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Solo *versus* collaborative writing: Discrepancies in the use of tables and graphs in academic articles

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Abstract The number of authors collaborating to write scientific articles has been increasing steadily. And, with this collaboration, other factors have also changed, such as the length of the articles and the number of citations. However, little is known about potential discrepancies in the use of tables and graphs between single and collaborating authors. In this paper we ask whether multi-author articles contain more tables and graphs than single-author articles and we studied 5,180 recent articles published in six science and social sciences journals. We found both that pairs and multiple-authors used significantly more tables and graphs than single authors. Such findings indicate that there is a greater emphasis on the role of tables and graphs in collaborative writing, and we discuss some of the possible causes and implications of these findings.

Keywords Academic Writing · Textual Design · Collaboration · Tables · Graphs

Introduction

It is a well reported fact that the numbers of authors for individual scientific articles have been increasing for a long time. Indeed, as de Solla Price (1963, p. 86-91) put it for Chemistry, perhaps tongue in cheek: "the proportion of multi-author articles has accelerated steadily and powerfully, and it is now so large that if it continues at the present rate by 1980, the single-author paper will be extinct." Today commentators are more circumspect. Abt (2007, p. 358), for example, writes: "We conclude that single authored papers will decrease in frequency in the coming years, but will not disappear ... [because] ... the rapid increase between 1900 and 1960 did not continue, but changed into an exponential that will never reach zero."

Supporting Information Additional Supporting Information may be found in the online version of this article: Appendix S1, see `http://www.irit.fr/publis/SIG/2014_JASIST_CHH.zip`.

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Currently we estimate that about 30% of the articles in *JASIST* are single-authored (Cabanac & Hartley, 2013).

The numbers of authors contributing to scientific articles covers a considerable range — from *single-* to *hyper-authorship* (Cronin, 2001, 2005, pp. 41–70). There are articles with over one hundred authors in some domains (e.g., see Adiga et al., 2002; Foster et al., 2004), and, of course, there is the spectacular contribution by Aamodt et al. (2010) with its 1,055 co-authors.

Together with this increase in the numbers of authors there has been an increase in the numbers of articles about the effects of co-authorship. Table 1 lists the findings from some of these studies. Of course, many articles were published in the 1960s-90s (see Speck, Johnson, Dice, & Heaton, 1999) and these pre-date the electronic revolution that now facilitates collaborative writing today.

Table 1 Findings from previous research comparing multiple with single authors. N.B.: Articles on research collaboration published before 2005, whilst of general interest, do not reflect the changes in academic writing brought about by new technology.

Articles by Multiple Authors	
• Receive more citations	Bahr and Zemon 2000; Figg et al. 2006; Skilton 2009
• Are not always of higher quality	Bridgstock 1991
• Require less revision	Bahr and Zemon 2000
• Are accepted more quickly for native English authors	Tregenza 2002
• Have fewer acknowledgments to others	Hartley 2003
• Take longer to be reviewed (pre-electronic conditions)	Hartley 2005
• Have longer titles	Lewison and Hartley 2005; Yitzhaki 1994
• Have longer texts	Lewison and Hartley 2005
• Use fewer colons in their titles	Lewison and Hartley 2005

Of course different authors collaborate in different ways. Indeed, for the purposes of this article, it might be of interest for the reader to know that the article was initially proposed to James (Hartley) by Guillaume (Cabanac) working with Gilles (Hubert), who had suggested the study. Guillaume and Gilles carried out the data collection and analysis, and then the article was initially written in six parts. James drafted the Introduction and squabbled over various titles. Guillaume and Gilles wrote up the method, and the results section. James wrote the Discussion and the Conclusions, whilst Guillaume completed the reference section. But in all of these stages the manuscript passed backwards and forwards electronically between us numerous times with suggestions for improvement and agreement on every section. Then the final version was checked by James for appropriate English before it was checked by Gilles and Guillaume for submission by Guillaume.

Nonetheless, various patterns of collaboration do have to have certain features in common. There has to be a senior author responsible for the submission. Everyone has to agree with the final version. Different authors contribute different things — so the more authors there are the more areas there are for discussion and perhaps disputation. Some authors are seen as more expert than the others on different issues. So deciding on the order of the authors

on the title page can sometimes present problems (Kosmulski, 2012; Waltman, 2012) and sometimes, as here, the author who proposed the study comes last!

There have to be negotiations too about the amount of detail to contain in the Introduction, the Method, the Results and the Discussion sections. There needs to be agreement over the numbers and suitability of the tables, graphs, and references. And, after submission, the criticisms of editors and referees have to be discussed and responded to by all or by a selection of the authors.[1]

In this article we focus on the numbers of tables and graphs in single and co-authored articles. There have not been, as far as we are aware, any previous articles on this topic. So we have no specific hypotheses generated by earlier research, but we feel that as 'more heads are better than one' there might be more tables and graphs in articles written with more authors. The earlier research summarized in Table 1 does indeed suggest that increasing the numbers of authors appears to lead to increases in other key features in academic publications.

Accordingly we made the following predictions:

- On the use of tables:
  - H1: Multi-author articles feature more tables than single-author articles.
  - H2: Two-author articles feature more tables than single-author articles.
- On the use of figures:
  - H3: Multi-author articles feature more figures than single-author articles.
  - H4: Two-author articles feature more figures than single-author articles.

Method

We tested these hypotheses using the 6-step method detailed below. It relies on processing all of the articles published in each issue of selected research journals during a specific time period.

1. Retrieve the full-text of each article and count the following: number of pages, number of authors, number of tables, and number of figures.
2. Discard articles with less than 4 pages to get rid of non-research articles, such as book reviews, editorials, errata, letters to the editor, notes, and so on.
3. Group articles according to their number of authors. We thus defined "Group 1A" and "Group 2A+" for single-author and multi-author articles, respectively.
4. Use boxplots to inspect visually the differences in the distribution of the number of tables and figures between Groups 1A and 2A+, for each journal.
5. Test the statistical significance of these differences with the non-parametric Mann-Whitney U test on two independent samples. The null hypothesis H_0 assumes that the distribution of the variable under study (e.g., number of tables) is not statistically significant between single- (Group 1A) and multi-author articles (Group 2A+). When H_0 is rejected, we report the level of significance of the test (two-sided) according to the classical three levels $p < 0.05$ denoted by *, $p < 0.01$ denoted by **, and $p < 0.001$ denoted by ***.
6. Further analyze the data to check if any such a difference can also be observed (or not) between single-author and two-author articles (instead of multi-author articles). This

[1] We wonder how Aamodt et al. (2010) collaborated in these respects! Hence the need to differentiate between contributors and co-authors, as suggested by Rennie, Yank, and Emanuel (1997).

analysis repeats steps 3–5 to compare the use of tables and figures among single-author articles (Group 1A) and two-author articles (Group 2A).

Data

In order to have a range of different types of journal for our study, we considered several journals related to various scientific domains. We then selected six peer-reviewed journals listed under the two editions of the Thomson-Reuters *Journal Citation Reports* (*JCR* 2011), namely the *Social Sciences* and *Sciences* editions. Moreover, these journals appear in various categories of the *JCR*, some of them being listed in more than one category (Table 2).

Table 2 *JCR* editions and categories of the six journals under study.

Journal	Editions and Categories in the *JCR* 2011	
	Social Sciences Edition	*Science* Edition
AREA	Geography	
JASIST	Information Science & Library Science	CS, Information Systems
JASP	Psychology, Social	
JOI	Information Science & Library Science	
SCIM	Information Science & Library Science	CS, Interdisciplinary Applications
WE	Business, Finance Economics International Relations	

CS: Computer Science

The following criteria were considered in selecting these journals:

1. The journals had to publish a large number of articles per year for our analyses. We thus focused on the top journals of *JCR* categories according to the "Articles" field.
2. The journals had to publish at least 60% of articles featuring tables and figures. This was not the case of some fields, such as Pure Mathematics.
3. The journals had to publish a reasonable ratio of single-author *versus* multi-author articles. Journals that mainly publish multi-author articles (or only single-author articles) do not meet this requirement (e.g., often in in Physics and in Biology).
4. The journals had preferably to publish articles by researchers involved in a diversity of scientific domains. Multidisciplinary journals were of particular interest in this respect.
5. The journals had to publish articles in HTML format. This pragmatic requirement allowed us to count the number of tables and figures systematically and in the same way for each journal.
6. The journals had to have no restrictions on the numbers of tables and figures allowed per article — as sometimes occurs in medical and science journals (e.g., see *Journal of Biological Chemistry*, *International Journal of Pharmaceutical Science and Research*).

Table 2 shows our six selected journals that complied with these criteria. Journals listed in only one category of the *JCR* are *Area* (*AREA*), the *Journal of Applied Social Psychology* (*JASP*), and the *Journal of Informetrics* (*JOI*). Note, however, that the researchers publishing in *JOI* come from various backgrounds (e.g., Economics, Chemistry, Computer Science, Psychology, Sociology). There is one journal listed in three categories of the *Social Sciences*

edition, namely *The World Economy* (*WE*) and two journals appear in both *JCR* editions: the *Journal of the American Society for Information Science and Technology* (*JASIST*) and *Scientometrics* (*SCIM*). Similarly to *JOI*, these multidisciplinary journals feature authors from different backgrounds.

The journal parts considered in this study are shown in Table 3. For each journal, we retrieved the latest and every part published in HTML format. The number of retrieved articles ranged from 389 to 1,834. *JOI*, the newest journal in our dataset had the lowest number of articles. In addition, we note here that focusing on recent articles controls for a bias related to any potential lack of up-to-date software used for designing tables and figures in earlier sources.

Table 3 Source of the 5,180 articles under study, with features of the considered six journals.

Journal	Volumes and Issues Considered		Number of articles	Single-author articles
	Earliest	Latest		(%)
AREA	35(1) of 2003	45(1) of 2013	714	62
JASIST	52(14) of 2001	64(3) of 2013	1,834	30
JASP	36(12) of 2006	43(2) of 2013	1,010	12
JOI	1(1) of 2007	7(2) of 2013	389	28
SCIM	82(2) of 2010	92(3) of 2012	684	26
WE	29(12) of 2006	36(1) of 2013	549	30

Figure 1 shows that the share of single-author (12% – 62%) articles was not uniform across our journals. These substantial differences may be due to the varying numbers of contributors required to complete a piece of work in the various scientific domains. Indeed, Barrios, Villarroya, and Borrego (2013) have documented limited number of single-author articles in Psychology (9%). In our dataset, more than two-thirds of the articles are multi-authored, except for the journal *AREA* (Geography) where single-author articles prevail (62%).

As far as the multi-author articles are concerned, the distribution of articles per number of co-authors is not uniform across journals (Figure 2). For all journals, the number of published articles is inversely proportional to the number of co-authors. In addition, there are notable differences in the formatting of articles (e.g., number of columns (one, two or even three), fonts and type-sizes). Moreover, in this study, each journal contributes a different number of articles. Thus it was necessary to sample articles at the journal level, as opposed to studying the distribution of tables and figures regardless of the journal in which they appeared.

We used the SOFA statistical package in this study (`http://www.sofastatistics.com`). For reproducibility concerns, the data used in this study are released as an online Supporting Information (Appendix), following the advice of Hanson, Sugden, and Alberts (2011).

Results

Differences in the use of tables

We first consider the case of tables by addressing the following question: Are there differences in the use of tables in single-author articles *versus* multi-author articles (H1), as well as two-author articles (H2)?

Fig. 1 Distribution of single-author and multi-author articles for the six journals under study. All journals but one publish more multi-author articles than single-author articles (between 12% and 30%).

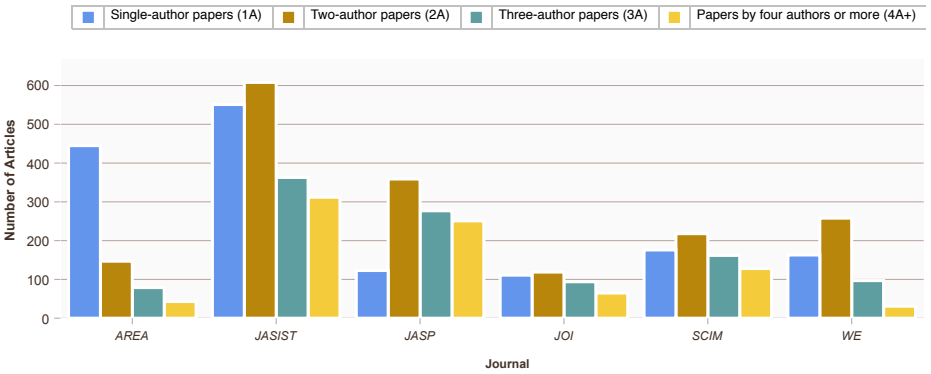

Fig. 2 Distribution of the articles according to their number of co-authors: one author (1A), two authors (2A), three authors (3A), and four authors or more (4A+) are considered.

H1: There are more tables in multi-author articles than in single-author articles

Multi-author articles feature more tables than single-author articles, as suggested in Figure 3. Visual inspection reveals differences between the two distributions for each journal, except for *JASP*. The middle 50% of the distributions, as showed by the boxes, is lower for single-author articles compared to multi-author articles.

Statistics reported in Table 5 in the Appendix confirm this visual observation. For instance, multi-author articles in *JASIST* contain on average 1.82 more tables (+50%) than single-author articles. The difference found between single- and multi-author articles is significant for all journals but *JASP*, which actually shows an average 6% decrease. H1 is thus supported for five of the six journals selected.

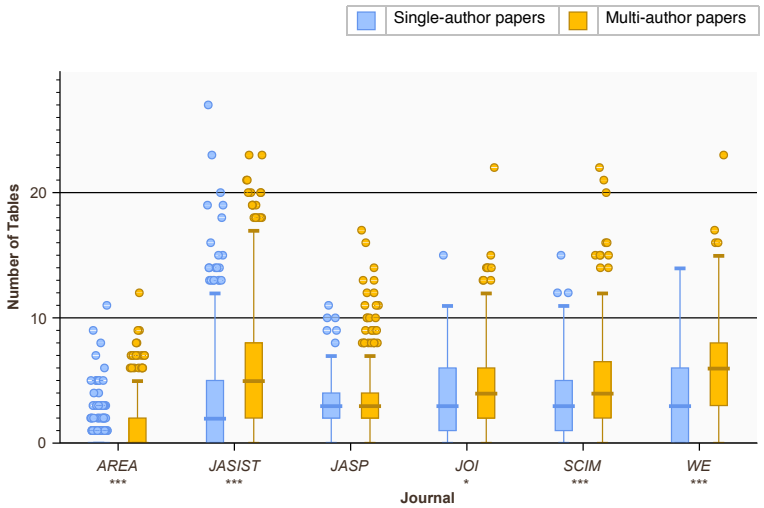

Fig. 3 These boxplots show the number of tables in single-author *versus* multi-author articles. Visual inspection and significance tests (see asterisks under journal names) show that there are more tables in multi-author articles compared to single-author articles for five out of six journals. H1 is thus supported.

H2: There are more tables in two-author articles than in single-author articles

Two-author articles still feature more tables and figures than single-author articles, as suggested by Figure 4. Visual inspection reveals differences between the two distributions for each journal. The middle 50% of the distributions is lower for single-author articles compared to multi-author articles for all journals but *JASP* and *JOI*.

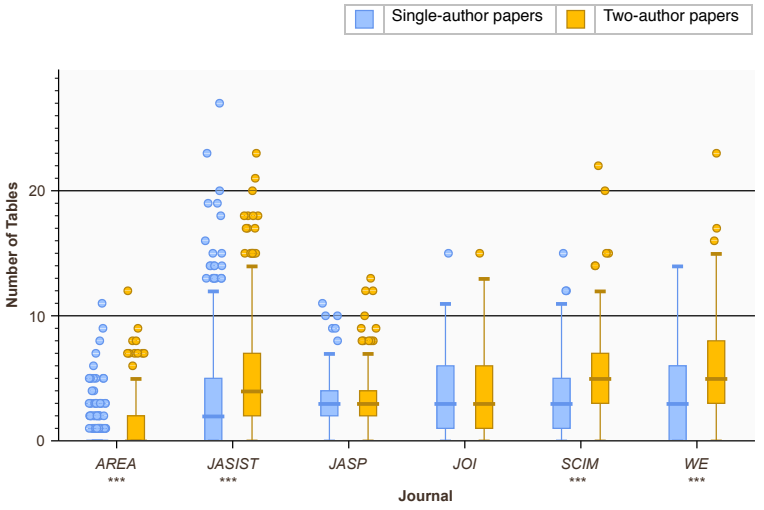

Fig. 4 These boxplots show the number of tables in single-author *versus* two-author articles. Visual inspection and significance tests (see asterisks under journal names) show that there are more tables in two-author articles compared to single-author articles for 4 out of 6 journals. H2 is thus partially supported.

Statistics reported in Table 6 (Appendix) confirm this visual observation. For instance, two-author articles in *JASIST* contain on average 1.67 more tables (+46%) than single-author articles. The difference found between single- and multi-author articles is significant for all journals except *JASP* and *JOI*. H2 is thus partly supported.

Differences in the use of figures

Having found a difference in the use of tables between single-author *versus* two-author (H1) or multi-author (H2) articles, we now repeat our study by focusing on figures (H3 and H4).

H3: There are more figures in multi-author articles than in single-author articles

Multi-author articles feature more figures than single-author articles, as suggested by Figure 5. Visual inspection reveals differences between the two distributions for each journal. The middle 50% of the distributions is lower for single-author articles compared to multi-author articles.

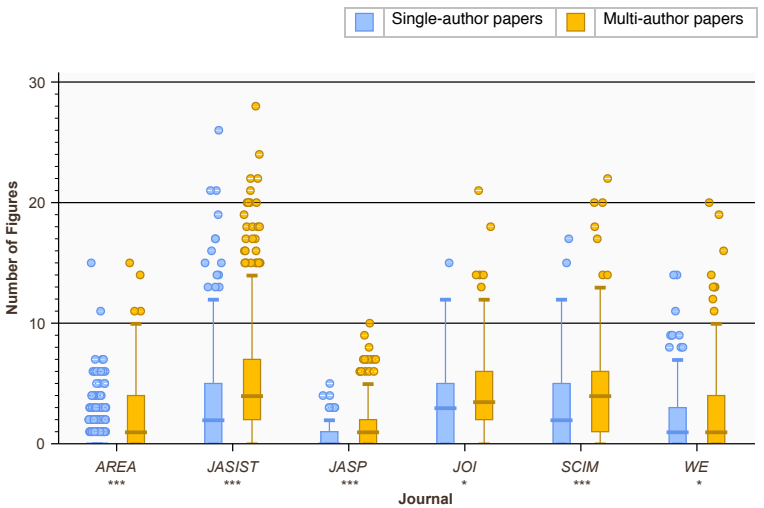

Fig. 5 These boxplots show the number of figures in single-author *versus* multi-author articles. Visual inspection and significance tests (see asterisks under journal names) show that there are more figures in multi-author articles compared to single-author articles for all journals. H3 is thus supported.

Statistics reported in Table 7 (Appendix) confirm this visual observation. For instance, multi-author articles in *JASIST* contain 1.60 more figures (on average +52%) than single-author articles on average. The difference found between single- and multi-author articles is significant for all journals. H3 is thus supported.

H4: There are more figures in two-author articles than in single-author articles

Two-author articles still feature more tables and figures than single-author articles, as suggested by Figure 6. Visual inspection reveals differences between the two distributions for

each journal. The middle 50% of the distributions is lower for single-author articles compared to multi-author articles.

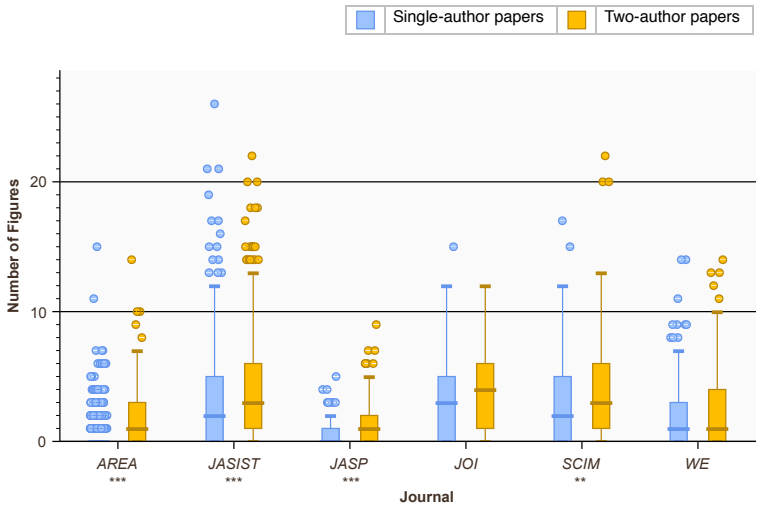

Fig. 6 These boxplots show the number of figures in single-author *versus* two-author articles. Visual inspection and significance tests (see asterisks under journal names) show that there are more figures in two-author articles compared to single-author articles for 4 out of 6 journals. H4 is thus partially supported.

Statistics reported in Table 8 (Appendix) confirm this visual observation. For instance, two-author articles in *JASIST* contain 1.07 more figures (+35%) than single-author articles on average. The difference found between single-author and multi-author articles is significant for all journals but *JASP* and *WE*, which nonetheless show a 8% increase on average. H4 is thus supported.

Discussion and concluding remarks

The two main findings from this study are:

- Authors in groups use significantly *more tables* than single authors (H1). Indeed, this is also noticeable between paired and single authors (H2). For instance, in *JASIST*, authors in groups use 50% more tables than single authors in their articles.
- Authors in groups use significantly *more figures* than single authors (H3). This is also noticeable between paired and single authors (H4). For instance, in *JASIST*, authors in groups use 52% more figures than single authors in their articles.

This balance between the use of tables and graphs by single and multiple-authors is present in *JASIST*. Some other journals, however, feature a different balance, such as *The World Economy (WE)*. Here the difference in the use of tables (48%) is larger than the difference in the use of figures (13%).

These findings, although clear, require some explanation. We need to consider the role of tables and figures in academic articles, and, more especially, features of writing together *versus* writing alone.

The role of tables and figures

There is a considerable literature about what tables and figures (and their derivatives) are actually for, and when a table is more appropriate than a graph, and vice versa (e.g., see Durbin, 2004; Kastellec & Leoni, 2007; Vessey & Galletta, 1991). The *Publication Manual of the American Psychological Association* provides recommendations regarding the use of tables and figures, and how they should be presented (APA, 2010, Chap. 5). Generally speaking, it is commonly suggested that tables are best when one wants to present/retrieve exact numbers, and that graphs are best at showing trends. However, some authors (e.g., Gelman, Pasarica, & Dodhia, 2002; Kastellec & Leoni, 2007) advocate turning tables into graphs to improve the presentation of results. Gelman et al. (2002) demonstrate the effects of doing this with graphs based on actual tables from articles in *The American Statistician*. As an aside we might note here that Tartanus, Wnuk, Kozak, and Hartley (2013) found that agricultural journals containing a higher number of graphs had higher impact factors than did those with a smaller number. Further, Gelman et al. (2002) and Hartley (2012) both argue that increasing the caption lengths to explain more fully what the data actually show can increase the readers' comprehension of both tables and figures.

Collaborative writing and authors' features and skills

The findings above suggest that groups of authors use more tables and figures in their articles than single authors. The question is, of course, why do such results occur?

Earlier, in the Introduction, we outlined how we as authors had set about writing this article. We now want to note here how this description, although perhaps helpful at the time to the reader, appears to give no more than one freeze frame from a lengthy film. And that any bland description of how two (or more) authors collaborate together cannot be the same for everyone. As Noël and Robert (2004) point out, there are too many sets of multiple and overlapping variables. Different authors in a team may differ in terms of age, sex, nationality, background knowledge on the topic, discipline, mathematical, computing, statistical and verbal skills, etc. Some may work together in the same office (Gilles and Guillaume); some may never have met in person the other authors that they collaborate with (James and Gilles); whereas some may be close friends (Guillaume and Gilles). Some may prefer graphical complexity (Guillaume and Gilles) to verbal simplicity (James)! And, finally, none of us have used any of the more complex computer based tools written to facilitate co-authorship (e.g., see Churchill, Trevor, Bly, Nelson, & Cubranic, 2000; Noël & Robert, 2004; Sharples, 1999).

The more authors there are the more substantial is the mix of these multi-faceted attributes. In writing this article Gilles and Guillaume have tended to talk about tables and graphs supporting collaboration in writing research articles, as though they emerge in some way out of the collaboration. In contrast, James has preferred to think that those with a visual bent can help make the verbally oriented writer clearer, and that such people will bring these tools 'ready-made' as it were. It would indeed be interesting to discuss these issues further with other groups of co-authors, or trace the history of particular articles written in different ways by different groups of authors. Table 4 lists some recent related studies in this respect and it is interesting to note that studies on how and why tables and figures support collaboration in academic writing call for additional, qualitative research.

Table 4 Some representative reports on how jointly-written articles and book chapters have been written.

Articles	Chapters
Katz and Martin 1997	Sharples 1999
Noël and Robert 2004	MacArthur 2006
Rigby and Edler 2005	Moore and Barrett 2010
Wyatt, Gale, Gannon, and Davies 2010	Nevin, Thousand, and Villa 2011
Hurford and Read 2011	
Badenhorst et al. 2013	
Egghe, Guns, and Rousseau 2013	

Appendix: Detailed results

Table 5 Testing of H1: Are there more tables in multi-author articles (2A+) compared to single-author articles (1A)? The table reports means (M), standard deviations (SD), difference in means (ΔM), and the significance of the difference between the two distributions (p-value) according to the U test (two-tailed).

Journal	Tested Samples				Difference	
	articles 1A		articles 2A+		$\Delta M(\%)$	p-value
	M	SD	M	SD		
AREA	0.43	1.26	1.47	2.15	241***	0.000
JASIST	3.62	4.48	5.44	4.57	50***	0.000
JASP	3.26	2.25	3.07	2.16	−6	0.336
JOI	3.70	3.33	4.50	3.68	22*	0.044
SCIM	3.56	3.07	4.75	3.35	33***	0.000
WE	3.79	3.50	5.62	3.75	48***	0.000

* significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$

Table 6 Testing of H2: Are there more tables in two-author articles (2A) compared to single-author articles (1A)? The table reports means (M), standard deviations (SD), difference in means (ΔM), and the significance of the difference between the two distributions (p-value) according to the U test (two-tailed).

Journal	Tested Samples				Difference	
	articles 1A		articles 2A		$\Delta M(\%)$	p-value
	M	SD	M	SD		
AREA	0.43	1.26	1.25	2.23	190***	0.000
JASIST	3.62	4.48	5.29	4.57	46***	0.000
JASP	3.26	2.25	2.98	2.08	−9	0.220
JOI	3.70	3.33	3.98	3.50	8	0.537
SCIM	3.56	3.07	4.88	3.37	37***	0.000
WE	3.79	3.50	5.60	3.88	48***	0.000

* significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$

Table 7 Testing of H3: Are there more figures in multi-author articles (2A+) compared to single-author articles (1A)? The table reports means (M), standard deviations (SD), difference in means (ΔM), and the significance of the difference between the two distributions (p-value) according to the U test (two-tailed).

Journal	Tested Samples				Difference	
	articles 1A		articles 2A+		$\Delta M(\%)$	p-value
	M	SD	M	SD		
AREA	0.64	1.60	2.26	2.82	255***	0.000
JASIST	3.09	4.00	4.69	4.04	52***	0.000
JASP	0.65	1.03	1.27	1.56	96***	0.000
JOI	3.40	3.29	4.19	3.51	23*	0.026
SCIM	3.16	3.40	4.17	3.60	32***	0.000
WE	2.21	3.63	2.51	3.31	13*	0.042

* significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$

Table 8 Testing of H4: Are there more figures in two-author articles (2A) compared to single-author articles (1A)? The table reports means (M), standard deviations (SD), difference in means (ΔM), and the significance of the difference between the two distributions (p-value) according to the U test (two-tailed).

Journal	Tested Samples				Difference	
	articles 1A		articles 2A		$\Delta M(\%)$	p-value
	M	SD	M	SD		
AREA	0.64	1.60	1.88	2.52	196***	0.000
JASIST	3.09	4.00	4.16	3.98	35***	0.000
JASP	0.65	1.03	1.23	1.57	89***	0.000
JOI	3.40	3.29	4.02	3.13	18	0.069
SCIM	3.16	3.40	4.07	3.73	29**	0.004
WE	2.21	3.63	2.39	3.15	8	0.089

* significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$

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