"Can I write *this is ableist AF* in a peer review?": A corpus-driven analysis of Twitter engagement strategies across disciplinary groups

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Abstract

At a time when scholars are increasingly expected to participate in public knowledge dissemination, social media platforms like Twitter hold great promise for engaging both experts and non-experts. However, it remains unclear in what ways academic tweets are shaped by disciplinary concerns and how this might, in turn, impact audience engagement. Our paper reports an early-stage corpus-driven analysis of 4,000 English tweets from 40 scholars' Twitter accounts across four disciplinary groups: Arts and Humanities (AH), Social Sciences (SS), Life Sciences (LS), and Physical Sciences (PS). Engagement rates, multimodal elements, tweet types, and interaction markers were quantitatively calculated using corpus and computational methods and qualitatively analysed through close reading. Our findings revealed some disciplinary variation in the corpus: specifically, LS used more multimodal elements than SS on Twitter; SS used fewer interactional markers than LS and PS on Twitter. We further found that LS also has the highest number of threads and the longest threads, often to unfold their multimodal information. Despite being the least multimodal and interactive disciplinary group, SS has the highest engagement rate. Our analysis suggests that explicit evaluation and critique play an important role in eliciting responses on Twitter, particularly with regard to current social or political issues—a finding that resonates with previous research on science communication and popularization. The findings can be applied in science communication training to raise disciplinary awareness in shaping one's social media presence.

Keywords: academic Twitter, interaction strategies, disciplinary differences, genre, corpus linguistics

Resumen

"¿Puedo escribir esto es discriminatorio AF en una revisión por pares?": Un análisis de corpus de las estrategias de implicación en Twitter entre grupos disciplinarios

En un momento en el que se espera cada vez más que los académicos participen en la difusión pública del conocimiento, las plataformas de medios sociales como Twitter ofrecen grandes posibilidades para atraer tanto a expertos como a no expertos. Sin embargo, sigue sin estar claro de qué manera los tuits académicos están determinados por intereses disciplinarios y cómo esto podría, a su vez, afectar a la participación de la audiencia. Nuestro artículo presenta un análisis de corpus inicial de 4.000 tuits en inglés extraídos de 40 cuentas de Twitter de académicos de cuatro grupos disciplinarios: artes y humanidades, ciencias sociales, ciencias de la vida y ciencias físicas. Las tasas de "implicación" (*engagement*, en la bibliografía anglófona), los elementos multimodales, los tipos de tuits y los marcadores de interacción se calcularon cuantitativamente mediante métodos computacionales y de corpus, y se analizaron cualitativamente mediante lectura detallada. Nuestros resultados revelaron cierta variación disciplinar en el corpus: en concreto, en ciencias de la vida se utilizaron más elementos multimodales que en ciencias sociales; en ciencias sociales se utilizaron menos marcadores interaccionales que en ciencias de la vida y ciencias físicas. Además, descubrimos que en ciencias de la vida se da el mayor número de hilos y es donde aparecen los hilos más largos, a menudo para desarrollar su información multimodal. A pesar de ser el grupo disciplinar menos multimodal e interactivo, ciencias sociales tiene el mayor índice de implicación. Nuestro análisis sugiere que la evaluación y la crítica explícitas desempeñan un papel importante a la hora de desencadenar respuestas en Twitter, sobre todo en relación con cuestiones sociales o políticas de actualidad—un hallazgo que está en línea con investigaciones previas sobre comunicación y popularización científica. Los hallazgos pueden aplicarse a la formación en comunicación científica para aumentar la conciencia disciplinaria en la configuración de la propia presencia en los medios sociales.

Palabras clave: Twitter académico, estrategias de interacción, diferencias disciplinarias, género, lingüística de corpus

1. Introduction

Scholars are increasingly expected to engage in public knowledge dissemination, as part of broader calls for the democratization of science. Digital genres and social media are central to this effort, as they enable users to reach diverse audiences simultaneously and instantaneously by creating,

sharing, and commenting on multimodal content (Luzón & Pérez-Llantada, 2019, 2022). Although Twitter has at times facilitated the spread of misleading or harmful claims, igniting concerns over its "hands-off" approach to content moderation, the platform also seems very promising when it comes to communicating with the public (e.g., Zappavigna, 2012; Mazarakis & Peters, 2015; Squires, 2016). Indeed, academics have successfully used tweets to raise awareness of pressing issues, such as climate change, and to disseminate relevant scientific knowledge more widely (Walter et al., 2019). Orpin (2019) and Tardy (2023) showed how a European health agency and U.S.-based epidemiologists, respectively, used Twitter microblogs (tweets) to reach lay audiences, allowing them to enhance their public visibility and provide a necessary corrective to vaccine misinformation. Case studies have also noted promising uses of Twitter by individuals and research groups in other disciplines, ranging from sociology (Holmberg & Thelwall, 2014; Schneider & Simonetto, 2017) and marine ecology and conservation (Darling et al., 2013) to engineering, medicine, and chemistry (Luzón & Pérez-Llantada, 2022). Like the epidemiologists in Tardy's (2023) study, these academics tweeted for various reasons, including self-promotion, professional networking, and public outreach, drawing on a wide variety of semiotic and linguistic resources (Luzón & Pérez-Llantada, 2022; see also Veletsianos, 2011).

Studies have thus begun to examine the characteristics of science-related tweets and to explore their unique affordances in communicating with peers, journalists, policy-makers, and the interested public at large (Côté & Darling, 2018). At the same time, several aspects of academic Twitter remain underresearched, and those who would like to use Twitter or other social media to increase their outreach might be unsure how to do so, especially since professional writing support is often limited (Negretti et al., 2022). The first aspect that still needs to be considered is the question of whether and how rhetorical strategies and features on Twitter may be tied to discipline. A large-scale scientometric study of academic Twitter (Holmberg & Thelwall, 2014) did find some disciplinary variation in the hypertextual and cross-referencing practices of individual academic Twitter users, including the act of "retweeting," or simply reposting, others' messages (most common in biochemistry) and the inclusion of URLs (most common in economics). However, the authors did not offer possible explanations for these differences, nor did they consider linguistic or multimodal features of the tweets in much detail. More recently, Luzón and Pérez-Llantada (2022)

examined a multidisciplinary corpus of 600 tweets by six Spanish research groups, and concluded that the groups' choice of language (English, Spanish, or Catalan) in different kinds of tweets was likely influenced by their discipline and topic, among other factors. This finding suggests that other discursive choices in academic tweets could also be shaped by disciplinary considerations, such as the nature of one's research and the possible contribution to public debates.

The second aspect that requires further attention is the strategic use of the various elements in science-related tweets, including linguistic (e.g., self-mentions, attitude markers), multimodal (emojis, images, videos), and hypertextual ones (hashtags, mentions, URLs). Thus far, a handful of applied linguists have investigated how academics tailored their messages to specific purposes and audiences (Orpin, 2019; Luzón & Albero, 2020; Luzón & Pérez-Llantada, 2022; Tardy, 2023), and how doing so allowed them to convey their expert authority while also taking on more relatable roles, such as those of "engaged or critical citizen, politically minded person, witty tweeter, or parent" (Tardy, 2023, p. 11). Regarding the multimodal content, Tardy's (2023) study found that about half of the epidemiologists' tweets which drew the most attention included images. It is worth testing if images are frequently used by academics in other disciplines too, and if this or other elements could help predict the potential for a tweet to reach a large audience (or even "go viral").

Interaction markers (Hyland, 2005) also seem to provide an important peer and public engagement strategy (Orpin, 2019), though it is still unclear how their use compares to traditional academic writing practices; here too, preferences might vary by discipline, as seems to be the case for academic blogs (Zou & Hyland, 2020). Finally, it is necessary to consider how word choice might help to adapt, or "recontextualize" (Tardy et al., 2020), information for different audiences. For example, Walter et al. (2019) demonstrated that scientists who tweeted about climate change tended to use more negative, emotionally charged language when addressing non-experts as opposed to peers, perhaps to emphasize the urgency of the topic or to incite action (Luzón & Pérez-Llantada, 2022). If we want to provide effective support for science communication on Twitter or other social media platforms, it is important to consider whether Twitter users in other disciplines adjust their word choice for non-experts, as well as to what degree this may help them reach a broader audience.

The present study explores these issues through a corpus-driven analysis of 4,000 English-language tweets that were posted between August 2021 and February 2022 by individual academic users across four disciplinary groups: Arts and Humanities (AH), Social Sciences (SS), Life Sciences (LS), and Physical Sciences (PS) (Nesi et al., 2005). The aim of the study was to uncover how semiotic choices differed across these groups, as well as how the use of certain devices might be linked to peer and public engagement, measured through the number of replies, retweets, and "likes" elicited by the tweets.

Below, we briefly review key concepts from the literature on academic Twitter and disciplinarity that informed our approach, before discussing our method and findings in more detail. We conclude the paper by discussing future directions for research on public scholarship and social media and by considering the practical implications for science communication training.

2. Literature review

2.1. Key characteristics of academic Twitter

Given Twitter's widespread popularity and accessibility, it is perhaps not surprising that the microblogging site has attracted a large number of scientists and now serves as an important tool for science communication. Indeed, previous studies estimated that 40% of scientists are active Twitter users (Côté & Darling, 2018), and this percentage has likely grown. One explanation for the platform's appeal is its potential for users to reach multiple audiences globally (Tardy, 2023). Not only are tweets visible to one's "followers"; they may also be circulated more widely by those who like, comment on, or share them, whose followers in turn will also be able to view them. This way, messages may be read by audiences outside of the user's own network, including ones that fall outside the scope of the intended or anticipated audience. A common measure of the attention generated by a tweet is its engagement rate, or the degree to which a user's followers visibly interact with it, whether by "liking" it, reposting ("retweeting") it, or replying to it. More specifically, the engagement rate is calculated as follows: the number of engagement "actions" (i.e., replies, retweets, and likes) is divided by a user's total number of followers, and then multiplied by 100, resulting in a percentage (Tardy, 2023). Engagement rates may vary considerably. In recent years, news media have increasingly relied on Twitter to incorporate

quotes in their articles, whether to capture popular opinion or expert viewpoints, and tweets can also be shared through other social media platforms such as Facebook, which could further increase their circulation and thus their engagement rate. In fact, a tweet may even "go viral," in which case it spreads so rapidly between networks that it can quickly attract a lot of attention across the internet. The resulting blurring of traditional boundaries between contexts and audiences, also known as "context collapse" (Marwick & Boyd, 2011), takes place across digital media, but it is especially noticeable in the case of Twitter, where any given message can find its way to diverse audiences, transcend networks, and accomplish multiple purposes simultaneously (Reid & Anson, 2019). This makes it difficult to distinguish between "expert-facing" tweets, whose content is addressed to academic audiences (e.g., fellow experts or scientific groups/organizations) and "public-facing" tweets, which are directed at journalists, decision-makers, government agencies, or any interested members of the public. Thus, while the potential for both "inreach" and "outreach" (Côté & Darling, 2018) makes Twitter a powerful tool for science communication, it also poses unique challenge, as users must consider the possibility that their tweets will be read by multiple audiences and in different ways (Pérez-Llantada, 2021; Tardy, 2023).

Another important characteristic of academic Twitter is that it is fairly easy to use: after choosing a Twitter handle or username (beginning with the "@" symbol) and a display name and creating a brief profile, users can immediately start writing short posts or tweets consisting of up to 280 characters, and they may search for and "follow" other users. As found by Tardy (2023), tweets can incorporate a wide range of elements in the form of language, emojis, images, videos, GIFs, URLs, hashtags (keywords or phrases used to mark, categorize, and search for content; see also Scott, 2015), and mentions (the inclusion of other users' handles). These multimodal elements are key to academic Twitter's success, as they enable users to present specialized knowledge in innovative and relatable ways, leading to increased engagement rates through replies, retweets, and likes. In this regard, Orpin (2019) has considered science-related tweets and other social networking messages as "popularization genres," or genres which adapt or recontextualize information in order to make it more easily understandable, appealing, or salient for non-experts (Calsamiglia & van Dijk, 2004; Tardy et al., 2020). As a case in point, appeals to novelty in science tweets might invoke news headlines or current public debates, for

example through hashtags (Scott, 2015), rather than contributions to a scholarly discipline, as would be typical for novelty claims in research articles.

2.2. Disciplinary writing practices and conventions

Prior research has revealed cross-disciplinary variation in academic writing, particularly in research articles, but it remains unclear to what degree these findings apply to digital genres. In particular, Hyland has examined reporting verbs, citation types, and linguistic interaction markers (i.e., expressions such as *we, important,* and *however* that adopt a point of view in relation to both the issues discussed in the text and to others who hold points of view on those issues) in published research writing. He noted that the use of such devices seems to be tied to "epistemological assumptions and social practices" (2002, p. 1098) within scholarly disciplines. For example, it appears that writers in the natural sciences show a greater preference for non-integral citations and more often avoid self-reference or cognitive verbs such as *think* or *believe*, in line with positivist notions of knowledge production (Hyland, 2002, 2008). Those in the social sciences and humanities, in contrast, seem to acknowledge their own and other researchers' agency more readily through the use of integral citations as well as self-mentions and attitude markers, which serve to express stance. Interaction markers, which enable writers to appeal directly to their readers, also occur more frequently in "soft" disciplines such as philosophy, sociology, applied linguistics, and marketing (Hyland, 2005). Studies have further made note of disciplinary conventions and preferences in other traditional forms of academic communication, including spoken genres (Hyland & Bondi, 2006). Clearly, mastery of such conventions can play an important role in presenting oneself as a competent scholar and disciplinary insider.

However, empirical accounts of disciplinary variation in digital popularization genres remain lacking. An exception is a study by Zou and Hyland (2020) on academic blog posts, which provided limited evidence that this genre does follow certain traditional patterns, including the more frequent use of attitude markers and questions in the soft disciplines (Zou & Hyland, 2020). The scientometric Twitter study by Holmberg and Thelwall (2014) further suggested that the use of Twitter-specific citation types in science-related tweets varied by discipline: the digital humanities researchers in their corpus included more mentions, while economists used more hyperlinks (URLs) to external content; in comparison, biochemists more frequently chose to retweet others' posts. Yet, on the whole, the

available research rather points to general tendencies in popularization genres, regardless of the discipline. These genres generally appear to minimize complexity, express greater certainty, and include more personal evaluation than traditional research writing, while increasing proximity and intimacy with readers through interactional features (Luzón, 2013; Zou & Hyland, 2020); they thus blend discursive practices and registers from academic, journalistic, and personal realms (Luzón, 2013; Tardy, 2023). To gain a better understanding of academic Twitter, then, it is important to examine whether and how the use of "traditional" interaction markers differs across disciplines. In addition, given the ubiquity of multimodal and hypertextual elements on Twitter, it is necessary to consider the disciplinary use of these elements and their possible relation to engagement rates as well.

Although writing practices are clearly shaped by disciplinary values and beliefs, including understandings of knowledge (ontology) and how it is produced (epistemology), it is important to avoid overgeneralizing such findings. Obviously, stylistic differences can also be attributed to individual preferences on the part of the author. In addition, disciplinary boundaries seem rather porous: academic discourse communities such as university departments, professional organizations, research groups, and conferences do not always neatly align, and research activities often extend across such communities. In order to examine disciplinary tendencies, then, it seems sensible to compare writing samples in disciplinary groupings, rather than individual disciplines. Nesi et al. (2005) noted the benefits of such an approach in reference to corpora of student writing and lectures, concluding that "[t]his system has the merit of allowing some degree of comparability between corpora, and is broad enough to accommodate many university modules which might straddle more highly specified groupings" (p. 6). Here, we have chosen to follow Nesi et al.'s (2005) grouping of four disciplinary domains (Arts and Humanities (AH), Social Sciences (SS), Life Sciences (LS), and Physical Sciences (PS)), which previously provided the basis for other well-known and influential academic corpora, such as MICASE (Simpson et al., 2002) and BASE (Thompson & Nesi, 2001).

Based on our above review of the literature, this study addresses the following questions:

1) What are the average engagement rates for academic Twitter users from the four disciplinary groups?

2) How are specific tweet types (single tweet, tweed thread, and quote

tweet), multimodal and hypertextual elements, and interaction markers related to engagement rate, and how does their use vary across disciplines?

3. Methodology

3.1. The corpus

The selection of disciplines in this study, as discussed in the literature review, follows the four broad disciplinary groups proposed by Nesi et al. (2005). Nesi and Gardner (2012, p. 10) further identified a number of common disciplines under each group, which provided the base for this study to select five from each (see Table 1) and 20 in total (see Table 1) in the current research. Closely related disciplines (e.g., linguistics and applied linguistics) were avoided to increase the representativeness of disciplines in each group.

For the selection of Twitter accounts, two per discipline were chosen, resulting in 10 per disciplinary group and 40 in total (see Table 1). Our selection criteria drew on Veletsianos' (2011) study and followed four steps: 1) A keyword search for each discipline (e.g., linguistics + professor) on Twitter resulted in a list of accounts that include a bio that indicates the discipline and an academic title (e.g., assistant professor, associate professor or professor). 2) Starting from the top of the list, an account would be selected if most of its tweets are in English (not necessarily native English) as English is the lingua franca for the authors of this paper; it has a number of followers between 2,000 and 40,000 (based on our observation, many active scholars on Twitter fall in this range); the account owners are teaching- and research-active; and the account posts at least once per week. 3) To increase the representativeness of scholars from different higher education institutes, each account owner is based at a university different from the other 39 scholars. 4) We also balanced the proportions of gender (five females and five males) and racial categories (four non-white and six white) across disciplinary groups. Although identifications based on photos and names may not be accurate, and the boundaries between these categories can be fuzzy (Talbot, 2022), such considerations help minimise racial and gender biases (e.g., selecting 40 white male scholars) and increase the representativeness of the data.

For the selection of tweets for each account, a tweet is defined as either a single tweet (see Figure 1) or a tweet that forms part of a thread (see Figure

2); each can also be a retweet (see Figure 2). However, a retweet without any comment from the account owner is not considered a tweet for its little value from a discursive point of view. The target period for selection is 1st August 2021 to 31st April 2022. Our third author wrote a Python program to randomly sample 100 tweets per account, generating 4,000 tweets in total. An overview of the corpus is given in Table 1.

Figure 1. An example of a single tweet

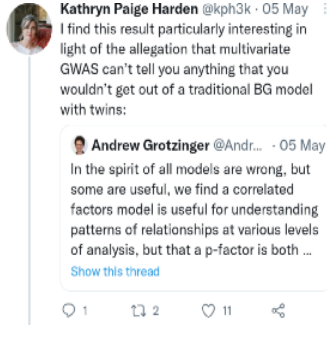


Figure 2. An example of a thread tweet which is also a quote tweet

Disciplinary groups	Disciplines	No. of accounts	No. of tweets	No. of characters
AH	Linguistics, Classics, Archaeology, History, Philosophy	10	1,000	186,643
SS	Anthropology, Business, Education, Politics, Sociology	10	1,000	167,920
LS	Agriculture, Biological science, Medicine, Food science, Psychology	10	1,000	180,995
PS	Chemistry, Engineering, Mathematics, Physics, Architecture	10	1,000	141,598
	Total	40	4,000	677,156

Table 1. The corpus description

3.2. Data analysis

Our units of analysis are drawn from the analytical framework proposed by Tardy (2023), who considered engagement rates as well as discursive resources that might contribute to engagement rates, such as multimodal elements, tweet types, and interaction markers from Hyland's model (2005). The four units were chosen for their usefulness in gauging a tweet's success, as discussed in the literature (Holmberg & Thelwall, 2014; Luzón & Pérez-Llantada, 2019; Zou & Hyland, 2020; Tardy, 2023). While these units could be further consolidated, we have decided to adhere to Tardy (2023) and Hyland (2005) for the purposes of clarity and brevity. The numeral differences in each analytical category across disciplinary groups were statistically tested using standard error, followed by qualitative scrutiny of ten percent of the instances. Each of the four aspects will be introduced below.

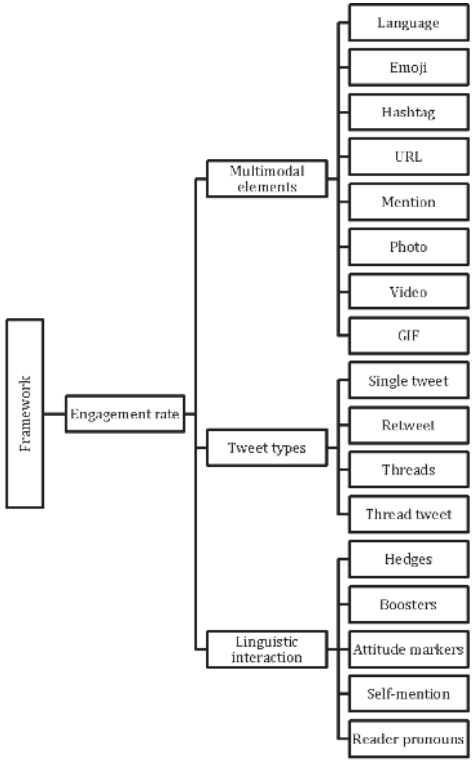


Figure 3. The analytical framework

Engagement rate. Following Tardy (2023), we calculated the engagement rate for each collected tweet. As shown in Figure 4, it first sums up the number of replies, retweets (including retweets with no comments) and likes received by a tweet, and then divides the sum by the total number of followers of this account, and lastly, multiplies the result by 100 to generate a number in percentage. Any percentage above 1% can be considered a very high engagement tweet, 0.16% to 0.99% a high engagement tweet, 0.05% to 0.15% an average or good engagement tweet, and 0% to 0.04% a low engagement tweet (see also Tardy, 2023). We used Python (Van Rossum & Drake, 2009) to calculate each collected tweet's engagement rate and then each disciplinary group's average engagement rate for disciplinary comparisons.

Figure 4. Engagement rate formula

Multimodal elements. In order to examine differences in the use of multimodal resources, we also used Python to identify eight multimodal elements (i.e., language, emoji, hashtags "#", URLs, mentions "@", images, videos, and GIFs) and calculated their average number of occurrences from users in a given disciplinary group.

Tweet types. For each disciplinary group, we used Python to calculate the average number of single tweets, retweets, and threads from users of each group as well as the number of tweets per thread from users of each group. The numbers from each group were compared afterwards.

Interaction markers. Following Tardy's (2023) study, our analysis applied Hyland's (2005) interaction framework to identify linguistic discursive markers that concern the ways users present themselves and convey their judgements, opinions, and commitments as well as the ways users relate to their receivers with respect to the positions advanced in the text. User-receiver interaction can be initiated through devices such as hedges (e.g., *possible, might, perhaps*—withhold complete commitment), boosters (e.g.,

clearly, obviously, demonstrate—express certainty), attitude markers (e.g., *agree, unfortunately, fascinating*—indicate the user's positive or negative attitude), self-mention (e.g., *I, we, our*—present interpersonal information), reader pronouns (e.g., *you, your*—bring readers into a discourse), directives (e.g., *note, imagine, it is important to understand*—instruct the reader to perform an action), questions (e.g., *Why does the capacitance behave this way*?—lead the interlocutor to the user's viewpoint), shared knowledge (i.e., position readers within apparently naturalised boundaries of disciplinary understandings), and personal asides (i.e., address readers directly by briefly interrupting the argument to offer a comment on what has been said). However, not all categories were applied. Similar to Tardy's (2023) study, we excluded shared knowledge and personal asides because both types are propositions difficult to be identified using corpus techniques such as word search. We also excluded questions as a question mark may not be strictly associated with one question (e.g., "?????" and "!?!?!") as well as directives as they highly depend on context. To annotate the other interaction devices in our data, we first contacted Hyland and obtained the list of pre-search items for his 2005 study, and excluded the items for shared knowledge, personal asides and directives. We also excluded the items under attitude markers in the list and applied VADER (Hutto & Gilbert, 2014) for annotating attitude markers. VADER is a highly accurate sentiment analysis tool widely applied in NLP studies. It takes into account lexical, grammatical and syntactical conventions for expressing positive and negative sentiment. It provides higher accuracy of positive and negative markers than the pre-list of attitude markers from Hyland (2005). For the other four categories (i.e., hedges, boosters, self-mention, and reader pronouns), we annotated the items from Hyland's pre-list items. Although the items are derived from research articles and may not transfer neatly to Twitter discourse, they still cover a good range of markers based on our experience with Twitter. For each disciplinary group, the normalised frequency (per 1,000 words) of each interaction category was calculated using Python, followed by disciplinary comparisons.

4. Results

4.1. Differences in engagement rate

The average engagement rate for the accounts belonging to each disciplinary group is shown in Figure 5. All four groups have an average rate between

0.16% and 0.99%, which can be regarded as high (Tardy, 2023). However, the rate of SS (0.82%) is significantly higher than the rate of AH (0.30%), as the average of AH is not within one standard error from the average of SS; it is twice that of LS (0.42%) and PS (0.45%). This means that the social scientists' tweets somehow received more responses from their readers through replies, retweets and likes. The following sections will shed light on why SS stands out as particularly engaging by revealing the differences in the use of multimodal elements, tweet types, and interaction markers across the four groups.

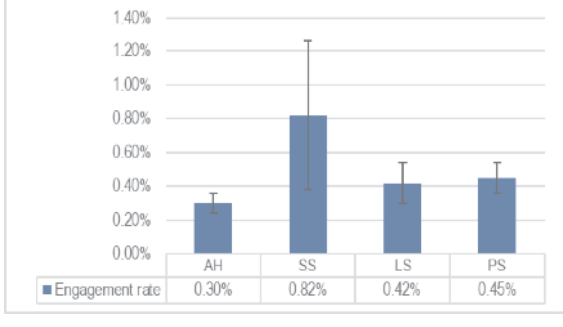
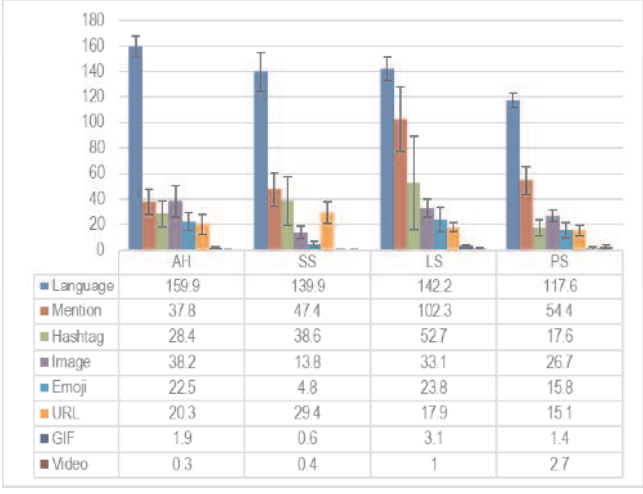


Figure 5. Average engagement rates of the tweets in the four disciplinary groups

4.2. Differences in multimodal elements

The average number of each multimodal element from users belonging to each disciplinary group is presented in Figure 6, except for the element of language, where it shows the average length of tweets (measured in characters) from users belonging to each disciplinary group.



	AH	SS	LS	PS
Language	159.9	139.9	142.2	117.6
Mention	37.8	47.4	102.3	54.4
Hashtag	28.4	38.6	52.7	17.6
Image	38.2	13.8	33.1	26.7
Emoji	22.5	4.8	23.8	15.8
URL	20.3	29.4	17.9	15.1
GIF	1.9	0.6	3.1	1.4
Video	0.3	0.4	1	2.7

Figure 6. Multimodal elements in the tweets of the four disciplinary groups

The highest and lowest numbers of each multimodal element indicate that LS is the most multimodal group, and SS is the least multimodal one. For example, LS's number of *mentions* per 100 tweets (102.3) significantly doubles that of the other groups (AH 37.8; SS 47.4; PS 54.4); its number of *emojis* (23.8) is higher than that of AH (22.5) and PS (15.8) and significantly quintuples that of SS (4.8); its number of *GIFs* (3.1) is significantly higher than that of the other groups (AH 1.9; PS 1.4; SS 0.6); and it has more *hashtags* (52.7) than the other groups (SS 38.6; AH 28.4; PS 17.6), although this difference is not statistically significant. A close look at a few multimodal samples from the LS group (see Figure 7) reveals that the LS scholars often mentioned colleagues in their promotion of research output or activities. This might be due to particularly large teams and communities common in LS, such as the team with 46 authors mentioned in Figure 7B. Research keywords or names of events were commonly made searchable through *hashtags,* as in Figure 7A. *Emojis* were often used to express positive attitudes such as excitement, appreciation, and cheerfulness about research achievement, collaboration and events. This upbeat attitude was sometimes enhanced by *GIFs,* as in Figure 7A. It is also common to see visualisations of research data intended to draw colleagues' attention and provide more details regarding their research findings. Generally speaking, the multimodal efforts made by the LS scholars targeted their peers and students rather than the public, creating a collegial, informative, and interactive impression of the research community.

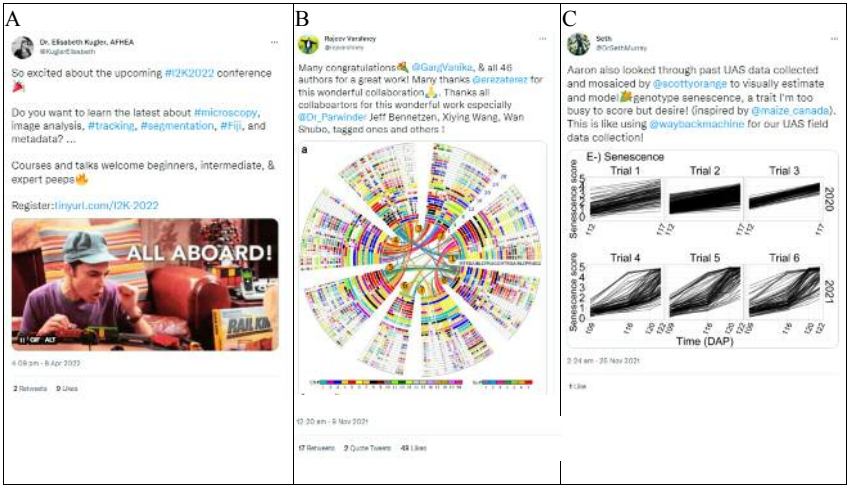


Figure 7. Three representative tweets from LS

In contrast to the multimodal tweets from LS, social scientists significantly used fewer *images* (13.8 as opposed to 38.2 for AH, 33.1 for LS and 26.7 for PS), *emojis* (4.8 as opposed to 22.5 for AH, 23.8 for LS and 15.8 for PS), and *GIFs* (0.6 as opposed to 1.9 for AH, 3.1 for LS and 1.4 for PS), as can be seen in the three tweets in Figure 8. However, the SS scholars used more URLs (29.4) than the other groups (AH 20.3; LS 17.9; PS 15.1). The links often lead the audience to news articles regarding social issues, which are central to the research interest of SS scholars. However, it is more difficult to interpret whether the intention of a tweet is to engage with peers or the public. For example, Figure 8A made a comment on an issue in education which could be read as a call for research attention from peers as well as a call for public attention to the pressing issue and a change for the better.

Figure 8. Three representative tweets from SS

The frequency of multimodal elements of AH and PS seems to lie in between LS and SS. AH has the highest numbers for *language* (159.9) and *image* (38.2) but the lowest for *mention* (37.8) and *video* (0.3). PS has the highest numbers for *video* but the lowest for *language* (117.6), *hashtag* (17.6) and *URL* (15.1). The AH scholars often used language to explain expert knowledge (see Figure 9A) and blend their work and personal life (see Figures 9B and 9C) in their engagement with peers, students, and the public. Unlike the LS scholars, who often visualised research findings in images, the AH scholars showcased objects or personal photos to complement their verbal explanations. They also rarely mention colleagues, perhaps due to extensive individual work and small teams and communities.

On the other hand, PS scholars used fewer words (see the tweets in Figure 10) but more videos and images to illustrate scientific knowledge to engage with colleagues, students, and the public.

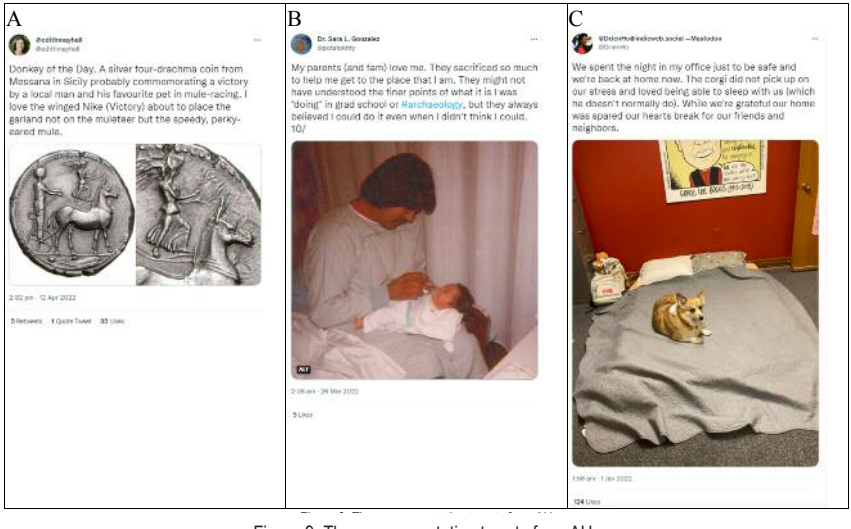


Figure 9. Three representative tweets from AH

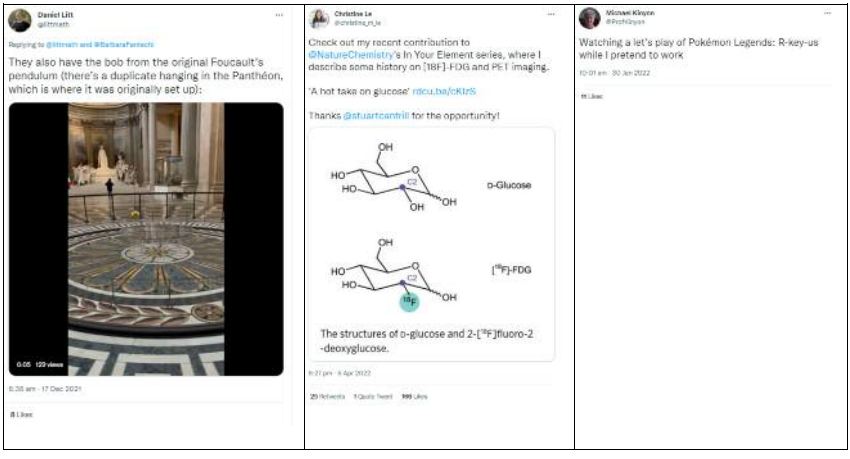
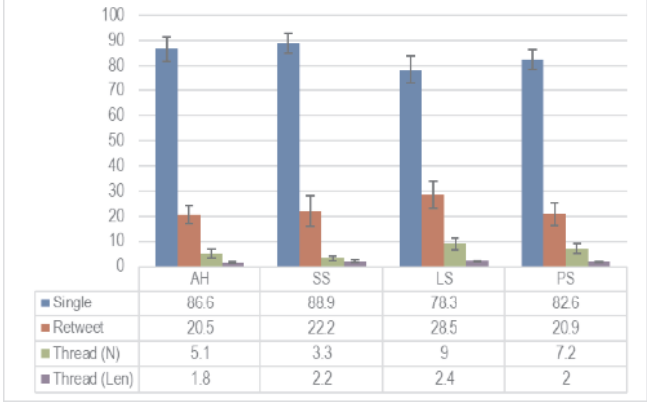


Figure 10. Three representative tweets from PS

4.3. Differences in tweet types

Figure 11 presents the average number of single tweets/retweets/threads from users of each group, as well as the average number of tweets per thread from the users of each group.



	AH	SS	LS	PS
Single	86.6	88.9	78.3	82.6
Retweet	20.5	22.2	28.5	20.9
Thread (N)	5.1	3.3	9	7.2
Thread (Len)	1.8	2.2	2.4	2

Figure 11. Tweet types of the four disciplinary groups

The two disciplines that stood out in section 4.2., LS and SS, also show distinctive differences in terms of tweet types. AH and PS are often in between and present similarities more than differences. LS is found to use threads significantly more often (9) than SS (3.3) and AH (5.1); its number is

also higher than that of PS (7.2), though not significantly. LS also wrote longer threads (2.4) than other groups (AH 1.8; SS 2.2; PS 2), although not significantly. On the other hand, SS used single tweets more often than the other groups; its number (88.9) is significantly higher than LS (78.3) and higher than AH (86.6) and PS (82.6).

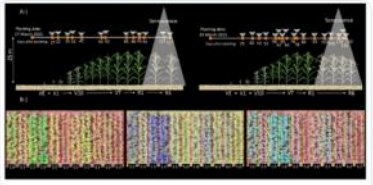
Close scrutiny of a few samples suggests the association between the use of threads and the multimodal traits of LS found in 4.2, such as mentioning collaborators in a big team, visualising research data, and positivity expressed through emojis. For example, the first thread in Figure 12 promoted to peers the work of a PhD student from his network. In this case, a single tweet is not sufficient to explain verbally the key contributions or visually the key findings of the project for the purpose of drawing the attention of peers. In contrast, the thread allows the life scientist to elaborate with a greater number of appealing visualisations of dry numbers to increase the readability and accessibility of the texts. This thread also helps build a narrative of why this work is significant and invites peers in this same area to partake in the conversation through several mentions of other individual life scientists or teams in the same field.

The second thread in Figure 12 promoted a research event. This long thread allows the life scientist to document the series of research talks chronologically. She also engaged the speakers through mentions and treated the event as a festivity through the use of positive emojis and GIFs. Hashtags of the event's name and research topics were also used frequently to increase the chance of appearing in search results. Such strong community-building practices are, however, rarely seen in SS. As shown in Figure 8 earlier, single tweets with little multimodality are considerably common.

Thread 1 (the second column is the continuation of the first one)

Seth @DrSethMurray

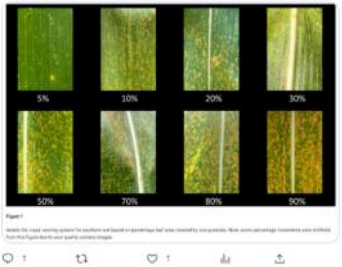
Aaron DeSalvio, new @TAMUGENE PhD student, rotated in @MAIZE_TAMU field and lab July-Oct. In that short time, working with Alper Adak he learned to turn field data he collected and some UAS data into a very cool study and led a submitted paper! Wow! 1/6 researchsquare.com/article/rs-110...



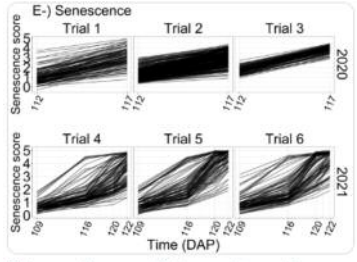
2:24 am · 25 Nov 2021

1 Retweet 12 Likes

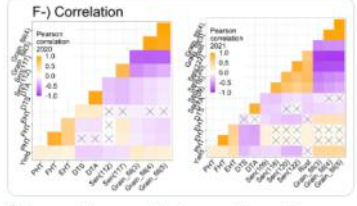
Seth @DrSethMurray · 25 Nov 2021
Replying to @DrSethMurray
Southern rust (Puccinia polyspora) prediction on maize was pretty cool and will help select more resistant varieties independent of maturity. I also think potential to help farmers to predict when they will reach an economic threshold to spray fungicide researchsquare.com/article/rs-110...



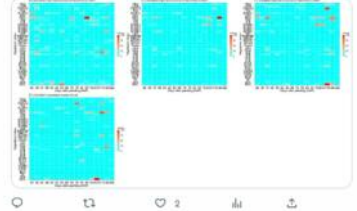
Seth @DrSethMurray · 25 Nov 2021
Aaron also looked through past UAS data collected and mosaiced by @scottyorange to visually estimate and model genotype senescence, a trait I'm too busy to score but desire! (inspired by @maize_canada). This is like using @waybackmachine for our UAS field data collection!



Seth @DrSethMurray · 25 Nov 2021
This gets even cooler! Alper and Aaron used [predicted senescence date - flowering date] on 1640 yield trial plots as a "grain filling period" proxy which was 44% correlated to grain yield in a year accelerated by southern rust! Unsurprising, but never before feasible to measure!



Seth @DrSethMurray · 25 Nov 2021
There is too much exciting stuff in this article to cover everything, but two last exciting points are that like other phenomic studies, valuable phenotypes can be predicted well in advance. Also ROC is a great vegetative index for maize in Texas! 6/6 researchsquare.com/article/rs-110...



Thread 2 (the second column is the continuation of the first one)

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth

And #CBIAS2021 is kicked off by David Barry

Session 1: "Segmentation" will start shortly with speakers Anna Kreshuk .@ilastik_team, .@weioyang, and .@computingnature.

#science #conference #networking

9:05 pm · 22 Nov 2021

2 Retweets 8 Likes

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth · 22 Nov 2021
Replying to @KuglerElisabeth, @ilastik_team and @computingnature
After a mind-blowing future-facing #session1 chaired by .@martinjones78, #CBIAS2021 is progressing now to Tech Bites #1 with .@arivisAG, .@NikonInst, and .@ZEISS_Group -- see the full programme here: crick.ac.uk/whats-on/crick...

1 4 8

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth · 22 Nov 2021
After the first session and Tech Bites, #CBIAS2021 starts its first #coffee break, before joining .@RoyalMicroSoc at 15:50 GMT and session #2 on "High-Throughput" at 16:00 GMT.

Great opportunity to network in #GatherTown and ask all burning questions on #BIAnalysis

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth · 23 Nov 2021
Following this inspirational full-on power-packed session, #CBIAS2021 moves on to Tech Bites #2 with .@LeicaMicro and .@MathWorks.

Following these, there is a coffee break, allowing us to explore the booths and recharge for session 4 on "Super-resolution and particle tracking".

1 1 4

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth · 23 Nov 2021
Next up "Super-resolution and particle tracking" with Sumin Lee, Dylan Owen, and .@EdwardAvezov.

#CBIAS2021 organizers David Barry, .@martinjones78, .@SuperResoluSian, Todd Fallesen & .@VirginieUhlmann rock various platforms simultaneously, making sure the event runs smoothly

1 1 4

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth · 23 Nov 2021
After this inspirational session on super-resolution, next up are Tech Bites #3 by .@imarisSoftware Bitplane and .@nvidia.

This will be followed by workshops and lunch

And then we have the amazing .@rita_strack from .@naturemethods talk to us about #publishing

1 3 4

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth · 23 Nov 2021
After a fantastic talk by .@rita_strack, #CBIAS2021 starts session 5 on "Electron Microscopy" chaired by .@JemimaBurden and talks by: .@albertcardona, Lucas Pagano, .@martinjones78, and Michele Darrow.

#BIAnalysis #tutorials #networking

1 4

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth · 24 Nov 2021
photo time
.. and the last #CBIAS2021 session will be on "Light-sheet and 3D surface analysis" - super excited to chair this session with the speakers: Till Brettschneider, .@alxndrkalinin, Andreas Kist, and Meghan Driscoll.

#lightsheet #LSFM #science #conference

1 1 4

Dr. Elisabeth Kugler, AFHEA @KuglerElisabeth · 24 Nov 2021
Huge thanks to all the speakers, poster presenters, and participants

Fantastic organization - huge thanks for all the hard work by the team and everyone in the background and .@TheCrick events team.

Lastly, thank you to all sponsors for supporting the symposium.

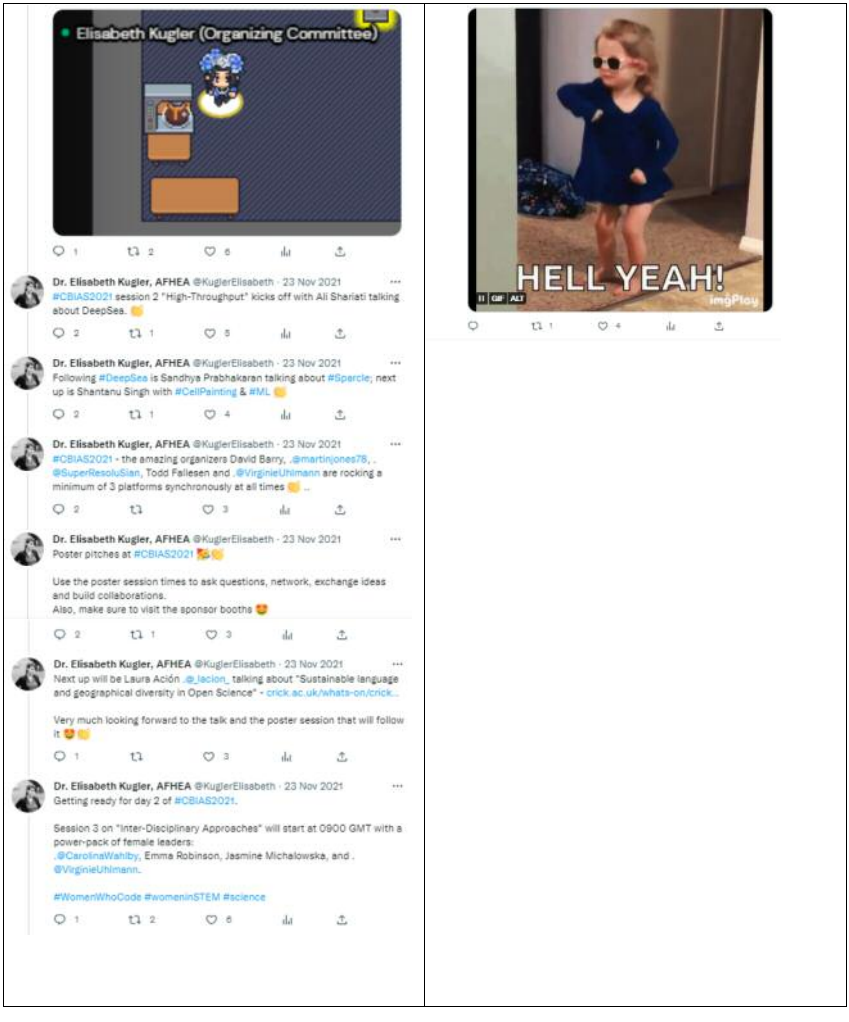
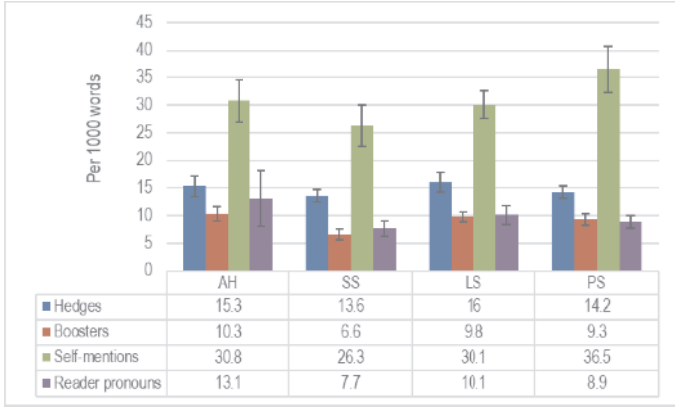


Figure 12. Two threads from LS

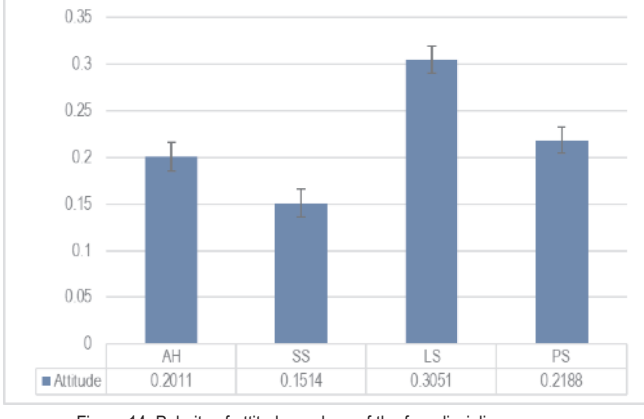
4.4. Differences in interaction types

Differences in the four types of interactions (i.e., hedges, boosters, self-mentions, and reader pronouns) across the disciplinary groups are shown in Figure 13 (per 1,000 words). The polarity of attitude markers is shown in Figure 14 (the bigger the number, the more positivity).



	AH	SS	LS	PS
Hedges	15.3	13.6	16	14.2
Boosters	10.3	6.6	9.8	9.3
Self-mentions	30.8	26.3	30.1	36.5
Reader pronouns	13.1	7.7	10.1	8.9

Figure 13. Four engagement types of the four disciplinary groups



	AH	SS	LS	PS
Attitude	0.2011	0.1514	0.3051	0.2188

Figure 14. Polarity of attitude markers of the four disciplinary groups

Interestingly, SS is found to have the lowest number for three interaction types (see Figure 13): boosters, self-mentions and reader pronouns. Its number of hedges is only slightly higher than that of PS but lower than that of AH and LS. SS is also significantly more negative than the other groups (see Figure 14). These features of SS are reflected in the samples in Figure 8 arguments expressed through *be* verbs (e.g., this is…, it is…, education is, being an academic is…), asserting the propositions as facts without holding back commitment (i.e., avoiding the use of hedges). Although boosters are not used in these claims, the compelling effect is not less, if not more. Negative attitude markers are also common in the tweets of SS, as shown in

Figures 1 and 8 (e.g., *ableist, serious, terrifying, bad, hate, oppression, worrying, blame, war*). Such framing of arguments seems to be commonly used by social scientists for the purposes of critically commenting on recent events, calling attention to societal problems (e.g., social/economic inequalities), and questioning academic practices.

In contrast, LS is significantly more positive than other groups and used more hedges and boosters. As can be seen in the tweets from Figures 7 and 12, positive attitude markers are commonly used (e.g., *excited, welcome, congratulations, great, wonderful, thanks, desire, cool, help, valuable*). Similar to the use of positive emojis, positive verbal markers are also often used to express excitement, appreciation, and cheerfulness about research achievements, collaborations, and events.

The opposing discursive choices of SS and LS (i.e., negative vs positive) seem to go beyond their differences in topics (i.e., negative social issues vs neutral objects of study) and nature of work (i.e., individual/small teams vs collegial large teams). Even for comments on the same topic, for example, peer reviews (see Figure 15), the social scientists took a critical perspective while the life scientists expressed gratefulness. It seems that the social scientists' critical perspective on social objects of study often extends to other topics on Twitter (e.g., academic practices, personal anecdotes, crowdsourcing and even self-promotion). However, it might be the witty and snarky comments that provoked peers, students and the public to respond, working as a powerful tool for Twitter engagement.

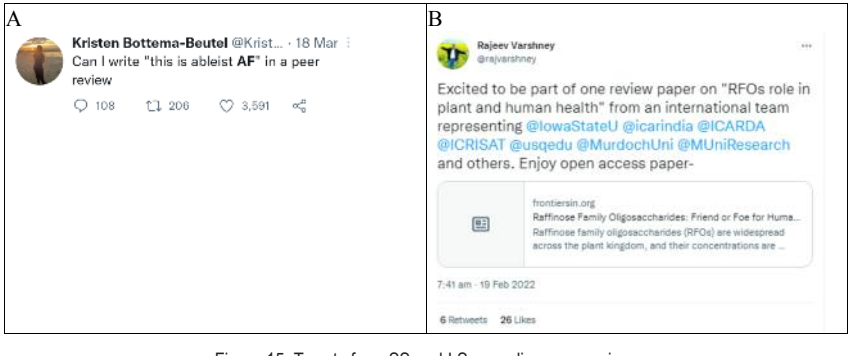


Figure 15. Tweets from SS and LS regarding peer reviews

5. Discussion

The results of discursive features in the Twitter discourse revealed that some disciplinary differences are tied to soft and hard disciplinary conventions. We found that the LS and PS scholars used more multimodal resources, such as images, GIFs, and videos, than the AH and SS scholars for the purpose of visualising scientific data, procedures, and findings and, as a result, increasing the accessibility of information. This finding is consistent with the preferred use of visual aids by scientists for the same purposes found in previous studies. For example, in research articles, scientists tend to visualise knowledge using graphical abstracts and figures (Khedri & Kritsis, 2020); as digital genres develop, there has been a trend in science to use videos in digital research articles for readers to access experimental details more easily (Hafner, 2018); Tardy's (2023) study found that epidemiologists tend to use a wide variety of multimodal resources on Twitter for the purpose of communicating scientific knowledge. Although the AH scholars in the current data also used a great number of images, they tend to be geared towards the sharing of personal life rather than their research particulars. The LS and PS scholars on Twitter also maximised their use of multimodal resources, when necessary, by using the thread function to build a multimodal and informative narrative of scientific argument (e.g., why a particular study is excellent). This suggests that although traditional boundaries between contexts and audiences seem fuzzy on Twitter (Reid & Anson, 2019), universals, quantities, numbers, formulae, and an intelligible presentation of such information are still a concern to LS and PS scientists in their construction of persuasiveness. On the other hand, the AH scholars tend to write more words than other groups. This is in line with the common observation in research articles that scholars from soft disciplines tend to write longer articles to allow interpretations of particulars, qualities, and complications (Becher & Trowler, 2001). This feature also seems to have become habitual and affected the style of personal tweets as the AH scholars used considerably more words in sharing personal experiences than the PS scholars.

However, the SS and LS scholars deviated extensively from disciplinary conventions when it comes to the use of interaction markers. In the previous studies of research articles (Hyland, 2005) and academic blog posts (Zou & Hyland, 2020), writers in soft disciplines were found to lack the same confidence as scientists in shared knowledge assumptions. As a result, they tend to use more hedges and boosters to engage alternative voices, self-mentions to claim authority, and reader pronouns to express solidarity.

Surprisingly, these features occurred the least often in the SS group in this Twitter data, even less than PS. Reading this finding together with the discovery that the SS group has the highest intensity of negativity, it is possible that assertive claims used in conjunction with negative and emotionally charged language are a common strategy adopted by SS scholars, perhaps to raise awareness of pressing social issues and to incite responses and actions as their communicative goals. In contrast, LS, as a hard disciplinary group, used more interaction markers than SS and is very close to the most interactive group, AH. LS also has the highest intensity of positivity both linguistically and visually. These discursive features might have been affected by the need in LS to work within a large team or community where a collegial environment is key to maintaining and expanding networks. Expressions of tolerance and mutual support can help realise these communicative goals.

Another interesting finding is that despite being the least multimodal and interactive and the most "negative" group, SS still achieved the highest average engagement rate. The data seem to suggest that the boundaries between public and professional identities are blurrier for SS as their research expertise generally concerns society, meaning that a personal comment on societal issues may draw on their expert knowledge and vice versa. The blurred boundaries may have allowed them to easily connect their expertise to trending social events or issues. In fact, the SS scholars used URLs of news articles most frequently amongst the groups, increasing the timeliness and newsworthiness of their tweets and drawing attention from all kinds of audiences. This feature is also coupled with negative and assertive language to elicit reactions. Although Walter et al. (2019) found that scientists also raise awareness of pressing issues on Twitter, such as climate change and address non-experts in their dissemination of knowledge through negative language, the scale of topics relevant to individual life and society is not comparable to SS. In a way, SS could be seen as being more amenable to popularisation than other disciplinary groups and may have an advantage in public engagement on Twitter.

6. Conclusion

This study has unveiled the different discursive choices in tweets across four disciplinary groups, as well as how the use of certain devices might be linked

to public and peer engagement. Qualitative and quantitative tendencies in soft and hard sciences, respectively, were found to persist in the multimodal construction of persuasiveness on Twitter. On the other hand, SS and LS scholars moved beyond traditional boundaries as a result of shifting communicative goals (calling for responses/actions for SS and building collegial networks for LS). LS was even found to be "softer" than SS in certain aspects (e.g., reducing the force of claims), suggesting that the traditional image of disciplines as distinct "academic tribes" and "territories" (Becher & Trowler, 2001) becomes reductive on Twitter. However, the context of Twitter, where the public audience is involved, seems to have also given rise to new disciplinary differences as the overall relevance of topics to public life varies across the groups.

The patterns and examples found in this study can be illustrated in science communication training to raise rhetorical awareness of disciplinary cultures. In particular, the conventions that transcend traditional research and Twitter discourses, as well as the unconventional strategies due to shifting needs, can be factored into shaping one's social media presence. The particular success of the SS scholars in engaging the audiences also implies that other disciplinary groups could learn to relate their tweets to public life/issues, adopt negative markers, and take a critical position if the intention is to elicit public reactions.

As the first attempt to analyse discursive differences across disciplinary groups on Twitter, this research calls for studies of larger datasets to validate the findings. Interviews with the academics who achieved high engagement rates can also help uncover contextual factors "behind the scenes". Bilingual academic accounts were not considered in this study but were observed as a prominent group on Twitter worth investigating; these accounts seem to face the challenge of engaging nationally with non-English speakers as well as internationally in global academia using English as the lingua franca.

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