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LARGE-SCALE CORPUS LINGUISTICS OF SCIENTIFIC RESEARCH REPORTS: DISCIPLINE-SPECIFIC RHETORICAL STANCE

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Abstract- The rhetorical stance that scientists choose in reporting their research offers insights into discipline-specific differences in social conventions and into underlying mechanisms of the scientific process, and perhaps more. We examined the incidence of plural forms of first person indexicals (we, us, our, ours) in nearly half a million abstracts from 348 journals extracted from the Web of Science for the period 2001-2005. We found significant differences in the pronoun rates confirming several patterns that had been suggested based on narrower studies of one or rather few journal sources. There was a strong difference between basic versus applied science with technology reports only rarely using first person. Our work also revealed anomalous patterns in areas of mathematics and chemistry which have not been addressed by prior research. We offer several hypotheses in explanation of the patterns observed including one that posits the existence of a biological basis for discipline-specific stances.
Key words- autism, corpus linguistics, discourse, indexicals, personal pronouns, rhetorical stance, scientific communication.

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Introduction

The journal article is the principle means by which scientists communicate their findings and ideas. The way in which researchers represent themselves in these documents, their stance, varies [1] [2] and serves as a window into how scientists view their relationship to their data and work, and into the social conventions that govern these representations. A study of such dynamics is interesting at a basic level by illuminating a fundamental process of science. On a pragmatic level, the topic is relevant to the success of the researcher wishing to enter an ongoing dialogue but must first adopt, or at least convey, a certain perspective that resonates with peers in the field. The relevant rhetorical stances most studied are grammatical person and voice.

Grammatical person concerns the set of personal pronouns used in a language. Kaplan [3] [4] has been influential in the area of indexicals, or word variables; see also Nunberg [5] for treatment of plural indexicals. Rules partition individuals in a discourse into categories of speaker (1st person; e.g., 'I', 'we'), listener (2nd person; e.g., 'you'), and person talked about (3rd person; e.g., 'he', 'she', 'they'). As Siewierska [6] points out, the 1st and 2nd person pronouns not only distinguish speaker from addressee, but also clarify '*this* speaker' and '*this* addressee', since once these tokens are employed, the personal identities of the speaker and listener are fixed. This is not so for 3rd person in which clear identity requires an additional move such as ostension whereby one points to the person to clarify which one. Thus, 3rd person enjoys a certain anonymity.

Grammatical voice, on the other hand, describes a relationship imparted by a transitive verb binding a subject and object in a sentence. Active voice conveys agency to the subject (e.g., 'The student lifted the beaker.'), whereas in passive voice the subject receives the action (e.g., 'The beaker was lifted by the student.'). Often grammatical person and voice work together, along with tense (or temporality), to convey agency in discourse. For example, 'I lift the beaker' (1st person, active voice, present tense) conveys more agency to the individual present during the event compared to 'The beaker was lifted by him' (3rd person, passive voice, past tense).

Much of the work in this area of scientific discourse comes from studies of the journal *Philosophical Transactions of the Royal Society of London* (hereafter, *PT*). These [7-11] indicate that rhetorical structure of scientific communications has changed considerably along with the method of science over the past several centuries. The early writings (1600s) of the *PT* reflected the then new view of science shifting credibility away from ancient authorities (e.g., Aristotle) to a contemporary authority grounded in immediate experience and observation. At first the researcher was distanced from his work, submitting a letter, sometimes anonymously, to the editor who then passed along information to the readership. Rhetorical distance was in keeping with the early view that researchers were simply revealing the underlying organization of nature, and therefore should not be the focus of a discovery. But it was not long before the scientist became closely associated with his own work. Scientific research later in the 1600s became in many ways the gentleman naturalist's vocation, and the researcher in part offered his name as his word in assurance of the credibility of his report. Atkinson [11] proposed that the increased use of first person stance was critical to the success of early modern science. But the rise in experimentation and theory across the 17th - 20th centuries was associated with a reversal in the voice of the researcher from a subjective stance to an objective one. The researcher eventually became eclipsed by the research event.

Modern academic writing tends to be less personal, though this is not to suggest that it speaks with a uniform, monolithic voice. The largest study to date on modern journals, to our knowledge, is Hyland [2] who showed that not all disciplines treat first person pronouns the same way. He examined 240 published journal articles, thirty articles from each of eight disciplines, and considered the frequency of the indexicals ' I', 'me', 'he', 'we', 'us', and 'our' in the full texts. He found that their use was minimal in the hard sciences and engineering whereas they were much more common in journals from the humanities and social sciences.

Here we examine the use of first person plural indexicals (FFPIs) in scientific journal abstracts. We examined roughly half a million abstracts from 348 journals spanning the hard sciences (from math through biology), engineering, and to a lesser degree the social sciences and humanities. We present a formal statistical analysis of indexical frequencies, something that has not been typical thus far, or on this scale. We examined the occurrences of 'we', 'us', 'our', and 'ours', focusing on the plural simply to avoid problems associated with the polysemous use of 'I' as both a personal pronoun and a Roman numeral.

The following specific questions were addressed:

a) Is there statistically significant variation across disciplines for the use of FPPIs?
b) If so, do they occur significantly more or less often in the hard sciences versus social science and humanities?
c) Within the hard sciences, is there significant variation?
d) If so, which disciplines use them significantly more often? Finally,
e) is there a significant association between the use of FPPIs and the journal's focus on basic versus applied science (i.e., technology)?

We devote much of the discussion to presenting a series of hypotheses, some original and some borrowed from others, to explain the patterns we reveal. These explanations do not form a mutually exclusive or exhaustive set, but we believe that collectively they can account for much of the rhetorical variation we have revealed, and perhaps they may provide inspiration for future studies in this area.

Materials and Methods

Data Acquisition

Over half a million (n = 511,459) journal abstracts were obtained from Web of Science (now ISI Web of Knowledge, Thomson-Reuters, http://thomsonreuters.com/; hereafter WOS) for a total of 343 journals covering the five year window 2001-2005. These data represent the full set of articles appearing in these journals over this time period, and so our observational unit is the level of the journal (343 observations). We used Perl script to remove truncated entries and entries that did not meet our minimal author number $n > 1$ criterion - thereby avoiding cases involving the singular but polysemous 'I' used both as a pronoun and Roman numeral. In total, 43,598 entries (8.5%) were purged leaving 467,861 entries in the data for analysis.

Each of the 343 journals was assigned to one of nine categories (see Appendix). There were seven science and technology categories including four representing the 'hard' sciences: biology (BIOL), chemistry (CHEM), physics (PHYS), and mathematics (MATH). Two categories were technological: engineering (ENGI) and computer science (COMP). One category represented the general and wide readership journals such as *Science* and *Nature* (GENR). We also included two categories from the humanities and social sciences: philosophy (PHIL) and sociology (SOCL).

We judged journal categories based on (*1*) journal title, (*2*) journal description at publisher website, and (*3*) journal description and category at the Genamics JournalSeek web site (http://journalseek.net/). Interdisciplinary journals were assigned by their primary emphasis and target audience. For example, the *Journal of Biochemistry* involves both biology and chemistry, but we considered the subject matter as mainly the study of a certain type of chemistry, the biological type - so we placed the journal in the CHEM group.

The frequency of first person plural indexicals (FPPIs) was estimated for each abstract in the study. The corpus of words was isolated from each abstract using Perl/REGEX and the total number of FPPIs ('we', 'us', 'our', and 'ours') determined and retained.

Statistical Analysis

Analysis of variance (ANOVA) was used when comparing the different disciplines. If a significant difference existed between at least two of the sample means, multiple pairwise comparisons were conducted using Tukey's Honestly Significant Difference (HSD) test. This test maintains the Type I error rate and has narrower confidence intervals making it harder for a difference to actually exist [12-14].

All analyses were conducted using the statistical software R [15]. The aov function was used to conduct ANOVA and the TukeyHSD function was used to conduct the multiple comparisons.

Results

Usage of FPPIs differed significantly across disciplines. The ANO-

VA for comparison of the nine disciplines was highly significant (P < 0.001).

As a general trend (Table 1), FPPIs were used most in the humanities / social sciences (PHIL, SOCL), followed by the hard sciences (MATH, PHYS, CHEM, BIOL), and least by the applied sciences (ENGI, COMP). Usage did not differ significantly when the humanities / social sciences were compared with the hard sciences / technology group (*P* = 0.3743). However, there was considerable variation for FPPI usage within the hard sciences (*P* < 0.0001).

Table 1- Mean values for use of FPPIs across journals

DISCIPLINE		N		AVERAGE	
BIOLOGY		145		1.3186	
	BASIC		84		1.5458
	APPLIED		61		1.0056
CHEMISTRY		51		0.4713	
	BASIC		40		0.5443
	APPLIED		11		0.2059
COMPUTER SCIENCE		7		0.9903	
	BASIC		1		1.1876
	APPLIED		6		0.9575
ENGINEERING		26		0.2232	
	APPLIED		26		0.2232
GENERAL		3		1.5739	
	BASIC/APPLIED		3		1.5739
MATH		43		1.9802	
	BASIC		25		2.1215
	APPLIED		18		1.7838
PHILOSOPHY		16		1.6243	
	BASIC				1.6274
	APPLIED				1.6110
PHYSICS		37		1.2100	
	BASIC		31		1.3475
	APPLIED		6		0.4994
SOCIOLOGY		15		0.9626	
	BASIC		7		0.8868
	APPLIED		8		1.0290

There were multiple significant pairwise differences in FPPI usage among journal type categories based on Tukey's HSD (a = 0.05, corrected for multiple comparisons, Table 2, Figure 1). MATH used FFPIs more than any other discipline (mean, 2.0 indexicals per abstract, Table 1), significantly more than any other category except PHIL (mean = 1.6) and GEN (mean = 1.6, e.g., *Science* and *Nature*). The disciplines using FFPIs least often were ENGI (mean = 0.2) and CHEM (mean = 0.5). Usage in ENGI (mean = 0.2) was significantly less than all other disciplines except the other applied science (COMP, mean = 1.0) and CHEM. Usage in CHEM was significantly less than the other hard science (MATH; PHYS, mean = 1.2; BIOL, mean = 1.3) as well as PHIL (mean = 1.6).

When journals were split according to an emphasis on basic versus applied research, FFPI usage differed within some but not all of the disciplines. ANOVA showed a statistical difference between basic and applied usage across the full data set (*P* < 0.001). The strongest pattern was seen in BIOL (*P* < 0.0001), MATH (*P* = 0.0219), CHEM (*P* = 0.0169), and PHYS (*P* = 0.0353); it is perhaps noteworthy on this account that BIOL was the discipline that we sampled most heavily. But not all disciplines were differentiated in this fashion. The following did not exhibit a difference in usage between journals with an applied versus basic emphasis: COMP (*P* = 0.7988), PHIL (*P* = 0.9759), SOCL (*P* = 0.7325).

Table 2- Pairwise comparisons of categories for TPIs.

Discipline 1	Discipline 2	Difference of Means	Tukey P-Value	
CHEMISTRY	BIOLOGY	-0.8473	<0.0001	*
COMPUTER SCIENCE	BIOLOGY	-0.3282	0.9514	
ENGINEERING	BIOLOGY	-1.0954	<0.0001	*
GENERAL	BIOLOGY	0.2553	0.9994	
MATH	BIOLOGY	0.6616	<0.0001	*
PHILOSOPHY	BIOLOGY	0.3057	0.7636	
PHYSICS	BIOLOGY	-0.1086	0.9952	
SOCIOLOGY	BIOLOGY	-0.3560	0.6211	
COMPUTER SCIENCE	CHEMISTRY	0.5191	0.6454	
ENGINEERING	CHEMISTRY	-0.2481	0.8630	
GENERAL	CHEMISTRY	1.1026	0.1616	
MATH	CHEMISTRY	1.5089	<0.0001	*
PHILOSOPHY	CHEMISTRY	1.1530	<0.0001	*
PHYSICS	CHEMISTRY	0.7387	<0.0001	*
SOCIOLOGY	CHEMISTRY	0.4913	0.2825	
ENGINEERING	COMPUTER SCIENCE	-0.7672	0.1928	
GENERAL	COMPUTER SCIENCE	0.5835	0.9522	
MATH	COMPUTER SCIENCE	0.9898	0.0155	*
PHILOSOPHY	COMPUTER SCIENCE	0.6340	0.5342	
PHYSICS	COMPUTER SCIENCE	0.2196	0.9976	
SOCIOLOGY	COMPUTER SCIENCE	-0.0278	>0.9999	
GENERAL	ENGINEERING	1.3507	0.0409	*
MATH	ENGINEERING	1.7570	<0.0001	*
PHILOSOPHY	ENGINEERING	1.4011	<0.0001	*
PHYSICS	ENGINEERING	0.9868	<0.0001	*
SOCIOLOGY	ENGINEERING	0.7394	0.0307	*
MATH	GENERAL	0.4062	0.9875	
PHILOSOPHY	GENERAL	0.0504	>0.9999	
PHYSICS	GENERAL	-0.3640	0.9942	
SOCIOLOGY	GENERAL	-0.6113	0.9003	
PHILOSOPHY	MATH	-0.3558	0.7150	
PHYSICS	MATH	-0.7702	<0.0001	*
SOCIOLOGY	MATH	-1.0175	<0.0001	*
PHYSICS	PHILOSOPHY	-0.4144	0.5484	
SOCIOLOGY	PHILOSOPHY	-0.6617	0.1697	
SOCIOLOGY	PHYSICS	-0.2474	0.9634	

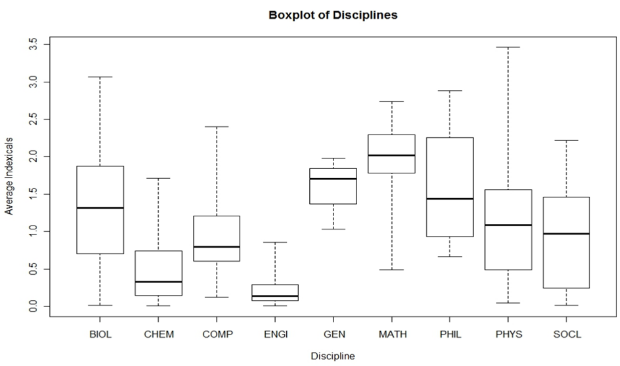

Fig. 1- A boxplot of the different disciplines with regard to average FPPI.

Discussion

The English language is not especially rich in personal pronouns compared to, for example, the Fijian language which has 135 [6]. Referential richness enters through the fact that pronouns, as indexicals, can stand for many different entities and so are in some ways similar to mathematical variables. But meaning is ultimately revealed by context and use [16]. In this study we have examined patterns of usage of FPPIs in the context of their application in academic journals and found significant differences among disciplines. We place our findings in context of prior work, highlight our novel findings, and attempt to explain some of the patterns by posing testable hypotheses for future research in this area.

Disciplines Differ Significantly in Usage of First Person Plural Pronouns

Our results show significant differences in the usage of first person plural pronouns across disciplines, and a generally lower rate of employment within the hard sciences. This agrees with other published works [2, 11] though these generally did not examine chemistry or math, two of the most interesting disciplines by our results.

Editorial Influence

One might assume that discipline-specific differences in such rhetorical practices might be dictated by editors. Editors can and do at times play a role in directly forming the style of discussion in journals with regards to grammatical person. Some journals, though not all, have specific directions for authors on these points. To be clear, though, editors do not act in a vacuum, or necessarily against the will of the community of scientists that read their journal - they are part of the community of researchers with its conventions and practices. Moreover, it is unclear to us that the editor's tendency to influence the rhetoric would necessarily lean one way or the other, for or against use of first person pronouns. If editors indeed make such decisions independently of the other factors we describe herein then their influence on the process would likely contribute to random noise, working against the discipline-specific signal that we have detected in our data. Therefore we exclude this factor as a causal hypothesis in the present work.

Default Explanations for Personal Pronoun Usage Trends

Much of the conversation on grammatical person in science writing has turned on three basic explanations for favoring/avoiding first/third person pronouns. It is unclear to us if any one person deserves credit for originating these first three perspectives, so we offer general citations [17-19].

Grammatical Hypothesis.

Authors that seek to avoid clumsy and convoluted writing will adopt first person stance (and active voice), and avoid third person (and passive voice).

Objectivity Hypothesis.

Authors that emphasize objectivity will adopt a third person stance (and passive voice), and avoid first person. They seek to maximize focus on the object under study. Use of first person is seen as unnecessarily distracting and possibly betraying a subjective bias.

Representational Hypothesis.

Authors that seek to represent the fact that they indeed did conduct the research will adopt first person stance (and active voice), and avoid third person (and passive voice) which may be viewed as a slightly disingenuous stance.

While these three factors likely play a large role in the employment of FPPIs in academic writing, it is unlikely that they account for all the variation we observed. For example, it is not likely that chemistry and engineering are the only disciplines interested in maintaining an objective viewpoint, nor do they necessarily desire to write in a clumsy way, nor should we automatically see them as misrepresenting their role in research events. Other factors likely contribute, and we develop some of these in the following sections.

The Human Condition: Genetic Foundations of Language Use

Though it might seem odd on first consideration, it is reasonable to assert that there may be a genetic predisposition for differences in pronoun usage, and that these differences might break along disciplinary boundaries in some cases.

Pronoun reversal is widely observed in studies of autistic children [20-24]. The cause is still debated but likely derives in part from a theory of mind deficit combined with a tendency to echo words that are heard. Mastery of pronoun usage requires a complex grasp of speech roles and the ability to apply indexicals in varying contexts. These skills benefit from a well-developed theory of mind [25] which is the ability to comprehend what is going on in the minds of others while one is trying to communicate with them. People with autism form an extreme example of individuals not able to form a coherent theory of mind, and this extends into problems with self- and other-referential cognition [26]. Since the autistic mind can be rather rigid and literal in its interpretation of words, this leads to confusion in the shifting landscape of indexicals. In fact, echolalia is prevalent in autistic children, which is the automatic repetition of words spoken to them by others. This tendency, along with a poorly developed theory of mind, appears to yield pronoun reversals; the autistic child misapplies the word "you", for example, to refer to himself since others around him use "you" when speaking directly to him. The result is a reduced usage of first person pronouns.

This phenomenon would be less interesting for our purposes were it isolated to highly incapacitated individuals with severe autism. However, there is increasing recognition that the autism phenotype occurs along a spectrum (autism spectrum disorders, ASDs) ranging from the severe to the milder (high functioning autism, Asperger Syndrome) [27]. As much as 1% of the general population is thought to reside somewhere along the spectrum (CDC [28]), including several notable scientists such as Einstein and Newton [27, 29].

This variable ASD phenotype displays one of the highest, if not the highest, heritabilities among genetically-based human behavioral disorders [30-32]. Genetic mechanisms are still poorly understood but it is widely agreed to be a polygenic trait scattered across several chromosomes [33].

There is also high heritability for factors that could translate into preferences for or against academic disciplines. On one level, the general intelligence (*g* factor in psychometric research) is recognized as highly heritable, beginning low at around 30% in childhood and increasing to over 50% in adulthood [34]. On another level, there is also high heritability (in some cases > 90%) for aptitudes and talents in the domain-specific arenas [35] [36] including creativity [37], language [38], math [39-41], memory [41, 42], music [43, 44] and writing [41].

Given a strong genetic basis for autism and for traits that could influence disciplinary path choice, is there a correspondence between the two? Anecdotal evidence suggests there is, such as the high geographic density of autism cases near centers of higher learning and computer technologies [45]. Formal studies also point to a strong association, such as Baron-Cohen et al. [46] who found that children of engineers were twice as likely to have autism as were children from the general population. Indeed, a common trait of autism is a fascination with mechanical objects; whereas a person with severe autism might spend hours turning a water faucet on and off, one with mild Aspergers might hold a job as an engineer and design a new water faucet. The autistic spectrum has several phenotypes, and under the hyper-systemizing model [47] the brain is especially pre-occupied with and skilled at categorizing and organizing; here a person with severe autism might apply this skill to counting match sticks, while one with Aspergers might become a taxonomist, and meticulously catalogue and identify all of the plants found on a remote tropical island.

Our assertion is certainly not that all engineers and scientists have autism/Aspergers. Rather we propose the model that some rhetorical habits might share a genetic basis with some skills that are beneficial to certain professions. The point has already been made [27] that the autistic spectrum includes several behaviors that, if applied properly, would contribute positively to a career in engineering or science including focusing on a single task for long periods, attention to detail, fascination with understanding how things work, a strong sense of satisfaction at organizing and systemizing things, etc. It is reasonable to consider that alleles for genes influencing these positive traits may at times become bundled together with alleles for genes controlling rhetorical patterns - including pronoun usage - characteristic of the autistic spectrum.

Genetic Hypothesis

People choosing to enter fields such as engineering and some of the systemizing, categorizing sciences have a genetic predisposition for the subject matter that includes a predisposition for avoiding use of self-referential pronouns, preferentially adopting a third -person stance in their writing.

Basic Versus Applied Science

Across disciplines, the applied, technology-based sciences showed a significantly lower usage of FPPIs compared to the basic sciences. As a discipline, ENGI had the lowest of all FPPI usage rates in our study. This agrees with some of the qualitative findings of Hyland [2] who showed that Mechanical Engineering had a very low usage of first person pronouns, though Electronic Engineering exhibited moderate levels overall. In another study Hyland [48] found that engineering abstracts contain the most appeals to the utility of their work, whereas the scientific fields tended to emphasize the novelty of their findings.

One interpretation of this trend is that technology disciplines place a clear focus on the subject of study, leading authors to remove themselves from discussions of their research. The technician's and engineer's interest lies in the utility of the product of the research, not in the discovery or the researcher. Since technology writing seeks to convince others to adopt a way of doing things, the author is wise to depersonalize the writing to indicate that anyone can use the method. On the most practical level, researchers in industry may be bound for legal reasons not to lay claim to a discovery if they do not hold the patent rights. The antithesis of the technological stance would be the theoretical stance where the author seeks to have his name associated with a certain world view.

Technological Hypothesis

Applied sciences place the highest premium on the utility of the object studied and therefore distance the researcher (use third person, passive). The generic atmosphere established (for rhetorical and possibly legal reasons) suggests the method is accessible to anyone.

Mathematics

Math journals had the highest FPPI usage index in our study (2.0), significantly higher than all other disciplines except general science (GEN) and philosophy (PHIL). This makes sense in that math and philosophy overlap considerably at their base in the area of logic. Common statements in mathematical writing reveal a close rhetorical association between the author and the work product, such as "We show that…" and "We prove that…"

It is difficult to place our findings in the context of other rhetorical studies on mathematics since the principle indexical studies have not explicitly consider mathematics except for Atkinson [11]. In his study of the *PT* he noted that math and physics, in as much as they retained a theoretical bent, also appeared to retain a first person presence.

Interpretation of the extreme, if not anomalous, stance adopted by mathematicians that we have shown requires some grappling with at least the perception of whether math reveals an ultimate reality, something we certainly cannot resolve in this document. By one perspective mathematics is not especially interested in the description of real objects, preferring instead abstract generalizations regarding number, generalizations that derive in many cases from deductions from first principles, not by consideration of whether the math matches up to the physical world. With such a focus on properties of an ideal realm, it should come as no surprise that the rhetoric of mathematical writing should be very similar to that of philosophical writing. As such, math should display a high FPPI index just as does philosophy.

Taking the opposite perspective one could argue that mathematics deals with the most fundamental aspects of nature, that foundation on which all of the sciences rest. This may be true, but if this were the primary driver of pronoun usage, then by the Objectivity / Rhetorical Hypotheses outlined above one would expect that mathematicians should remove themselves from discussions of their discoveries. If the data of mathematics is so convincing it should require no propping up by declarations of 'I' and 'we' - it should then stand on its own. But, in fact, mathematicians appear to buttress their arguments with a personal presence (c.f., Rhetorical Hypothesis) more than any other discipline.

This prompts the third but related perspective - some have argued that mathematical knowledge is socially constructed [49-51]. Here it is allowed that mathematicians do deduce from first principles, and induce through comparisons with the physical world. However, these acts are supported through the establishment of social conventions. A collection of specialists agrees upon which first principles to use, and whether the math employed has any practical utility in understanding the world. Lakatos [51] famously enumerated how mathematical theorems were repeatedly repealed, even long after it was assumed the matter had come to rest. In these regards mathematics is very similar in character to the social constructivist view of the hard sciences [52-55] in which the strong form considers scientific knowledge as simply what scientists agree is the case.

Sociological hyphothesis

Authors whose findings derive from, only make sense within, a socially constructed world view will adopt first person (and active voice) stance. But authors who believe their findings reveal the fabric of nature, evident without social construction, will use third person.

It is unclear which of the above scenarios best explains the very high incidence of FPPIs in mathematics writing, or perhaps another factor has evaded our attention. The Grammatical, Representational, Rhetorical and Sociological hypotheses all predict a high FPPI. In any event, our findings reveal that mathematicians view themselves as being very close to their findings, indeed the closest of all the disciplines examined.

Chemistry- Applied Taxonomy of Many-Particle Systems?

Chemistry is perhaps the most interesting and enigmatic of the disciplines when it comes to usage of FPPIs. It speaks with a fairly monolithic voice that is low in usage, the lowest of the non-technology disciplines in the hard sciences. FPPI usage in chemistry was significantly less than in all the other hard sciences, and it had the lowest variance of the hard sciences. The only discipline lower in usage was Engineering.

As with mathematics, it is difficult to place our findings on chemistry in context of other work on the rhetoric of scientific communications. Other reviews have not considered this field in detail.

We propose three hypotheses to explain the downward bias of FPPI usage in chemistry. (*a*) We invoke the already stated Technological Hypothesis and suggest that many of chemistry's aims have an applied character that reduces FPPI usage. (*b*) We introduce the Systemizing Hypothesis which argues that in disciplines overtly concerned with placing items into categories, authors will rhetorically distance themselves from their work since their task is simply to expose underlying order in nature. (*c*) Finally, we introduce the Reductionist Hypothesis which holds that a field whose laws are readily reduced to those of another discipline will speak with a more distant voice.

First we suggest that chemistry, while clearly and rightly established as a basic science, has many features suggestive of a technological discipline. Indeed the early practitioners of this field were the alchemists of the Middle Ages [56] whose chief concern was the transmutation of materials into gold. Modern chemistry is very different though it retains a focus on learning what something is and how one might turn this entity into something else - a decidedly technological world view. From the perspective of other disciplines, much of the utility of chemistry comes in their assigning real world phenomena into discrete and non-overlapping categories of elements, compounds, and reactions. The taxonomist serves a similar role within the biological sciences where he dutifully sorts organisms into species so that the evolutionary biologist can speak to the mechanism and process of evolution. Thus the activity of systemizing carries a strong two-fold service of exposing the order of nature (basic science), and providing named items for use in process and mechanism work (applied utility) - and so we invoke the Technological Hypothesis to explain, in part, the very low FPPI usage in chemistry.

We further hypothesize that the scientists engaged in systemizing nature will be more likely to write from a third person stance, since their work is simply revealing the underlying structure of the world. Kronick [8] and others used the same argument to explain, in part, the authorship anonymity observed in the very early writings of the *PT*.

But the question arises why chemistry is unique, since clearly the other sciences also engage in categorization. One possible answer is that categories in chemistry are less disputed compared to those in physics and biology. The central organizing principle of chemistry is the periodic table of the elements which is about as close as science gets to pure, essentialist categories. Below the atom, particle physics explodes into a bestiary of subatomic particles, some known for certain, some hypothetical, and the list grows. Boundaries are even murkier as one rises in the biochemical hierarchy into cells, organisms, populations, and ecosystems where variation comes to dominate and generalizations are hard won. By contrast the chemist is secure in believing that, at the very least, the categories he has employed in his research are widely accepted, and so speaks from a more distant stance.

It is interesting that this interpretation of systemizing and pronoun usage overlaps with the Genetic Hypothesis. Autistic spectrum behavior includes individuals heavily given to organizing and systemizing things [47].

Systemizing Hypothesis

Authors whose research is concerned mainly with the placing of different entities into categories will view their activities as simply revealing the fundamental order in nature. If the categories are widely undisputed, the author is more likely to strike a third person (and passive) stance.

Our third hypothesis to explain chemistry, the Reductionist Hypothesis, maintains that a field whose laws are readily reduced to those of another discipline will speak with a more distant voice. Whereas the 'theory of everything' has yet to be formulated, it has long been the goal of the sciences to cast general and fundamental explanations for natural phenomena. The tension persists that models developed in the more holistic disciplines, such as chemistry [57], biology [58], and even human consciousness [59], might be explainable in purely physical or mathematical terms, thereby reducing to that level.

In his exploration of the reductionism problem, Nobel laureate Anderson [60] argued for an ordered taxonomy of the disciplines that ranged from the most fundamental to the most inclusive and holistic: particle physics, many body physics, chemistry, molecular biology, cellular biology, …, physiology, psychology, and the social sciences. If we align our data (FPPI indices) along this continuum, we find that chemistry is an outlier in the trend of math to sociology:

MATH	PHYS	CHEM	BIOL	SOCL
(2.0)	(1.2)	(0.5)	(1.3)	(1.0)

Is chemistry unique among the sciences in that its laws are more readily derived by the adjacent but more reductionist discipline, physics in this case? Both Dirac [57] and Anderson [60] proposed this is indeed the case, that in many regards chemistry is simply 'applied many body physics', and that many of the laws of chemistry are reducible to those of physics. But if one discipline is reducible to another discipline, then perhaps it is only the foundational discipline that is truly discovering things. Like Kuhn's [61], 'revolutionary' vs. 'normal' science, Anderson proposes that 'intensive' research deals directly with finding new fundamental laws whereas 'extensive' research applies existing fundamental laws to explain higher order phenomena.

Reductionist Hypothesis

Authors who view their work as 'intensive' and 'revolutionary' will use first person, active voice. Authors who view their work as 'extensive' and 'normal science' will defer and remove themselves when reporting what is a simple enumeration or application of these laws.

Anderson's point also supports our employment of both the Technological and Systemizing Hypotheses in the interpretation of FPPI usage in chemistry. If chemistry is not principally engaged with discovering new laws, if that is more often the role of physics, then chemists see their role as using the laws of physics to sort nature into workable groupings. These groupings are of tremendous utility to all the hard sciences. Thus chemists speak with a more distant voice by both the Technological and Systemizing Hypotheses, as well as the Reductionist Hypothesis.

Sciences versus the Humanities: The Grounds for the Argument

We showed a significant difference in FPPI usage between the hard sciences versus the social sciences and humanities, with the latter group using FPPIs more often. Hyland [2] found the same trend in his survey, arguing that the social sciences and humanities use first person more often because they generally have less measurable, tangible evidence for readers to judge their argument. As a result, the author tends to throw herself into the middle of the argument to lend direct support to the thesis. Indeed, passive third person writing in the humanities is often criticized as 'lacking in voice', leaving the reader wondering if the author believed his own position. The opposite view generally obtains in the hard sciences; an argument that cannot stand on the merits of its data alone is a weak argument.

Rhetorical Hypothesis

Authors that view their arguments as less obviously grounded in data for all to see, as more reliant on personal viewpoints and experiences are more likely to put themselves forward and adopt a first person (and active voice) stance in writing.

Hypothesis Testing and Falsificationism

Falsificationism was promoted by Karl Popper [62] and is the view that is well-represented today in modern statistics that one should pose a null hypothesis and then attempt to falsify it, not prove it true. The null model either is proven false or the researcher fails in her efforts to do so.

This contrasts with the verificationist world view wherein a hypothesis is tested to determine if it is correct, not false, which is a subtle but profound difference [55]. Not unlike in mathematics, the verificationist seeks to prove whether or not a proposition is true or not. Researchers in the 19th and early 20th centuries often used experiments to inductively verify whether a hypothesis was factual, and verificationism was a central feature of the Logical Positivist movement which attempted to completely fuse logic, math, and science.

What is important for our purposes is the stance that is fostered by these two world views. Under verificationism, the burden on the author is to prove an idea true, often not just any idea but the author's own idea. The idea belongs to the author who has become convinced of it, and wishes to be associated and credited with it, and to convince others of it. She therefore speaks using first person. By contrast, under falsificationism one is encouraged to be the harshest critic of one's own ideas, and would thus be expected to strike a more distant stance and use third person. If there are differences in the traditions of disciplines with regards to the role of verification versus falsification, this would explain some of the variation in FPPI usage we have observed.

Falsificationist Hypothesis

Under the falsificationist model, the author adopts a remote stance from the hypothesis and attempts to break it down, and so speaks from third person. By contrast, the verificationist adopts a first person stance, associating himself with the idea as he builds a case in support of it.

The Quantum Observer Meets the Observed

In closing we present our most curious explanation of FPPI usage, the Quantum Hypothesis which states in perhaps the strongest terms of all that a first person stance should be expected in the fields of quantum physics, and perhaps cosmology - due to the very findings of the science. Early in the development of the field of quantum physics, Werner Heisenberg [63] noted that the observer was central to the experiment. More technically, one cannot know both the position and momentum of subatomic particles, and the act of observing influences the outcome of the experiment.

Our sample sizes are small to test this hypothesis, though several of the nuclear and particle physics journals did use FPPIs at a fairly high rate, as did several astronomy and astrophysics journals. Tarone et al. [64] found active voice and first person plural (we) used quite often in their review of the text of two astrophysics journals.

Quantum Hypothesis

Authors are more likely to take a first person stance when the very findings of their research indicate the observer influenced the outcome of their experiment.

Summary

Our analysis supports the prior findings by others in this field that disciplinary discourse is quite varied with respect to the use of personal pronouns. We have shown that these differences are statistically significant in many cases. We also have offered several hypotheses (summarized in Table 3) in explanation of the patterns observed. In the process, we have highlighted the centrality of the tension between basic and applied science as it influences, or is influenced by, the stance researchers adopt. We also have revealed the extreme, if not anomalous, stances taken by the fields of math and chemistry which we believe cast light on some aspects of their culture, history, and presuppositions. Finally, we suggest that some forms of stance could have a biological underpinning which would indicate that the scientific disciplines and their distinct cultures which have evolved over time, and continue to change, are driven at least in part by our own genetic hardwiring.

Table 3- Summary of hypotheses regarding the sources of influence on the usage of first person (FP) pronouns in academic journal writing.

Hypothesis	Summary
Promoting use of first person (FP) pronouns	
Grammatical	FP used to avoid clumsy and convoluted writing
Quantum	FP is used when research indicates the observer influenced the experimental outcome
Representational	FP used to accurately divulge who conducted the research
Rhetorical	FP used to strengthen argument when data are not viewed as self-evident
Sociological	FP used in cases where social construction of knowledge is acknowledged
Limiting use of first person (FP) pronouns	
Falsificationist	FP avoided in falsification-based experimental research
Genetic	FP avoided for genetic reasons that also influence career field choice
Objectivity	FP avoided to shift focus of discussion toward the research
Reductionist	FP is avoided when research is highly dependent on another field's laws
Systemizing	FP avoided when the goal is simply to reveal the underlying order of nature
Technological	FP avoided when the focus is to promote a method that anyone can use

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Appendices

Appendix- Category designations for the journals used in this study.

Hard Science / General Science / Applied & Basic
Nature; Proceedings of the National Academy of Sciences of the United States of America; Science

Hard Science / Biology / Applied
Anesthesiology; Animal Biotechnology; Applied Microbiology and Biotechnology; Biodegradation; Biological Conservation; Biological Control; Bioresource Technology; Biosystems Engineering; Biotechniques; Biotechnology and Bioengineering; Biotechnology Letters; Biotechnology Progress; BMC Biotechnology; Brain Pathology; Canadian Journal of Forest Research-Revue Canadienne De Recherche; Circulation Research; Cloning and Stem Cells; Conservation Biology; Ecological Applications; Ecological Engineering; Environmental Research; Environmental Technology; Enzyme and Microbial Technology; Food Biotechnology; Forest Ecology and Management; Forest Products Journal; Forest Science; Gene Therapy; Global Change Biology; Global Environmental Change-Human and Policy Dimensions; Hemoglobin; Hypertension; Immunity; International Journal of Oncology; JAMA-journal of the American Medical Association; Journal of Applied Ecology; Journal of Applied Ichthyology; Journal of Bioscience and Bioengineering; Journal of Biotechnology; Journal of Clinical Investigation; Journal of Endocrinological Investigation; Journal of Environmental Engineering-ASCE; Journal of Experimental Medicine; Journal of Forestry; Journal of Industrial Microbiology & Biotechnology; Journal of Molecular Microbiology and Biotechnology; Journal of the National Cancer Institute; Journal of Veterinary Medical Science; Lancet; Landscape Ecology; Molecular Biotechnology; Molecular Breeding; Nature Biotechnology; New England Journal of Medicine; Pain; Plant Cell Tissue and Organ Culture; Radiology; Restoration Ecology; Tissue Engineering; Transgenic Research; Veterinary Microbiology.

Hard Science / Biology / Basic
Acta Biotheoretica; American Journal of Botany; American Naturalist; Animal Genetics; Annals of Botany; Antarctic Science; Aquatic Insects; Auk; Behavior Genetics; Behavioral Ecology; Bioinformatics; Biosystems; Biotropica; BMC Bioinformatics; BMC Cell Biology; BMC Genomics; BMC Genomics; BMC Molecular Biology; Bryologist; Bulletin of Mathematical Biology; Canadian Journal of Zoology-Revue Canadienne De Zoologie; Cell; Cell Death and Differentiation; Cellular Signalling; Copeia; Crustaceana; Ecological Modelling; Ecology; Ecosystems; EMBO Journal; Environmental and Ecological Statistics; Evolution; Evolution & Development; Experimental Cell Research; Functional Ecology; Genes and Immunity; Genetics; Genome; Genome Research; Global Biogeochemical Cycles; Heredity; Invertebrate Systematics; Journal of Animal Ecology; Journal of Biological Systems; Journal of Cell Biology; Journal of Ecology; Journal of Evolutionary Biology; Journal of Fish Biology; Journal of Heredity; Journal of Human Evolution; Journal of Mammalogy; Journal of Mathematical Biology; Journal of Molecular Biology; Journal of Theoretical Biology; Journal of Tropical Ecology; Journal of Zoology; Mammalian Genome; Marine Ecology-an Evolutionary Perspective; Mathematical Biosciences; Microbial Ecology; Molecular and Cellular Biology; Molecular Biology; Molecular Ecology; Molecular Phylogenetics and Evolution; Mycotaxon; Nematology; Nucleic Acids Research; Oecologia; Oikos; Oryx; Plant Cell and Environment; Plant Ecology; Plant Molecular Biology Reporter; Plant Systematics and Evolution; Population Ecology; Proteomics; Systematic Biology; Systematic Botany; Systematic Entomology; Systematic Parasitology; Taxon; Theoretical Population Biology; Theory in Biosciences; Zoological Journal of the Linnean Society

Hard Science / Chemistry / Applied
Applied Biochemistry and Biotechnology; Biochemical Engineering Journal; Chemical Engineering and Processing; Chemical Engineering Journal; Chemical Engineering Science; Chemistry of Materials; Chemosphere; Industrial & Engineering Chemistry Research; Journal of Chemical Technology and Biotechnology; Journal of Wood Chemistry and Technology; Theoretical Foundations of Chemical Engineering

Hard Science / Chemistry / Basic
Accounts of Chemical Research; Analytical Biochemistry; Analytical Chemistry; Biochemistry; Bioconjugate Chemistry; Biological Chemistry; Biomacromolecules; Biophysical Chemistry; Canadian Journal of Chemistry-Revue Canadienne De Chimie; Carbohydrate Research; Carbon; Chemical Communications; ChemPhysChem; Combinatorial Chemistry & High Throughput Screening; European Journal of Inorganic Chemistry; Inorganic Chemistry; International Journal of Quantum Chemistry; Journal of Biochemistry; Journal of Biological Chemistry; Journal of Biomolecu-

lar NMR; Journal of Carbohydrate Chemistry; Journal of Cellular Biochemistry; Journal of Chromatography B-Analytical Technologies in the Biomedical; Journal of Combinatorial Chemistry; Journal of Molecular Structure; Journal of Organic Chemistry; Journal of Organometallic Chemistry; Journal of Physical Chemistry B; Journal of Solution Chemistry; Journal of the Chemical Society-Dalton Transactions; Macromolecular Chemistry and Physics; Macromolecules; Organic Letters; Organometallics; Physics and Chemistry of Liquids; Protein Science; Semiconductor Nanocrystals and Silicate Nanoparticles; Tetrahedron; Tetrahedron Letters; Theoretical Chemistry Accounts

Hard Science / Mathematics / Applied

Advances in Applied Mathematics; Annals of Applied Probability; Annals of Probability; Annals of Statistics; Applied Mathematical Modelling; Applied Mathematics and Optimization; Applied Mathematics Letters; Applied Numerical Mathematics; Differential Geometry and Its Applications; Discrete Applied Mathematics; Journal of Applied Statistics; Journal of Pure and Applied Algebra; Linear Algebra and Its Applications; Mathematical Methods in the Applied Sciences; Nonlinear Analysis-real World Applications; SIAM Journal On Applied Mathematics; Studies in Applied Mathematics; Topology and Its Applications

Hard Science / Mathematics / Basic

Advances in Mathematics; American Journal of Mathematics; Annals of Global Analysis and Geometry; Annals of Mathematics; Annals of Pure and Applied Logic; Classical and Quantum Gravity; Discrete Mathematics; European Journal of Combinatorics; Fuzzy Sets and Systems; Geometry & Topology; Journal of Algebra; Journal of Combinatorial Theory Series A; Journal of Complexity; Journal of Differential Equations; Journal of Functional Analysis; Journal of Mathematical Chemistry; Journal of Number Theory; Mathematics of Computation; Multiscale Modeling & Simulation; Nonlinearity; SIAM Journal On Discrete Mathematics; SIAM Journal On Mathematical Analysis; SIAM Journal On Numerical Analysis; Topology; Transactions of the American Mathematical Society

Hard Science / Physics / Applied

Applied Physics Letters; Applied Thermal Engineering; Fusion Engineering and Design; Journal of Applied Clinical Medical Physics; Journal of Applied Crystallography; Journal of Applied Physics

Hard Science / Physics / Basic

Annals of Physics; Astronomy & Astrophysics; Astronomy Letters-a Journal of Astronomy and Space Astrophysics; Astrophysical Journal; Astrophysics; Chemical Physics; Chemical Physics Letters; Contemporary Physics; European Journal of Physics; Europhysics Letters; Journal of Chemical Physics; Journal of Fluid Mechanics; Journal of High Energy Physics; Journal of Physics G-nuclear and Particle Physics; Journal of the Acoustical Society of America; Low Temperature Physics; Molecular Physics; Nuclear Physics B; Optics Communications; Optics Letters; Physical Review Letters; Physics Letters A; Physics of Atomic Nuclei; Physics of Particles and Nuclei; Physics of Plasmas; Physics of the Solid State; Physics Reports-review Section of Physics Letters; Planetary and Space Science; Reports On Progress in Physics; Solar System Research; Theoretical and Mathematical Physics

Humanities / Philosophy / Applied

American Journal of Bioethics; Bioethics; Journal of Medical Ethics

Humanities / Philosophy / Basic

Annals of Science; Biology & Philosophy; British Journal For the Philosophy of Science; Foundations of Physics; History and Philosophy of the Life Sciences; Isis; Journal of the History of Biology; Philosophy of Science; Science in Context; Scientometrics; Studies in History and Philosophy of Modern Physics; Studies in History and Philosophy of Science; Synthese

Humanities / Sociology / Applied

Addictive Behaviors; Brain and Cognition; Demography; Experimental Gerontology; Psychiatry-interpersonal and Biological Processes; Social Science & Medicine; Social Work; Sociology of Sport Journal

Humanities / Sociology / Basic

Archives of Sexual Behavior; Cognitive Psychology; Journal of Biosocial Science; Psychology and Aging; Psychology of Addictive Behaviors; Social Biology; Social Studies of Science

Technology / Computational Science / Applied

Computer; Computer Methods in Applied Mechanics and Engineering; Computer Physics Communications; Computer Vision and Image Understanding; Computers & Chemical Engineering; Computers & Fluids

Technology / Computational Science / Basic

Cognitive Brain Research

Technology / Engineering / Applied

Cement and Concrete Research; Civil Engineering; Composite Structures; Construction and Building Materials; Engineering Computations; Engineering Failure Analysis; Engineering Fracture Mechanics; Engineering Geology; Engineering Structures; Journal of Adhesion Science and Technology; Journal of Aerospace Engineering; Journal of Aircraft; Journal of Composite Materials; Journal of Constructional Steel Research; Journal of Hazardous Materials; Journal of Materials Processing Technology; Journal of Materials Science; Journal of Propulsion and Power; Journal of Robotic Systems; Materials & Design; Microelectronic Engineering; Nanotechnology; Nuclear Engineering and Design; Soil Dynamics and Earthquake Engineering; Structural Engineering and Mechanics; Surface & Coatings Technology

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