets to be an author and what rank they should be listed in, there remains much ambiguity when it comes to how the various criteria are weighed by research faculty. Here we sought to quantify the relative importance of each of the 11 criteria we defined as being significant contributions for scientific authorship. We sent out an anonymous survey to approximately 564 faculty members at ten different research institutions across the United States. The faculty were from the biomedical engineering, biology, and bioengineering departments. The response rate was approximately 18% with a final sample size of 102 faculty members. We found that there was a consensus on some criteria as being crucial, such as time spent conducting experiments, but there was a lack of consensus regarding the role of obtaining funding. This study provides one of the first quantitative assessments of how faculty members in the biomedical sciences evaluated these 11 authorship criteria. We believe researchers will find this insightful and will narrow down the disparity between what they assume as being important and what faculty value. This understanding with also bring us closer to establishing a more standardized system for determining authorship and rank in the biosciences.

Introduction

Authorship on peer-reviewed journal articles and conference abstracts has become the main currency of academia and the core metric for assessing intellectual productivity and output. Thus, determining who gets authorship credit and how they rank in the authorship list has become a crucial part of responsible science. In certain scientific disciplines, such as mathematics, for example, authors are listed in alphabetical order. In the biosciences, however, there is a large emphasis on rank in the authorship list and author order is thought to correspond to certain types of contributions [1]. The last author is typically the senior author and is the principal investigator overseeing the lab, while the first author is the researcher, such as the student, postdoc or research scientist, that led the project and carried out the majority of the experimental work and manuscript writing. Unfortunately, the authorship list has become highly politicized where inventorship and authorship are drifting apart [2]. In addition, a variety of new types of authorship attribution have sprung up [3], including 'gift' authorship where a senior academic is awarded authorship for various reasons or 'ghost' authorship where people are left out of the authorship list altogether, and 'equal' authorship where two or more researchers contributed 'equally' [4]. Determining who should be listed as first author is usually not very difficult, but issues arise when there are multiple people involved in a study with various levels and types of contributions [5]. Since in the biomedical sciences, authors are ranked according to perceived "contribution", it is important to have an objective and fair mechanism by which these rankings are determined based on actual intellectual contribution and not social factors [6]. Fairness in assigning credit will avoid conflicts both within the research group members and with external collaborators. A recent study showed that almost two-thirds of authors do not fully agree with their defined contribution as indicated on journal submission disclosure forms [7]. In this article, we attempt to define the types of contirbutions and how research faculty in the biosciences value their importance for determening one's inclusion as an author and their rank on the authorship list.

Numerous universities have made an effort to write internal guidelines defining authorship. These include Stanford [8], Georgia Tech [9], Harvard University [10] and several others. The majority of scientific and engineering-based organizations have guidelines describing what constitutes an author and the type of contribution required [11]. While some attempts have been made to advise on how best to implement these guidelines practically within the health and biosciences [12], the criteria remain ambiguous and still do not necessarily answer the question of which are most valued and how they weigh in determine authorship rank. Specifically, there is a need to define these criteria explicitly and assess how research faculty value each of them. Biomedical journals mostly refer to guidelines set forth by the International Committee of Medical Journal Editors (ICMJE) [13]. Although these guidelines help define author inclusion, they are not of particular help when deciding authorship order. ICMJE recommends that an author meet all four criteria:

1. Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
2. Drafting the work or revising it critically for important intellectual content; AND
3. Final approval of the version to be published; AND

4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are investigated and resolved.

In most cases, the principal investigator of a lab has the final word regarding authorship order. In this study, we aim to break down these criteria further and elucidate how faculty in the biosciences weigh them for determining both inclusion as an author and authorship order. The results presented here provide new insight that is particularly helpful for graduate students and other researchers working on collaborative projects in the biosciences and clarify the disparity that might exist between what researchers often assume and what faculty truly value.

Materials and Methods

There are many types of contributions in any collaborative research study. While there is no clear consensus on how to classify these contributions, looking at prior literature [14] we decided to define explicitly 11 criteria which we believe the biosciences community thinks are important for both determining one's classification as an author and their rank on the authorship list. The 11 criteria are:

1- ***Total time spent on a project***: This refers to the total amount of time devoted to the research study. Including literature searches, planning experiments, performing experiments, analyzing data, writing and proofreading the manuscript.

2- ***Time spent carrying out background research and literature review***: This refers to intellectual efforts put into originally deciding on a certain research area and performing a literature review to see what has been previously accomplished in the field.

3- ***Contribution to hypothesis and idea generation***: The hypothesis for which the study is attempting to test in the case of hypothesis-driven studies or the idea for non-hypothesis-driven studies such as methodologies, tools, and exploratory studies.

4- ***The contribution of a special reagent, material or computer code***: Refers to unique material-based contributions such as a specific genetically modified cell strain, a synthesized molecule or computer code for some analysis or processing.

5- ***The extent of involvement in obtaining research funding***: This is typically in the form of fundraising through writing grant proposals to funding agencies.

6- ***Time spent doing experiments***: Refers to the total time of actually carrying out the experiments, whether its simulations as part of a computational project or being in the lab culturing cells or working with animals.

7- ***The uniqueness of experimental skills and techniques:*** Some laboratory-based skills are unique and require a considerable amount of prior knowledge or experience. For example, certain rodent surgical skills might take a very long time to acquire and perfect. Other skills such as changing cell media would not fit into this category.

8- ***Time spent analyzing data:*** This includes taking raw data, compiling it, analyzing it, performing statistical analysis and presenting it in visual or textual formats.

9- ***Contribution to written manuscript:*** Including creating an outline, putting together the figures and drafting the manuscript.

10- ***The quality of written contribution to the manuscript:*** Some people are more efficient at writing than others, so it is hard to assess written contribution without also evaluating the quality of the writing. Writing quality includes being able to explain research findings well, good grammar and spelling, good structure, and flow.

11- **Time spent editing and proofreading manuscript**: This refers to the final step before submission to the journal when the lead author sends the paper to all the listed authors for final comments, edits, and proofreading.

An anonymous online survey was sent to research faculty in biology, biomedical engineering, and bioengineering at ten different research institutions (**Table 1**). The institutions were chosen to represent a wide geographical area of the United States with a range of research interests covering the biomedical sciences. The survey was emailed individually to 564 total faculty members, and we heard back from approximately 102 respondents for a total response rate of %18.1. Faculty members were identified by their listings on the corresponding department webpage. All faculty that provided their email on the department page were sent the survey. No other criterion for sample selection was used. No follow-up reminders were sent nor other optimization strategies used for the purpose of this study [15]. The survey was kept intentionally straightforward and easy to fill out to achieve a high response rate. For each criterion, the respondent had to choose from a scale of 1-10 how important they thought the criteria was, with one being least important and ten being most important. Specifically, we asked:

"On a scale of 1-10, how important are the following factors in determining authorship and authorship rank on a peer reviewed journal paper? (Please note this only applies to life sciences/biosciences/biomedical engineering)."

Only the main title of the criteria listed above was provided to the survey respondents (bolded above). The descriptions listed under each criterion here are strictly for clarification purposes for the readers of the document.

Table 1: Institutions and departments the survey was sent to

Institution	*Department/Program*	*# of Faculty Contacted*
University of California - Los Angeles	Bioengineering	29
Georgia Institute of Technology	Bioengineering	98
Johns Hopkins University	Biomedical Engineering	62
Duke University	Biomedical Engineering	72
University of California - Davis	Biomedical Engineering	24
University of Texas - Austin	Biomedical Engineering	32
Texas A&M University	Biomedical Engineering	25
University of Washington	Biology	69
Stanford University	Biology	55
Arizona State University	Biology	98
	Total:	**564**
	Responses (Response rate):	**102 (%18.1)**

Statistical Analysis

A D'Agostino & Pearson omnibus normality test was contacted. It was found that only three of the 11 criteria were normally distributed. Thus in our results we focus on the median, and the 25th and 75th for data reporting as they are more descriptive in skewed non-normal distributions. We also use the coefficient of variation as a metric to explain the dispersion in the response histograms. All graphing and analysis was carried out using Graphpad Prism 6 (GraphPad Software Inc. La Jolla, CA, USA).

Results and Discussion

Many criteria are used to assess authorship. We found that the time spent performing experiments had the highest overall mean importance score as assessed by our faculty respondents. The intellectual contribution of the hypothesis (for hypothesis-driven research) or coming up with a study idea had the second highest score for determining authorship. The very act of contributing a reagent, material or computer code, even when it is unique to the person contributing it, score the least along with the extent of involvement in obtaining funding (such as in writing grant proposals). Overall there seems to be a consensus that the time spent doing experiments, coming up with a hypothesis, analyzing data and writing the manuscript are the four most important criteria for both determining one's authorship status and rank (**Figure 1A**). The total time spent on a project was assessed as being important, but 19.6% of the respondents had a neutral score of 5 indicating that by itself time spent does not necessarily factor in heavily into authorship. This might reflect the fact that time alone does not translate to prodcutivity. The median value was 7/10 and this criterion came in fifth (**Figure 1B**).

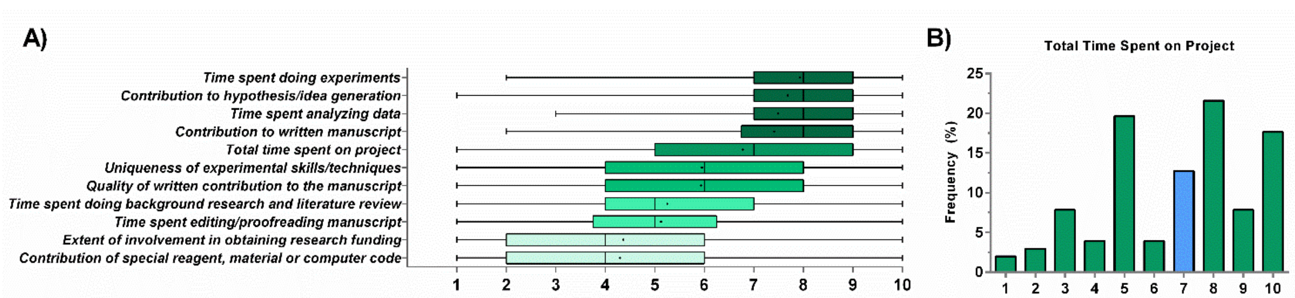

Figure 1: A) Ranking of various criteria according to research faculty in the biomedical sciences. The middle line represents the median, the edges of the box represent the 25% and 75% quartiles, the whiskers represent the range and the '+' mark is the mean. B) Total time spent has a high weight, but the majority of faculty do not appear to hold a strong opinion about this as reflected by the 19.6% of respondents giving it a score of 5, probably due to the fact that time spent does not necessary equate with an intellectual contribution to the study. N = 102 for all data presented. Blue bar indicates median.

The scores did not follow a normal distribution so we calculated the coefficient of variation as the main metric for quantifying spread instead of the standard deviation (**Figure 2**). While all the criteria had a CV greater than 23%, two criteria stand out as having a very high coefficient of variation. The first being the contribution of a material (CV = 53%) and the second having the highest CV, 57%, which is the extent of involvement in obtaining research funding. The four criteria as having the highest importance scores (see Figure 1A) also had the lowest CV values.

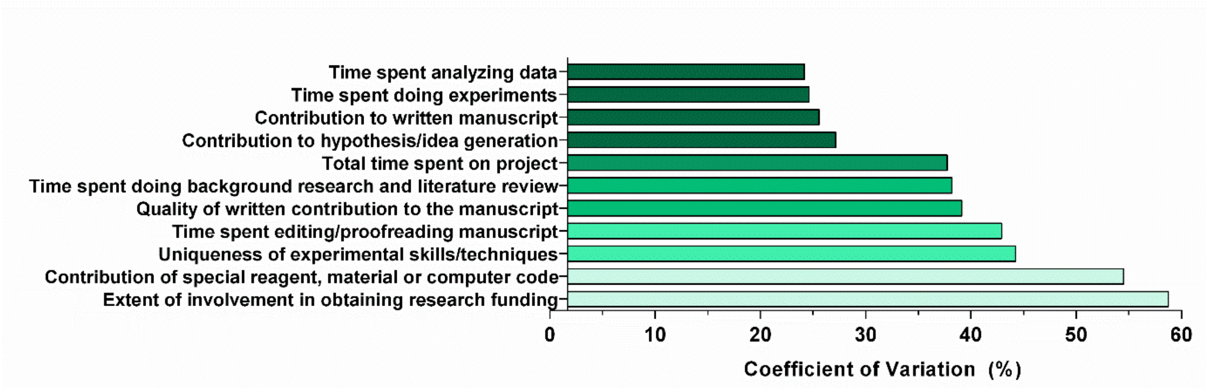

Figure 2: Coefficient of variation used as a metric to quantify spread of the scores. Lower values mean higher agreement between faculty on the importance sore. Higher values imply the distribution was highly dispersed and there was little consensus regarding the score.

Figure 3 presents the histograms of the responses describing four criteria that revolve around preparing for the study. These include background research, hypothesis generation, the contribution of various material goods and obtaining funding. We found that almost 23% of the respondents had a neutral opinion of the value of background research, as this by itself does not constitute direct involvement with the study. The median was 5/10 (**Figure 3A**). There was a clear consensus regarding the importance of generating a hypothesis or idea with the majority of faculty weighing this criterion strongly with a median of 8/10 and the majority giving it a 10/10 score (**Figure 3B**). The contribution of a special reagent, material or computer code did not constitute a grounds for authorship with the almost 23% of faculty giving it a 2/10 score with a median of 4 (**Figure 3C**). An issue of high controversy in an academic field is whether involvement in obtaining funding, such as writing a grant proposal, constitutes a ground for authorship. Although the median was 4, there was no clear consensus on the importance of this criterion as indicated both by the low median (**Figure 3D**) and high CV (**Figure 2**).

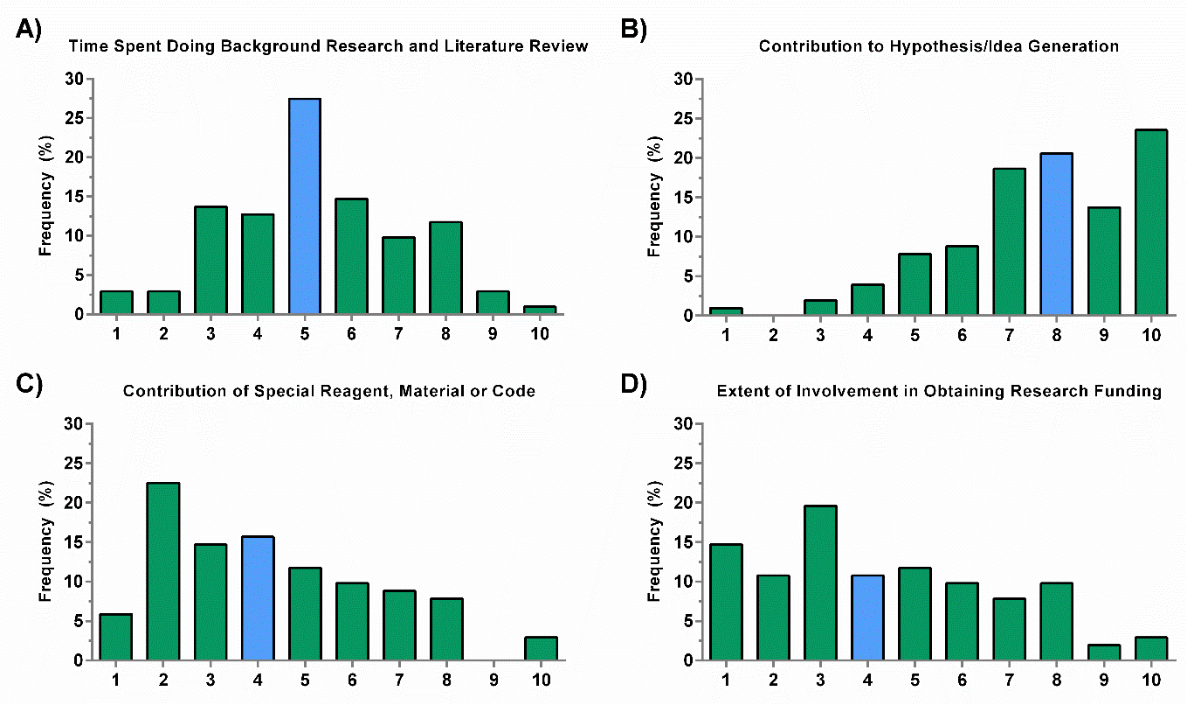

Figure 3: A) The majority of the responses regarding time spent doing background research are neutral. B) The histogram is clearly skewed indicating that contribution to the hypothesis and initial ideas is crucial. C) Although it is difficult to generalize to all material based contributions, our survey respondents lean towards the idea that contributing a special reagent, material or computer code does not by itself weigh in very much on authorship eligibility and rank. D) There is no clear consensus on the role obtaining funding plays considering this is a pivotal role of the faculty responders. N=102. Blue bars indicate median.

The next two criteria revolve around the actual experiments. These included the time performing the experiments as well as any unique skill or technique that is required. We found that the respondents highly value the time put into performing experiments with a median score of 8/10 and almost 22% of faculty rating it a 10/10 (**Figure 4A**). Some experiments require skills that involve more than simply following a protocol. These include things like surgical techniques, specific cell handling procedures…etc. Skills that would typically require much experience to adequately master and which cannot easily be replaced. Possibly due to the vague nature of these skills and the very diverse techniques across the biosciences there was no clear consensus on the importance of this criterion. The median was 6/10 (**Figure 4B**), but the scores had a high CV of 43%.

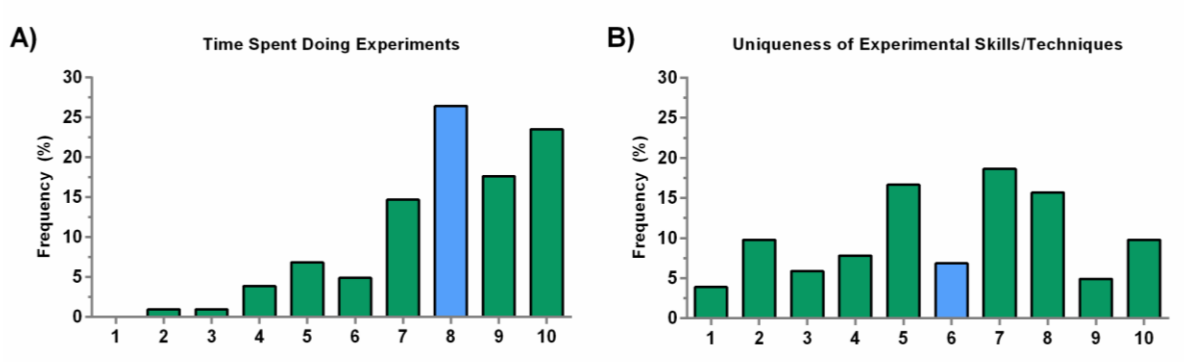

Figure 4: A) Time spent conducting experiments is important with the majority of faculty scoring it high. B) The uniqueness of experimental skills and techniques had a median of 6 with a high coefficient of variation.

Last but not least we considered four criteria corresponding to post-experiment. These included data analysis, writing the manuscript, actual quality of the manuscript content contribution and editing/proofreading the manuscript. Both times analyzing data and writing the manuscript were considered very important by the respondents with both having a median of 8/10 (**Figure 5A, B**). Almost 25% of the respondents agreed that the quality of the written content is important and gave it a 8/10 score, but there was a significant disparity in responses resulting in a median of 6/10 (**Figure 5C**). The final step of the paper submission which involves final edits and proofreading had a median of 5/10, again indicating that most respondents do not necessarily have a strong opinion about this criterion (**Figure 5D**).

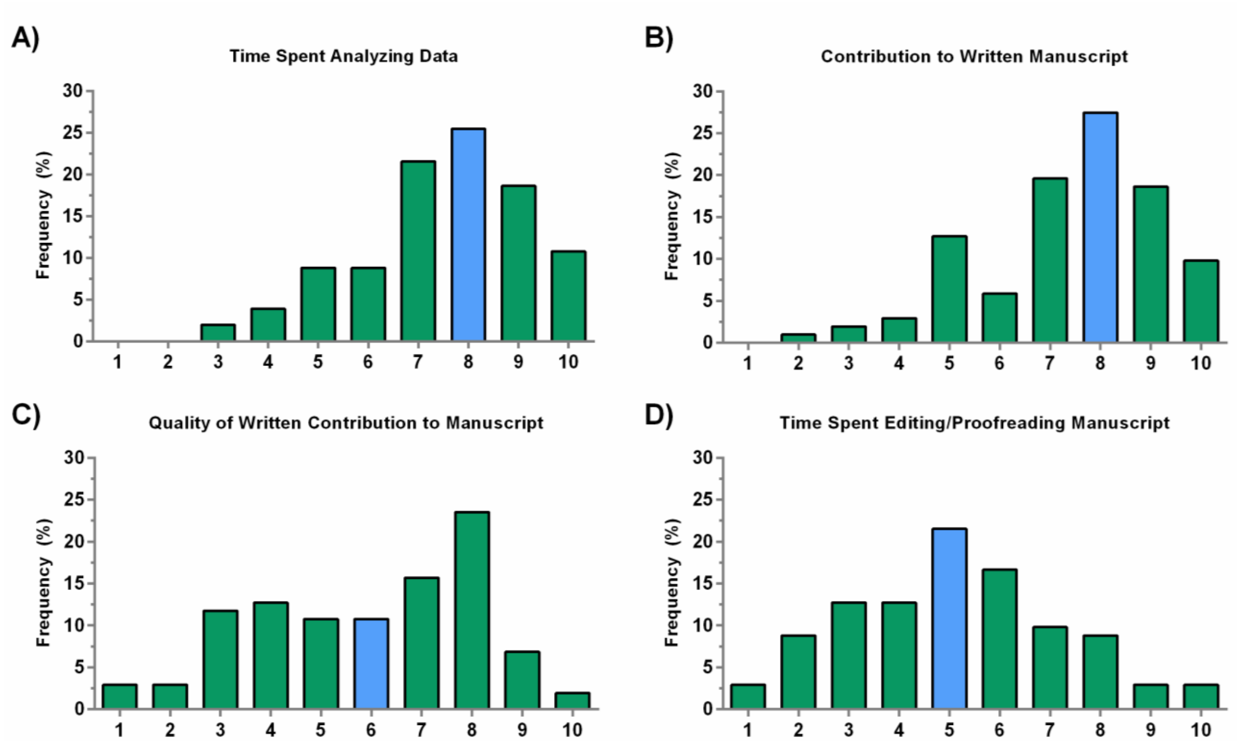

Figure 5: A) Amount of time spent analyzing data is as important as writing the manuscript (B). C) The quality of the contribution to the written manuscript is also important but there were several respondents that indicated that was not. D) The majority of the faculty had a neutral stance towards the time spent editing and proofreading the manuscript.

As scientific studies become more interdisciplinary and more collaborative in nature, there has been a growing trend of having an increasing number of authors on the authorship list. Here we attempted to quantify how faculty in the biosciences value various authorship criteria. Such information will be beneficial in arriving at a standardized method of assessing authorship inclusion and rank on the authorship list and will clarify to members of the biosciences community how faculty score various criteria. We propose that there needs to be an objective methodology where authorship is standardized across research laboratories and where author contributions can be better tracked. For example, there could be a centralized database that contains the full contributions of every author that employers and academic search committees can refer to to assess a candidate's academic productivity. A more standardized approach is required to level the playing field.

While our study is insightful, it has several limitations in how it was conducted. In some research projects, not all the criteria described here are involved, so if a certain criterion was ranked low this could be that it just does not exist within certain types of research and hence faculty respondents working in that research area might have scored it low, or given it a neutral score of five even though it could be important. This might account for some of the high CV values we see in the results. It is also important to mention that due to the small sample size, the scores here might not be representative of all the faculty in the biosciences community and a much more comprehensive study needs to be conducted to arrive at concrete conclusions.

Conclusions

We hope that our data provides insight and a push for further investigation in arriving at objective metrics for quantifying authorship. We are working on providing an algorithm called Authorships.work to the scientific community to make authorship decisions more fair by incorporating various data points including those presented in this study.

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