# Semantic Change in the Technical Terms of Victorian Logic

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## Abstract

According to a standard view, logic in the nineteenth century underwent dramatic conceptual change. First, the study of logic was revived in the 1820s. Second, the revived *Aristotelian* logic was overhauled in the 1840s. Then, it was overturned in the 1870s. All the while, senses of relevant terms competed for dominance, eventually, supposedly, coalescing around something more or less like the senses of the terms in modern formal logic. This project represents the first steps in computationally testing that narrative and mapping out the semantic, and conceptual, changes at least in the context of British logic. For the first steps, an exhaustive, yet small corpus of 44 first edition books published between 1826 and 1860 was prepared and a list of five technical terms were chosen to analyze with the SCAN model proposed by Frermann and Lapata (2016). The results of this analysis show representation for all senses of the terms persisting, but also occurrences of several interesting shifts in that representation. The conclusion drawn from this is that, at least in the world of monographs, no single understanding of logic as a subject dominated yet by 1860 despite noticeable semantic change.

## 1 Historical Introduction

In 1860, the mathematician, Augustus De Morgan (1806–1871), who is credited as one of the founders of formal logic,[1] gave a retrospective on the developments in the discipline that had occurred during his lifetime:

> First, much more attention is paid to the subject; secondly, innovations have been listened to in a spirit which seems to admit that Kant's dictum about the Aristotelian logic may possibly be false; thirdly, a disposition has arisen to distinguish logic from metaphysics and psychology, without losing sight of the psychological and metaphysical discussion which is necessary to a sound view of the meaning, province, and first principles of the science (De Morgan, 1860).

The German philosopher, Immanuel Kant (1724–1804), famously remarked that, "since Aristotle, [logic] has been unable to advance a step and, thus, to all appearance has reached its completion" (Kant, 1855). He then pointed out that some authors had attempted to expand on the nature of logic by treating *psychological* issues such as mental faculties, *metaphysical* issues such as the production of knowledge and certitude, and *anthropological* issues such as prejudices. According to De Morgan, however, logic was appropriately and successfully divorced from those issues by 1860, and even the *formal* logic that Kant considered complete was further developed.

De Morgan made the above remarks the year after he published a review of William Whewell's *Novum Organon Renovatum*. Whewell (1794–1866) represented the tradition of those who wanted to develop a *metaphysical* logic (in Kant's sense). In the review, De Morgan suggested that Whewell "restrict the words *logic* and *induction* to the meanings now well agreed upon," since the confusion was injurious to the discipline and its students (De Morgan, 1859). Whewell's next book, *On the Philosophy of Discovery*, was already complete, but he did add a preface acknowledging the distinction between his sense of induction and *logical* induction (Whewell, 1860). But, how well agreed upon were the meanings of logical terms? This project can be seen as a test of De Morgan's thesis.

[1] Although there is debate about whether he should be credited as a founder of *formal* logic, or *symbolic* logic

## 2 Philosophical Introduction

For this project, semantic changes in technical terms are taken to correspond to conceptual changes in the theoretical aspects of the subject they belong to. This is not a new idea. The incommensurability of scientific theories was a major issue in 20th-century history and philosophy of science. Among others, Kuhn (1962) and Feyerabend (1965) proposed that certain conceptual changes in scientific theories create problems of translation between old and new taxonomic systems. For example, the Newtonian concept of mass cannot be substituted for the Einsteinian concept of mass, at least in any straightforward manner. The terms corresponding to Newtonian mass and Einsteinian mass thus rely on their respective theoretical frameworks for meaning, and so are mutually exclusive. According to the incommensurability thesis, then, semantic change in the technical terms of a scientific theory follows conceptual change. These technical terms provide a convenient place to start to understand conceptual changes since they are explicitly and rigidly defined. So, they could, in principle, be compared directly according to given definitions. However, definitions do not provide context concerning the use of the terms. So, this project takes the incommensurability thesis for granted, but compares word senses taken computationally from context rather than relying solely on the few explicit definitions given.

## 3 Methodology

To track semantic change, and, by the incommensurability theses, conceptual change, in Victorian logic, this project is comprised of parts: the corpus, target technical terms, concordances of those terms, and a computational model to track changes to their senses over time.

### 3.1 Corpus

The project is bookended by two significant dates: 1826 and 1860. These were chosen for their historical significance and the manageability of the time-span. In 1826, Richard Whately (1787–1863) published his *Elements of Logic*, which is widely considered to have revived the study of logic in Britain. And, as explained above, Whewell's *On the Philosophy of Discovery* was published and De Morgan gave his retrospective opinion about the newly cohesive discipline in 1860.

The corpus contains only the first edition of books published in the period. Such limitations of the editions and the medium of publication yields a small corpus containing 44 texts; but, the corpus is exhaustive according to those limitations, containing all relevant books. So, representativeness of the corpus should not be an issue (save for one that will be discussed in the conclusions). The texts were also included only if they were explicitly on the subject of logic, so philosophical texts or other works that merely mention logic were excluded. This was done to focus primarily on the technical senses of the relevant terms as well as on the development of the discipline of logic itself.

The texts were all acquired from Internet Archive, and are in the public domain. However, this comes with some pitfalls. The quality of the texts depends on the quality of the published text, the scans produced from them, the OCR used, and the output format. 19th-century typeface can be difficult to read as it is, but scanning and OCR only compounds the issue. That said, the corpus was processed to remove as many extraneous characters and stopwords as possible with Python's NLTK. It should be noted, however, that the stopwords included in NLTK leave out many words that affected the results of the model described in a later section.

### 3.2 Technical Terms

The terms chosen as the targets for analysis were the following: **logic**, **induction**, **reasoning**, **inference**, and **syllogism** (see: Table 1). They were chosen for their historical significance at the time in question. The term **logic**, of course, has already been seen to have at least four senses according to Kant, and is used in distinct ways throughout the corpus. The term **induction** has also already been seen to have at least two common senses that were at issue in Victorian logic. The same goes for **inference** and **reasoning**, which were variously applied either to formal deduction or more *metaphysical* contexts in which conclusions are drawn. The term **syllogism** was chosen because of the way in which the traditional Aristotelian syllogism was modified with the advent of mathematical logic. A number of other terms could be added to this, and it is an interesting question whether there is a clear demarcation between technical and non-technical terms in a subject. One example of a word that could be included with a larger corpus is **deduction**, which unfortunately did not return enough

| target | tokens | frequency | rank |
|---|---|---|---|
| logic | 6717 | 0.0036 | 5 |
| reasoning | 4119 | 0.0022 | 28 |
| syllogism | 3120 | 0.0016 | 53 |
| induction | 2394 | 0.0013 | 94 |
| inference | 1386 | 0.0007 | 217 |

Table 1: Frequency and rank of target words in the corpus, which has 1,862,779 total tokens.

tokens for analysis in this project (likely due to issues in the *quality* of the corpus rather than its size).

### 3.3 Concordances

From the corpus, concordances were generated using AntConc (Anthony, 2019) with a context window of 6. However, to get the concordances into the right format for the model described in the next section, they had to be processed into the form:

[YEAR]\t[concordance]

This was done for each target word in the corpus using a simple Python script since each filename contained the year of publication.

### 3.4 Computational Model

There are several computational models for tracking semantic change across diachronic corpora. Some notable examples are given in Tang (2018). This project utilizes the SCAN model proposed by Frermann and Lapata (2016) because it satisfies a number of criteria given by the project's nature as a tool for historical argumentation. SCAN is a Bayesian model of semantic change based on topic modeling. It includes parameters for the numbers of bins allocated for time-slices and word senses. They are used to train the model and obtain comparable global semantics of words for all time-slices. SCAN is especially convenient for use when some properties of the word senses are already known as is the case in this project. Different values can be experimented with, as well, to get better or worse results. In any case, SCAN has been made readily available and is user-friendly.[2]

The SCAN model takes three inputs: a corpus, a list of target words, and text file for the model parameters. For this project, the concordances correspond to the corpus and the list of target words are the technical terms listed above. There are a number of parameters of interest that

[2]see: https://github.com/ColiLea/scan

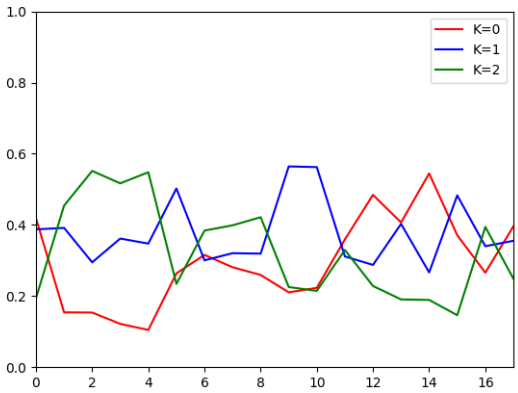


Figure 1: Relative representation (y) of the senses of **induction** (K) over time (x)

can be adjusted, including $num\_top$, $iterations$, $start\_time$, $end\_time$, and $time\_interval$. The concordances were kept separate so a new model with different parameters could be trained on each one. For example, if **logic** is expected to have four senses, then the parameter is set $num\_top = 4$. Similarly, if **induction** is expected to have two or three senses, then the parameter is set $num\_top = 2$ or $num\_top = 3$. Another parameter of interest is the number of iterations for training the model, which was set to 300 for all models. The $start\_time$ and $end\_time$ parameters were set to 1826 and 1860 respectively, and $time\_interval$ was set to two-year time-slices.

## 4 Results

This section will present the example results of training the model with the target word **induction**.[3] First, the model was trained using the **induction** concordances and target word with the following parameters: $window\_size = 6$, $num\_top = 3$, $iterations = 300$, $start\_time = 1826$, $end\_time = 1860$, and $time\_interval = 2$. The output was given in two ways—first chunked by type and then chunked by time-slice. The two outputs are identical in every way but formatting. An example of the distribution of the three senses in the first time-slice can be seen in Table 2.

From this output, it would seem that the model trained some recognizably distinct senses. $K = 0$ appears to relate to the more formal sense of induction as it deals with arguments and cases while

[3]The rest of the output can be found here: https://github.com/janeumanIU/VictorianLogic

| rep | time | sense | assoc. words |
|---|---|---|---|
| 0.42 | T=0 | K=0 | induction (0.021) |
| | | | reasoning (0.012) |
| | | | cases (0.011) |
| | | | argument (0.011) |
| 0.39 | T=0 | K=1 | conclusion (0.018) |
| | | | induction (0.014) |
| | | | fact (0.014) |
| | | | perfect (0.009) |
| | | | class (0.008) |
| 0.19 | T=0 | K=3 | logic (0.011) |
| | | | phenomena (0.009) |
| | | | reason (0.008) |

Table 2: SCAN output for **induction**

$K = 1$ relates to the more metaphysical sense of induction as it deals with facts, while $K = 2$ also appears to relate to the metaphysical sense, but without more weakly associated words.

A graph of the full output is given in Figure 1. In this figure, it would seem that the more formal sense of induction (if that is indeed an appropriate categorization) becomes more highly represented by the end of the period in question. This lines up with the historical situation, since the lectures of one of the co-founders of formal logic, William Hamilton (1788–1856), were published around that time; and, before that, he had gained a few followers whose works also appear in the corpus. The more metaphysical sense, $K = 1$ fluctuates some toward the middle of the period, perhaps around the time De Morgan would have published, but shows a more constant trendline than the other senses. Sense $K = 2$ is somewhat similar to $K = 1$ in that it ends about where it starts.

One of the more interesting aspects of this study is that words can be strongly associated with multiple senses of the target word, which perhaps can be interpreted as the sense of those words following the senses of the target word. If scholars doing different things call it *logic*, then it makes sense for all of the technical terms to get re-interpreted accordingly.

## 5 Conclusions

This project explores the possibility of modeling semantic change in the technical terms of a small chunk of texts in Victorian logic. In addition, the model suffered due to concordances that were unreliable because of poor typeface in the original books, poor digitization, poor OCR, and too many remaining stopwords. As for representativeness, some senses were overly represented just because an author published more, or published a longer book, than others. So, concordances should be sampled consistently across texts. The next steps for this project are thus to process the texts in much more thorough and responsible way; but, the steps after that will be to expand both the timespan of the corpus to generate more noticeable changes in word senses (not to mention to capture more of the historical context), and the types of media especially to include encyclopedia and journal articles.

Despite all of that, some conclusions can still be drawn from the project so far. While De Morgan believed that logicians had coalesced around the formal sense of their terms, the situation is at least not so clear-cut as that from a computational perspective. If anything, it is true that K=0 made advances over time, it was still only about evenly distributed with the others by 1860 (at least concerning *induction*).

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