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SCROLL DOWN FOR ARTICLE

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ABSTRACT

This article reports the findings of a diachronic study of acknowledgement practices in 300 randomly collected research papers published during three different periods (1998, 2004 and 2012) in the most prestigious American and European astrophysics journals written in English. In order to investigate the influence of these practices on authorship patterns, we analyzed the distribution over time of a series of quantitative variables (number, length and types of acknowledgements, mean number of words/number of acknowledgements per research paper and mean number of acknowledgements/number of authors per research paper, number of named and unnamed acknowledgees, number of identified and anonymous referees, and number of emotionally charged-words). Comparisons between periods were carried out and Student's t-tests were applied to the quantitative results. Our main findings show that acknowledgements are very common in astrophysics since they are present in 96% of the whole corpus. Financial, mainly public, and instrumental supports are the most frequently acknowledged categories. The number and length of acknowledgements and the mean number of words/number of acknowledgements per research paper grow over time. Financial, instrumental and conceptual assistance, unnamed individuals and anonymous referees increase over time, whereas moral, editorial and unclassified supports, named individuals and identified referees, and emotionally-charged words decline. If we focus on each journal publication context, we can observe that the research papers published in the American journals include more and longer

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acknowledgements, with a higher mean number of acknowledgements per author, more financial and instrumental supports, and a lower percentage of emotionally-charged words, whereas the European journals contain more conceptual and editorial supports. All these data can be understood in the frame of growing scientific professionalism, while a detailed cross-journal analysis may occasionally suggest honorary/guest/gift authorship.

Keywords: astrophysics, research papers, acknowledgements, authorship

RESUMEN

Este trabajo presenta los resultados de un estudio diacrónico de los agradecimientos en una muestra de 300 artículos de investigación recogidos al azar y publicados durante tres periodos diferentes (1998, 2004 y 2012) en las más prestigiosas revistas de astrofísica, americanas y europeas, escritas en inglés. Con el fin de estudiar la influencia de los agradecimientos sobre los patrones de autoría, hemos analizado la evolución de una serie de variables cuantitativas (número, longitud y tipos de agradecimientos, media del número de palabras/número de agradecimientos por artículo y media del número de agradecimientos/número de autores por artículo, número de personas agradecidas identificadas y no identificadas, número de árbitros mencionados por su nombre y anónimos, y número palabras con carga emocional). Hemos utilizado la prueba t de Student para comparar los resultados cuantitativos entre periodos. Nuestros resultados principales muestran que los agradecimientos son muy comunes en astrofísica ya que están presentes en el 96% de todo el corpus. Las ayudas económicas, principalmente públicas, instrumentales y conceptuales son las más frecuentes. El número y la longitud de los agradecimientos, así como la media del número de palabras/número de agradecimientos por artículo, crecen paulatinamente. El apoyo económico, instrumental y conceptual, los individuos no identificados y los árbitros anónimos también aumentan, mientras que el apoyo moral, editorial y no clasificado, los individuos y los árbitros identificados, y las palabras con carga emocional decrecen. Si nos centramos en el contexto de cada publicación, observamos que los artículos publicados en las revistas americanas incluyen más agradecimientos y que éstos son más largos, con una media mayor del número de agradecimientos/número de autores, más ayudas económicas e instrumentales, y un menor porcentaje de palabras con carga emocional, en tanto que los artículos publicados en las revistas europeas incluyen más ayudas conceptuales y editoriales. Todos estos datos se pueden entender en el marco de una creciente profesionalización de la ciencia, mientras que un análisis detallado de cada revista puede ocasionalmente sugerir la existencia de una autoría honoraria/invitada/regalada.

Palabras claves: astrofísica, artículo de investigación, agradecimientos, autoría

1. Introduction and motivation

The fact that teamwork, a characteristic feature of “Big Science” (Weinberg, 1961, 1968; de Solla Price, 1963) which relies on large-scale, big-budgeted, and hierarchically-organized projects funded by national governments or groups of governments (Galison, 1992), usually prevails nowadays, implies that research “is produced by and in a network of actors” (Shapin, 1995, p.

359). The network not only involves the work of primary author(s), but also of secondary author(s), or sub-authors (Patel, 1973; Cronin *et al.*, 2003), whose contribution to a study was not significant enough to qualify them as author(s) (Rennie *et al.*, 1997; Kassirer & Angell, 1991; Claxton, 2005; Slatcher & Pennebaker, 2006). It is therefore very common to find a section in academic and scientific articles where the authors express their thanks and gratitude to the diverse individuals (and/or entities) that have contributed, funded, supported, or discussed their work (Gesuato, 2004; Giles & Council, 2004; Khabisa *et al.*, 2012). In other words, acknowledgements (ACKs) demonstrate how new research is embedded within the different disciplinary communities and reveal like no other academic texts the intricate webs of interpersonal debts produced in the dialogic process of knowledge construction, where the expression of scholarly gratitude counts as a form of repayment for balancing such debts (Swales, 2004). A good index of the importance attributed to ACKs in today's scholarly communication is the proportion of studies that have been devoted to their analysis by scholars from a variety of different disciplines, genres and standpoints (for a comprehensive bibliographic review see Hyland, 2004 and Salager-Meyer *et al.*, 2009, 2011 among others).

Moreover, when research is carried out by very heterogeneous groups of scientists, "deciding who should or should not be an author or acknowledged can be a controversial issue" (Hare, 2001, p. 249), as has been put forward in many studies, especially in medical sciences (Gasparyan *et al.*, 2013; Vinther & Rosenberg, 2012, to name just a few). The multifaceted authorship problems in scholarly journals have given way to a range of inappropriate practices which include ghost, honorary, guest, and gift authorship. 'Ghost' authorship refers to scientists who are not listed as authors in spite of their substantial contributions to research. Conversely, 'honorary' authorship refers to authors who did not significantly contribute to the research but only provided facilities or technical support. 'Guest' authorship refers to listing as co-authors very well-known scientists who have had little to do with the work involved, with a hope to increase publication chances and career prestige. Finally, 'gift' authorship takes place when a colleague's name is added for encouraging collaboration, maintaining good working relations, attempting to boost his/her profile or as repayment for favours. The non-adherence to appropriate authorship criteria may give rise to significant variations in ACK-patterns. Within this changing scenario, the analysis of emotionally-charged words (Giannoni, 2006; Salager-Meyer *et al.*, 2009) may play a key role in understanding the practices in context.

In spite of the vast and heterogeneously rich literature on ACKs, there is a discipline where they have seldom been the object of study: astrophysics. It is a global and multidisciplinary science which combines astronomy, an observational science related to the description and the classification of the universe, and physics, which is concerned with the basic properties of celestial objects (Pedersen, 2009). Moreover, physics not only incorporates theory and practice (Newman, 2004), but also separate branches of fields of expertise, each one with its own characteristics: high-energy physics, particle physics, relativistic physics, solid-state physics, mathematics, chemistry, biology, mechanical/electrical/aerospace engineering, etc.

As far as we know, there is only an Astronomy Acknowledgment Index (AAI), compiled by Verner (1992, 1993, 1996), that lists personal ACKs included in papers published in the leading journals in astronomy. Indeed, the field of physics has been addressed in only a few occasions from linguistic, rhetoric, pragmatic, and/or bibliometric points of view. For instance, Suls & Fletcher (1983) performed a comparative study of ACKs between social and physical sciences; Hyland (1998) analysed metadiscourse in four academic disciplines (applied linguistics, astrophysics, marketing and microbiology); Tarone *et al.* (1998) conducted research on the use of the passive voice in astrophysics research articles; Bazerman (2000) devoted the third part of his volume *Shaping written knowledge: The genre and activity of the experimental article in science* to the changing forms of the experimental report within twentieth-century physics and the individual's activity in writing and reading texts; Butler Burton (2007) examined the growth of scientific authorship in the most prestigious astrophysics journals; Gentil-Beccot *et al.* (2009) approached the issue of citing and reading behaviours in high-energy physics papers; Costas & Leewen (2012) examined ACKs across different countries and disciplines, among them physics and astronomy; and Méndez *et al.* (2014a, 2014b) carried out a diachronic analysis of titling and authorship in astrophysics research papers (RPs) written in English.

It is thus our intention here to extend the line of research on astrophysics in general and on ACKs in particular by presenting the results of an empirical study of ACKs drawn from a corpus of 300 randomly collected RPs in astrophysics published between 1998 and 2012 in English-written journals (see 'Corpus' below). Since the present study completes our previous research on authorship (Méndez *et al.*, 2014b), we expect to provide a full picture of the construction of scientific knowledge and scholarly production in the field of astrophysics.

The present study then deals with the evolution of ACKs regarding their number, length, and types. Other questions related to the distribution over time of named and unnamed individuals, identified and anonymous referees, as well as the presence and evolution of emotionally charged-words, are also addressed in this research. More precisely, this study aims at answering the following main questions:

1. Are there any time variations in the frequency, length and types of ACKs?
2. Does the relationship between the number of ACKs and the number of author(s) per RP vary over time?
3. Does the frequency of acknowledging named and unnamed individuals, and identified and anonymous referees change over time?
4. Does the distribution of the variables above depend upon a journal's scope or its geographic orientation?
5. Does the use of emotionally-charged word change over time?

2. Corpus and methodology

In studies of this kind, it is recommended to draw the sample texts in top-ranking journals because, as Connor (2004) argues, the articles published in these journals have undergone a strict peer review and editorial scrutiny. Such a procedure thus assures that the articles selected are fairly representative of the journal genre in content and style or, in Bazerman's words (1994, p. 23), that the texts are "situationally effective" and are the results of an "expert performance" (Bazerman, 1994, p. 131). Following then Connor (2004)'s recommendation, our journal selection incorporated the following criteria:

1. Represent the best practices in the field;
2. Publish papers on observational data and/or theoretical analyses;
3. Be freely accessible online.

Four journals were found to meet the three criteria and were selected for this study: two European journals [*Astronomy and Astrophysics* (A&A), *Monthly Notices of the Royal Astronomical Society* (MNRAS)] and two US-based journals [*The Astronomical Journal* (AJ), and *The Astrophysical Journal* (ApJ)]². Since 1998

² The Impact Factors listed in the journal home page refer to the year 2012 (A&A 5.084, AJ 4.965, ApJ 6.733, and MNRAS 5.521).

was the initial free online access date shared by the four journals, we chose that year as the starting point of our research.

It is important to mention here that the guidelines of the journals selected in this study do not specifically require but only recommend an ACK-section to be included. For example, ApJ and AJ quote that “At the end of the paper individuals, institutions, or funding agencies may be acknowledged”, whereas A&A mentions that “A special section for acknowledgements may be included before the References list”, and MNRAS reads that “Conclusions should be followed by un-numbered acknowledgements.” In this sense, it could be stated that acknowledging any kind of help for the conduction of studies is not mandatory in these four astrophysical journals although, as it will be seen later on, the vast majority of the RPs included in our sample contain a section devoted to ACKs.

The best option to answer questions 1), 2), 3), and 4) formulated in the “Introduction” section is evidently the analysis of different time periods, journals and contexts. This is the reason why we randomly collected 300 RPs from three different time periods comprising 100 RPs each: Block A (1998), Block B (2004), and Block C (2012). In other words, the 100 RPs per Block comprise 25 RPs per journal, i.e. a total of 75 RPs per journal. Then we manually counted the number of RPs with ACKs, the number of ACKs and the words making up the ACK-sections. The concept of “word” was defined as the unit occurring between spaces.

Since ACKs embody different relationships among people, agencies, and institutions, we followed a classifying typology similar to that already used by Cronin (1995), Hyland (2003), Giles & Council (2004), and Salager-Meyer *et al.* (2009):

1. Financial support, i.e., recognition of external and/or intra-mural funding of national and/or international private and/or public educational institutions, federal/governmental research agencies and/or industrial sources/sponsors.
2. Instrumental/technical support, e.g., providing access to tools, facilities, technologies and infrastructural resource; furnishing technical expertise, help in data collection/entry/management.
3. Conceptual support, also called “academic support” (Hyland, 2003, p. 244) or “peer-interactive communication (PIC)” (McCain, 1991, p. 512), such as proffering thanks for advice and discussion, comments on the manuscript, critical insight, intellectual guidance, valuable suggestions, assessment on study soundness, etc.
4. Moral support: e.g. thanking someone for his/her enthusiasm, encouragement, wisdom.

5. Editorial/linguistic support, i.e., editing, proofreading or translating the manuscript.
6. Unclassifiable when it proved impossible to categorize an ACK according to any of the above categories whether because of inherent ambiguity, vagueness or lack of contextual clues.

We also recorded the number of named and unnamed individuals acknowledged. In the case of named individuals, they were identified either by their full name and surname or by their initial name and full surname, whereas the label “unnamed individuals” was applied to individuals and groups of people whose help in the research and/or comments/suggestions, etc. was acknowledged (staff, teams, colleagues, research centres, scientists, investigators, project and department directors, technicians, editor(s), referee(s), etc.). Finally, for our linguistic analysis and in order to answer question 5), we also registered all the emotionally-charged words included in our corpus in order to check if there were any diachronic differences across the four journals.

In the case of the quantitative/numerical variables, to assess whether some of the paired two-sample differences observed were statistically significant or not, we analysed our results by means of the Student’s *t*-test. The alpha value was set at 0.05.

3. Results

3.1. ACK-practices

As can be seen in Table 1 below, 96% of the 300 analysed RPs contain ACKs. Table 1 also shows that the greatest number of ACKs and of words making up the ACK-sections was recorded in AJ. The highest mean number of words/number of ACKs per RP and number of words/number of authors per RP was also found in AJ.

Statistically significant differences were found in the mean number of words/number of ACKs per RP ($p=0.0016$) and in the mean number of ACKs/number of authors per RP ($p=0.011$) between AJ and A&A. Statistically significant differences ($p=0.025$) were also appreciated in the mean number of words/number of ACKs per RP between MNRAS and A&A grouped together (14.0) and between AJ and ApJ grouped together (16.1). Further statistically significant differences ($p=0.038$) were also found in the mean

number of ACKs/number of authors per RP between MNRAS and A&A grouped together (1.7) and AJ and ApJ also grouped together (2.0).

Journals	AJ	MNRAS	ApJ	A&A	Total
No. of RPs with ACKs	74	73	71	70	288
No. of ACKs	461	405	393	367	1626
No. of ACK-words (ACK-length)	7223	6007	6024	5084	24338
Mean no. of words/no. of ACKs per RP	16.6	14.5	15.7	13.5	15.0
Mean no. of ACKs/no. of authors per RP	2.1	1.8	1.9	1.5	1.8

Table 1. Number of RPs with ACKs and of ACKs³, number of ACK-words, mean number of words/number of ACKs per RP, and mean number of ACKs/number of authors⁴ per RP

Diachronically speaking, Table 2 shows that the number of RPs with ACKs is the same in each of the three blocks. The total number of ACKs and of ACK-words rises steadily from Block A to Block C, mainly from Block B to Block C where the increase is quite sharp.

Periods	Block A	Block B	Block C	Total
No. of RPs with ACKs	96	96	96	288
No. of ACKs	512	510	604	1626
No. of ACK-words (ACK-length)	7130	7348	9860	24338
Mean no. of words/no. of ACKs per RP	13.5	14.5	17.2	15.0
Mean no. of ACKs/no. of authors per RP	2.0	1.7	1.7	1.8

Table 2. Evolution of the number of RPs with ACKs, of ACKs, of ACK-words, and of the mean number of words/number of ACKs per RP and number of ACKs/number of authors per RP

The mean number of words/number of ACKs per RP shows a statistically significant increase from Block A to Block C ($p=0.007$), whereas the decrease in the mean number of ACKs/number of authors per RP for the same time band is not statistically significant.

³ The total number of ACKs exceeds 75 (the number of articles sampled from each journal) because authors usually make acknowledgements for multiple reasons, such as external funding, conceptual, and technical/instrumental/moral support.

⁴ These data have been calculated by taking into account the number of authors (per journal and period) reported by Méndez *et al.* (2014b) in their study with the same corpus.

The evolution of the mean number of words/number of ACKs per RP per journal is plotted in Figure 1.

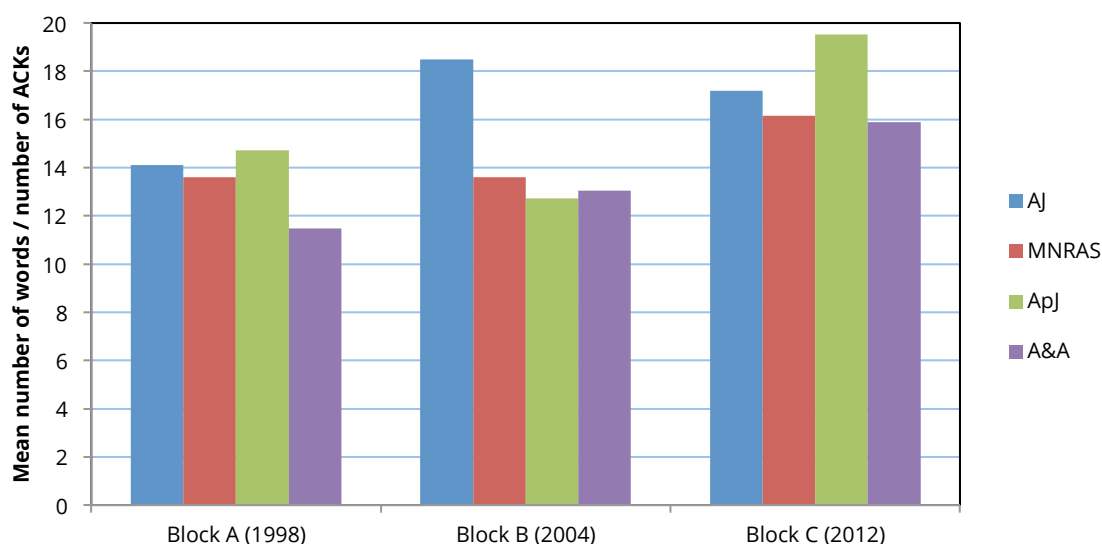


Figure 1. Evolution of number of words/number of ACKs per RP per journal.

The overall increase in the mean number of words/number of ACKs per RP from Block A (14.1) to Block C (17.2) is statistically significant ($p=0.047$). In AJ, the mean number of words/number of ACKs per RP rises in Block B (from 14.1 to 18.5, $p=0.011$) and falls in Block C, although with no statistically significant difference. The mean number of words/number of ACKs per RP grows steadily from Block A to Block C in MNRAS (from 13.6 to 16.1, $p=0.036$) and in A&A (from 11.5 to 15.9, $p=0.015$). In ApJ, the mean number of words/number of ACKs per RP shows the opposite behaviour when compared to AJ but with no statistical significance.

The distribution over time of the mean number of ACKs/number of authors per RP per journal is displayed in Figure 2.

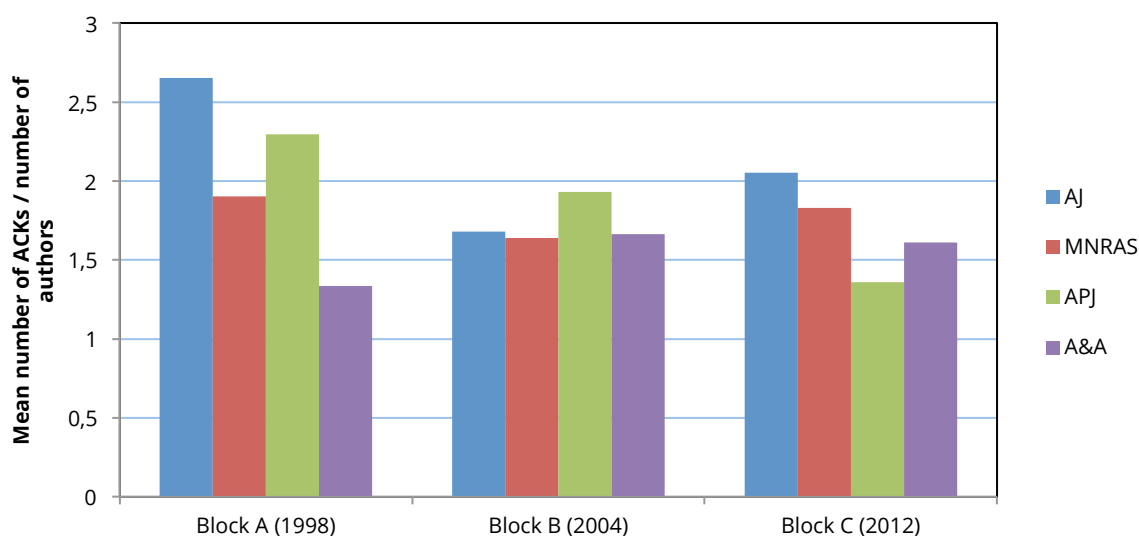


Figure 2. Evolution of the mean number of ACKs/number of authors per RP per journal.

In Apj, the mean number of ACKs/number of authors per RP falls steadily from 2.2 in Block A to 1.3 in Block C ($p=0.050$). The mean number of ACKs/number of authors per RP also falls in AJ from 2.7 in Block A to 1.7 in Block B ($p=0.050$) and rises in Block C although the difference is not statistically significant. If AJ and Apj are grouped together, there is a steady decrease from Block A (2.5) to Block C (1.7) with even higher statistical significance ($p=0.028$). On the other hand, MNRAS and A&A show opposite evolution patterns between them but with no statistical significance.

3.2. ACK-types

Table 3 shows that financial (40.40%), instrumental (30.87%) and conceptual (22.69%) ACKs top the list of ACK-types.

ACK-type	AJ	MNRAS	Apj	A&A	Total
Financial	186	161	170	140	657
Instrumental	174	114	111	103	502
Conceptual	80	106	87	96	369
Moral	10	11	16	14	51
Editorial	6	7	6	12	31
Unclassifiable	5	6	3	2	16
Total	461	405	393	367	1626

Table 3. ACK-types per journal.

The greatest number of ACKs (28.35%) is found in AJ and the lowest one in A&A (22.57%). AJ has also the highest number of financial (28.31%) and instrumental (34.66%) ACKs, and the smallest number of conceptual (21.68%) and moral (19.61%) ones. Conceptual (28.73%) and moral (31.37%) ACKs are prevalent in MNRAS and ApJ, respectively. Editorial ACKs (38.71%) are predominant in A&A. Unclassifiable ACKs are present in the four journals.

From a diachronic standpoint, Figure 3 shows an upswing in the number of financial assistance from Block A to Block C. Conversely, editorial, moral and unclassifiable assistance fall steadily (the unclassifiable type is almost absent in Block C), whereas instrumental ACKs decrease in Block B and increase in Block C and the opposite pattern is observed in conceptual ACKs.

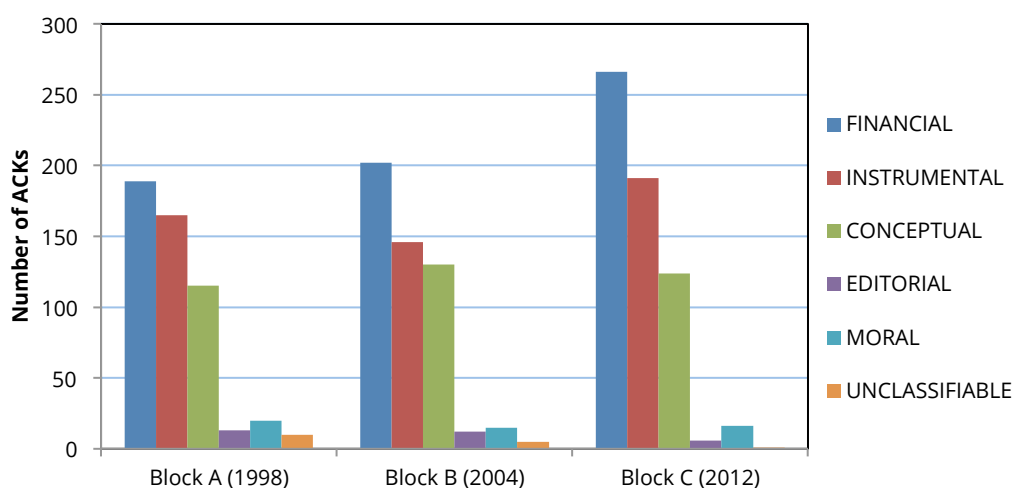


Figure 3. Evolution of ACK-types.

As can be seen in Table 4, financial ACKs rise steadily from Block A (28.77%) to Block C (40.49%). However, two discrepancies may be observed between AJ and the other journals: on the one hand, AJ has the highest percentage of financial ACKs (28.31%) and, on the other, their evolution shows an erratic pattern, whereas in MNRAS, ApJ and A&A, financial support increases from Block A to Block C.

Financial	Block A	Block B	Block C	Total
AJ	63	56	67	186
MNRAS	39	43	79	161
ApJ	49	58	63	170
A&A	38	45	57	140
Total	189	202	266	657

Table 4. Evolution of financial ACKs per journal.

As an aside, it is worth adding that 95.43% of financial assistance proceeds from public sources against only 4.57% from private ones.

Table 5 shows that along the same line as financial ACKs, instrumental ACKs increase from Block A (32.87%) to Block C (38.05%). Once more, AJ has the highest percentage of instrumental ACKs (34.66%) and their evolution over time also differs from the remaining journals.

Instrumental	Block A	Block B	Block C	Total
AJ	52	65	57	174
MNRAS	34	29	51	114
ApJ	42	29	40	111
A&A	37	23	43	103
Total	165	146	191	502

Table 5. Evolution of instrumental ACKs per journal.

Like financial and instrumental ACKs, conceptual ACKs (Table 6) also rise from Block A (31.16%) to Block C (33.60%). However, the highest percentage of this ACK-category is found in MNRAS (28.73%) and not in AJ which, in addition, shows the lowest one (21.68%). The evolution pattern of conceptual support also varies from one journal to the other.

Conceptual	Block A	Block B	Block C	Total
AJ	22	34	24	80
MNRAS	30	29	47	106
ApJ	32	31	24	87
A&A	31	36	29	96
Total	115	130	124	369

Table 6. Evolution of conceptual ACKs per journal.

The evolution of moral, editorial, and unclassifiable ACKs per journal is shown in Table 7, below. Unlike financial, instrumental and conceptual support, moral ACKs fall from Block A (39.21%) to Block C (31.37%). In this case, the highest percentage of moral ACKs is found in ApJ (31.37%). As for their distribution over time, AJ distinguishes itself once more from the remaining journals.

Like conceptual ACKs, editorial support decreases from Block A (41.93%) to Block C (19.35%). The greatest number of editorial ACKs is found in A&A (38.71%). As for unclassifiable ACKs, they decrease steadily from Block A (62.50%) to Block C (6.25%). The greatest number of this type of ACK is found in MNRAS (37.50%), and AJ is the only journal that includes them in Block C.

Moral / Editorial / Unclassifiable	Block A (1998)	Block B (2004)	Block C (2012)	Total
AJ	3 / 2 / 1	3 / 1 / 3	4 / 3 / 1	10 / 6 / 5
MNRAS	4 / 3 / 6	5 / 4 / 0	2 / 0 / 0	11 / 7 / 6
ApJ	7 / 1 / 1	3 / 3 / 2	6 / 2 / 0	16 / 6 / 3
A&A	6 / 7 / 2	4 / 4 / 0	4 / 1 / 0	14 / 12 / 2
Total	20 / 13 / 10	15 / 12 / 5	16 / 6 / 1	51 / 31 / 16

Table 7. Evolution of moral, editorial, and unclassifiable ACKs per journal.

3.3. Named and unnamed individuals

As can be seen in Table 8, the percentage of named individuals decreases steadily from Block A (38.71%) to Block C (28.44%). MNRAS (26.83%) and ApJ (26.10%) are the two journals with the greatest percentages of acknowledged individuals mentioned by their names. While the number of named individuals shows a similar behaviour in AJ and ApJ, MNRAS and A&A display an erratic pattern: in MNRAS the number of credited individuals decreases in Block B and increases in Block C, and in A&A it rises in Block B and falls in Block C.

Named/unnamed individuals	Block A	Block B	Block C	Total
AJ	63 / 13	51 / 10	44 / 12	158 / 35
MNRAS	60 / 7	58 / 5	65 / 5	183 / 17
ApJ	85 / 10	53 / 5	40 / 12	178 / 27
A&A	56 / 2	62 / 3	45 / 5	163 / 10
Total	264 / 32	224 / 23	194 / 34	682 / 89

Table 8. Evolution of named and unnamed individuals per journal.

Contrary to named individuals, unnamed individuals increase slightly from Block A (35.95%) to Block C (38.20%). The highest percentage of unnamed individuals is found in AJ (39.32%) and the lowest one in A&A (11.23%). Their evolution pattern also varies. What is more important, though, is that when named and unnamed individuals are grouped together, there is a considerable difference between the former (88.46%) and the latter (11.54%).

3.4. Identified and non-identified referees

Table 9 shows that identified referees fall from Block A (36.36%) to Block C (21.21%), whereas non-identified referees behave the other way round, i.e. they rise steadily from Block A (24.47%) to Block C (45.74%). Moreover, non-

identified referees (74.02%) amount nearly three times as much as identified ones (25.98%).

Identified / non-identified referees	Block A	Block B	Block C	Total
AJ	2 / 5	5 / 8	0 / 13	7 / 26
MNRAS	3 / 8	3 / 6	6 / 10	12 / 24
ApJ	3 / 3	1 / 9	1 / 8	5 / 20
A&A	4 / 7	5 / 5	0 / 12	9 / 24
Total	12 / 23	14 / 28	7 / 43	33 / 94

Table 9. Evolution of identified and non-identified referees per journal.

3.5. Linguistic aspects

Apart from expressing their ACKs by means of verbs such as “acknowledge”, “thank”, “supported”, etc., on some occasions acknowledgers use different emotionally-charged words which usually consist of laudatory adjectives, adverbs and nouns (all of them are listed in the enclosed appendix).

Laudatory adjectives top the list of emotionally-charged words (24 variants are mentioned on 377 occasions), whereas laudatory adverbs (12 variants) appear on 73 occasions and laudatory nouns (two variants) are mentioned on 15 occasions. The ceremonious adjectives mostly used are the predicate “grateful” (89 occurrences) after the verb “to be” and the attributive adjective “useful” (80 occurrences) before nouns such as “comments”, “suggestions”, etc. The attributive “helpful” appears in mid-position (66 occurrences) and the rest of attributive adjectives run from 18 occurrences (“careful”) to the one-time occurrence of “encouraging” and “positive”. The laudatory adverb mostly used is “gratefully” (19 occurrences), followed by “greatly” (13 occurrences), whereas “cheerfully”, “deeply” and “extremely” appear only once. As for laudatory nouns, the two variants are “gratitude” and “pleasure”, both with a similar frequency of appearance (seven and eight occurrences, respectively). The distribution per block and journal of the emotionally-charged words is displayed in Table 10, below.

As table 10 shows, the behaviour of the number of emotionally-charged words is not homogenous: it rises steadily in AJ, falls continuously in ApJ and A&A, and shows an up and down trend in MNRAS. Apart from including more variants, the ACKs in the European journals also contain more ceremonious words (53.33%) than those in the American ones (47.67%).

Emotionally-charged words	Variants	Block A	Block B	Block C	Total
AJ	23	28	38	46	112
MNRAS	30	41	44	38	123
ApJ	23	42	35	28	105
A&A	27	53	43	29	125
Total	38	165	160	140	465

Table 10. Evolution of the variants and number of emotionally-charged words per journal.

Figure 4 plots the distribution per block and journal of the percentage of emotionally-charged words in relation to the total length of ACKs. On the one hand, it can be observed that the peak of laudatory words is found in Block A in A&A and, on the other, that their number decreases from Block A to Block C in MNRAS, ApJ and A&A, whereas it increases in AJ in the same time span. Ceremonious words peak in 1998 in A&A and decrease from 1998 to 2004 in MNRAS, ApJ, and A&A. However, they increase over the three sample periods in AJ.

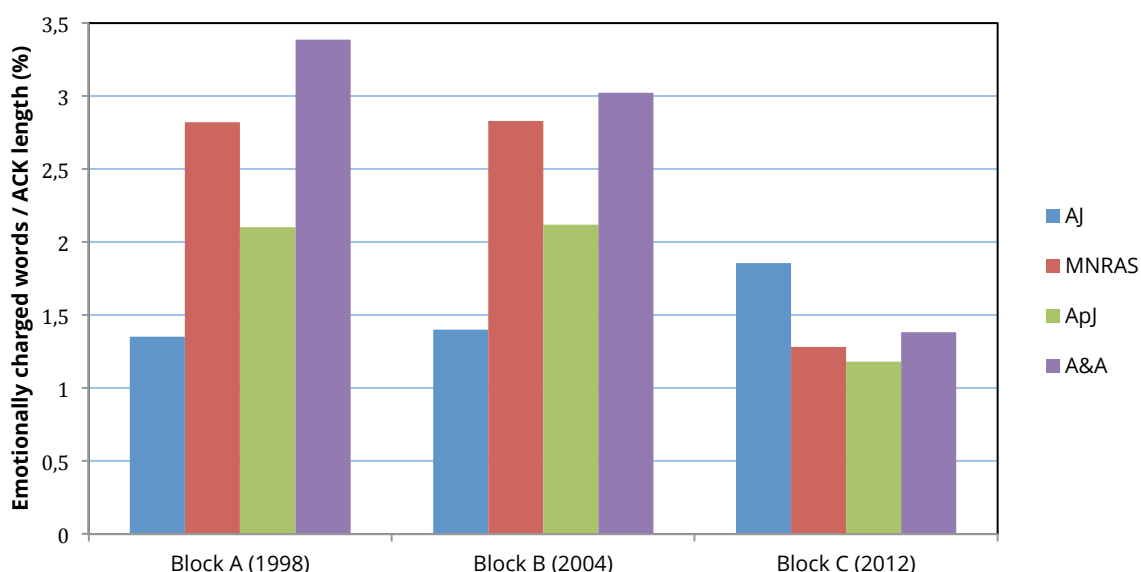


Figure 4. Evolution of emotionally-charged words (percentages) per journal.

Emotionally-charged words decrease in the two European journals grouped together (from 3.08% in Block A to 1.32% in Block C), whereas they increase in both American journals grouped together in the same time span (from 1.13% to 1.54%).

Laudatory adjectives are sometimes reinforced by boosters. Of the six variants encountered (see appendix), the highest frequencies of appearance correspond to the quantifier “many” (24 occurrences) and to the adverbial intensifier “very” (19 occurrences). Similarly to emotionally-charged words, there are more boosters and variants in the European journals (62.50%) than in the American ones (37.50%).

4. Discussion

The data displayed in our tables and figures reveal that ACK-patterns vary over time and per journal. Since the observed variations likely depend upon the scope of each journal and its publication context, the best option to discuss our most relevant findings is to start focusing on each journal individually, then follow with a summary of the main results and finally introduce a distinction between the American and European contexts.

In ApJ, a journal with a general publishing trend which includes experimental and theoretical results, the average ACK-length increases from Block A to Block C (Figure 1) and so does the number of financial ACKs (Table 4), whereas the number of conceptual ACKs decreases (Table 6). Instrumental, moral, editorial and unclassifiable ACKs do not show a great overall variation over time (Tables 5 and 7). The number of named individuals and of identified referees falls over time, whereas the number of unnamed individuals and anonymous referees shows an overall rise (Tables 8 and 9). All these data, as well as the significant overall decline in the mean number of ACKs/number of authors per RP (Figure 2) and the increase in the number of authors in Block C in comparison to Block A (see Méndez *et al.*, 2014b), can be explained in terms of the universal tendencies of globalization, the birth and development of Big Science, and the growing specialization and professionalization of science (Beer & Lewis, 1963; Gordon, 1980).

In addition, since financial ACKs are the only ACK-types that show a significant rise, we could speculate that some sub-authors, who were previously included in the ACK-sections in Block A and whose contributions to the RP used to be ceremoniously acknowledged, are now appearing as authors (Butler Burton, 2007), although they are only contributing with the mention of their research projects. In this sense, these individuals may be qualified as ‘honorary authors’ as they did not contribute substantially to be able to take public responsibility for the work. The decrease in the percentage of emotionally-charged words (Figure 4) may also reinforce the afore-mentioned idea, i.e. the previous addressees of laudatory words have

now turned into authors. Moreover, the Impact Factor of ApJ, indeed the journal with the highest one in our sample, would likewise encourage scientists to be willing to guest/gift authorship in order to increase the chances of publication of their papers or boost their careers (Curry & Lillis, 2004; Gómez *et al.*, 2006; De Faoite, 2010).

AJ, a journal that focuses primarily on observational research (the most experimental part of astrophysics) which requires complex instrumentation (telescopes, detection devices, space missions, etc.) and multidisciplinary teams, has the greatest number of ACKs and of ACK-words (Table 1), mainly due to the huge presence of instrumental ACKs when compared to the other three journals (Table 3). Likewise, it has the highest mean number of words/number of ACKs per RP and of ACKs/number of authors per RP (Table 1, Figures 1 and 2). Furthermore, AJ shows a significant increase in the mean ACK-length from Block A to Block B (Figure 1) together with an also significant decline in the number of ACKs/number of authors per RP in the same time band (Figure 2), which may be explained in terms of the enormous rise in the number of authors in Block B (see Méndez *et al.*, 2014b). The increase noticed in the number of authors in Block B runs parallel with a rise in the number of instrumental and conceptual ACKs (Tables 5 and 6), whereas financial ACKs (Table 4) decline. The number of named and unnamed individuals falls over time, whereas the number of identified and anonymous referees shows an overall increase (Tables 8 and 9).

Although the percentage of emotionally-charged words does not significantly vary from Block A to Block B (Figure 4), the previous data could suggest that a mixture of honorary/guest/gift authorship may also have taken place in Block B. Moreover, Block C shows a slight growth in the number of financial ACKs (Table 4), whereas instrumental and conceptual ACKs go down (Tables 5 and 6), and moral, editorial and unclassifiable ACKs remain more or less constant over time. Since the percentage of emotionally-charged words (Figure 4) and the mean number of ACKs/number of authors per RP (Figure 2) increase over time, and the number of authors decreases in comparison with Block B (see Méndez *et al.*, 2014b), it can be clearly stated that honorary/guest/gift authorship is no longer characteristic of Block C. In this sense, and taking into account that AJ is the most experimentally-oriented journal of our sample, we can argue that due to the worldwide economic crisis which started in the USA in 2006 (Tully, 2006), less funding was devoted to research. This meant that fewer new projects were carried out and less new technology was developed, which implies that the traced instrumental ACKs mostly refer to already well-known instruments, hence their lower number in Block C in comparison to

Block B. It may be then speculated that all the staff involved in the handling of those instruments, who perhaps qualified as authors in Block B (honorary authorship), are no longer considered as such in Block C.

MNRAS, a journal with the second highest impact factor and a publishing trend similar to ApJ, shows an increase in the average ACK-length (Figure 1) and in financial, instrumental and conceptual ACKs from Block A to Block C (Tables 4, 5 and 6), as well as in the number of named individuals, identified and non-identified referees (Tables 8 and 9). Conversely, moral, editorial and unclassifiable ACKs and unnamed individuals (Tables 7 and 8) decrease in the same time band. Likewise, there is a significant decline in the percentage of emotionally-charged words (Figure 4), whereas the number of authors rises outstandingly in Block C (see Méndez *et al.*, 2014b). Similarly to ApJ, financial ACKs are the type of ACKs that increases the most in MNRAS. All these results could be attributed once more to the growing professionalization of science. Nevertheless, and although the mean number of ACKs/number of authors per RP (Figure 2) actually shows a slight decrease from Block A to Block C, the absence of statistical significance in this indicator prevents us from clearly referring to the idea of honorary/guest/gift authorship.

In A&A, a journal that publishes papers on theoretical, observational, and instrumental astronomy and astrophysics, we notice once more an increase in the average ACK-length (Figure 1) and in the number of financial and instrumental ACKs from Block A to Block C (Tables 4 and 5). The number of unnamed individuals and anonymous referees (Tables 8 and 9) also rises over time. Conversely, a decline from Block A to Block C is observed in the number of editorial and unclassifiable ACKs, named individuals and identified referees (Tables 7, 8 and 9), whereas conceptual and moral ACKs (Tables 6 and 7) remain practically stable. Similarly to MNRAS, we also find an outstanding decrease in the percentage of emotionally-charged words (Figure 4) and an increase in the number of authors in Block C (see Méndez *et al.*, 2014b). All these data are in agreement with the already mentioned concept of professionalization of science. Moreover, the idea of honorary/guest/gift authorship has strongly to be dismissed in A&A as the mean number of ACKs/number of authors per RP shows a clear, although non-statistically significant, increase from Block A to Block C (Figure 2). Unlike in MNRAS, the afore-mentioned fall of laudatory words in A&A may be more clearly attributed to the growing use of a non-emotional and more impersonal register in science, reflecting thus the relationships among astrophysicists usually in force today.

From a general standpoint, it can be stated that the very high frequency of ACKs found in astrophysics (Table 1) is consistent with previous studies dealing with ACKs in other 'hard' disciplines such as, for example, chemistry (Cronin *et al.*, 2003, 2004), or medicine (Salager-Meyer *et al.*, 2009, 2011), to name just a few. Of all the ACKs recorded (Table 3), it is the financial support, mainly public, that is most frequently acknowledged. This should come as no surprise since research in astrophysics is a clear example of Big Science which needs huge amounts of money and the participation of many companies and governments to be carried out (see "Introduction" section). Our results regarding the main sources of funding in astrophysics research would be then at variance with medical research which has been reported to be financed by the private sector (Salager-Meyer *et al.*, 2009). The second most frequently acknowledged support is the technical/instrumental one, which is a clear reflection of the equipment-intensive nature of astrophysics research in the same line as other experimental research (Cronin & Franks, 2006; Salager-Meyer *et al.*, 2009). As for ACKs voiced at conceptual or peer interactive support, they have been considered foundational for identifying intellectual debts in fields such as astronomy (Verner, 1992, 1993, 1996), library and information science (Cronin *et al.*, 1993) and computer science (Giles & Council, 2004) to the point that some researchers have even considered them to be at least as valuable as citations (Edge, 1979; McCain, 1991; Cronin *et al.*, 1993; Cronin & Weaver, 1995). In other more social-oriented fields such as humanities and social sciences (Cronin, 1995; Cronin *et al.*, 2003; Díaz-Faes & Bordóns, 2014), or in PhD dissertations and MA theses (Hyland, 2003), academic assistance has also been found to be important and may be probably linked to lower levels of co-authorship (Costas & Leewen, 2012).

Diachronically speaking, the number of ACKs, their length and the mean number of words/number of ACKs per RP (Table 2) grow over time, although each type of ACK behaves differently. For example, financial, instrumental, and conceptual supports rise from Block A to Block C (Tables 4, 5 and 6), whereas moral, editorial and unclassified ACKs decline (Figure 3, Table 7). The numbers of emotionally-charged words (Table 10) and boosters, named individuals and identified referees (Tables 8 and 9) also show a decline from Block A to Block C, as opposite to unnamed individuals and anonymous referees (Tables 8 and 9) which increase in the same time span. Once more, all these data can be interpreted in the light of the concept of Big Science.

If we establish a differentiation between the American publication context (AJ and ApJ) and the European one (MNRAS and A&A), we can see that RPs

published in the American journals include more ACKs (Table 3), with a higher average-length and a higher mean number of ACKs/number of authors per RP (Table 1). Financial and instrumental ACKs predominate in the American context, whereas conceptual support prevails in the European one. Editorial ACKs are more prevalent in the European context, mainly in A&A where a vast majority of authors are non-native English speakers and may probably resort to editorial/ linguistic support. The number and variants of emotionally-charged words (Table 10) and boosters are lower in the ACKs published in the American journals. Since ACKs are usually longer in this context (Table 1), the percentage of this type of words is even lower (Figure 4). All these results may suggest that scientific professionalism is much more evident in the American context than in its European counterpart. The statistically significant decline noticed in the mean number of ACKs/number of authors per RP (Figure 2) in the American context may also suggest a growth in the referred scientific professionalism. However, the fact that emotionally-charged words increase in the American context, mainly led by AJ, as opposed to their decrease in the European context (Figure 4), must prevent us from drawing any clear and static picture. Likewise, the potential presence of honorary/guest/gift authorship, different for each journal, may even more tangle up the scenario.

5. Conclusions

In this paper, we have conducted a research study on the practice of ACKs, an important and standard feature of the scholarly communication process that reflects sub-author collaboration beyond co-authorship. We have analysed it in astrophysics, a field which has somehow been discursively left unaddressed but for a few exceptions.

The material presented here for the four principal scholarly journals in the field of astrophysics support the following general conclusions:

1. ACKs are an almost omnipresent section in astrophysics RPs.
2. The number of ACKs, their length, and the mean number of words per ACKs per RP grow over time.
3. Financial support is the most frequent type of ACKs, followed by technical/instrumental support. Public financial assistance predominates in contrast to other 'hard' sciences.
4. Financial, instrumental, and conceptual supports grow over time, whereas moral, editorial and unclassified assistance decline.

5. The numbers of emotionally-charged words and boosters, named individuals and identified referees show a decline over time, in contrast with the number of unnamed individuals and anonymous referees.
6. All these data can be understood in the frame of growing scientific professionalism.
7. A detailed cross-journal analysis may suggest the occasional appearance of honorary/guest/gift authorship.
8. The RPs published in the American journals include more ACKs, with a higher average-length and a higher mean number of ACKs/number of authors per RP.
9. Financial and instrumental ACKs predominate in the American publication context, whereas conceptual and editorial ACKs prevail in the European one.
10. The percentage and variants of emotionally-charged words and boosters are lower in the ACKs published in the American journals.

Nevertheless, the complexity of the matters involved in such a heterogeneous discipline as astrophysics and the erratic changes noticed in some of the data analysed (for example, the slight increase over time of emotionally-charged words in the American context) limit the generalizability of these findings and cannot allow us to achieve very conclusive results. A larger sample would probably “unravel” the depicted situation and would support more robust claims on the behaviour of ACKs in the field of astrophysics.

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Appendix

Emotionally-charged words

Emotionally-charged words	AJ	Apj	MNRAS	A&A	TOTAL
careful	0-1-3	1-1-0	2-1-2	5-2-0	18
carefully	0-0-0	0-0-0	0-1-0	0-1-0	2
cheerfully	0-1-0	0-0-0	0-0-0	0-0-0	1
constructive	1-2-0	1-2-1	1-1-1	1-3-2	16
deeply	0-0-0	0-0-0	0-0-0	1-0-0	1
encouraging	0-0-0	0-0-0	0-0-0	0-1-0	1
enlightening	1-0-0	0-0-0	0-0-1	0-0-0	2
(e)special	1-0-0	0-0-1	0-0-1	0-0-0	8
(e)pecially	0-0-0	1-0-2	1-0-1	2-1-0	8
excellent	1-0-2	2-0-1	1-0-0	0-0-2	9
extremely	0-0-0	0-0-0	0-0-0	0-1-0	1
fruitful	0-0-0	0-0-0	0-0-1	2-3-1	7
generous	0-3-1	1-0-0	0-2-0	0-0-0	7
generously	0-0-0	1-0-1	0-0-0	0-0-0	2
grateful	5-8-14	8-6-4	7-9-7	11-6-4	89
gratefully	2-2-1	1-3-0	3-1-1	4-1-0	19
gratitude	0-3-0	0-0-0	0-0-2	2-0-0	7
great	0-0-0	0-0-1	0-0-1	1-0-1	4
greatly	1-2-3	2-0-1	2-0-1	1-0-0	13
illuminating	0-0-0	1-0-0	0-0-0	0-0-1	2
interesting	0-0-0	2-1-0	2-2-0	0-0-0	7
insightful	0-1-0	0-1-2	0-1-0	0-0-0	5
invaluable	2-0-0	0-0-0	1-1-0	2-1-1	8
kind	0-1-0	0-0-0	1-2-0	3-0-0	7
kindly	2-0-1	1-0-0	0-1-0	1-2-1	9
pleasure	0-1-1	1-1-0	3-0-1	0-0-0	8
positive	0-0-1	0-0-0	0-0-0	0-0-0	1
significant	1-0-0	1-0-1	0-0-0	0-0-0	3
significantly	0-0-0	0-0-0	0-1-1	1-0-0	3
sincere	1-0-1	0-0-0	0-0-0	1-0-0	3
stimulating	0-0-0	0-2-0	1-2-0	0-1-0	6
thankful	0-0-0	0-0-0	0-1-0	1-0-2	4
thoughtful	0-1-0	1-0-0	0-0-1	0-0-0	3
useful	3-5-8	6-8-6	3-10-6	5-15-5	80
valuable	2-3-0	2-4-0	4-1-3	1-2-4	26
warmly	0-0-0	0-0-0	0-1-2	0-0-1	4

Boosters	AJ	Apj	MNRAS	A&A	TOTAL
a number of	0-0-0	0-0-0	0-0-1	0-0-0	1
many	3-0-1	2-3-1	2-4-4	1-3-2	26
numerous	0-0-0	0-1-0	0-1-2	1-1-0	6
plenty	0-0-0	0-0-0	0-1-0	0-0-0	1
several	0-0-1	0-1-0	1-0-0	0-0-0	3
very	1-2-4	0-1-1	0-1-2	2-4-1	19

NOTE: Each number in each column corresponds to a period of time. For example, in AJ, the first number in “careful” refers to Block A (0 occurrence), the second number to Block B (one occurrence), and the third number to Block C (three occurrences).